University of Zawia
Postgraduate Studies and Training Administration
Faculty of Economics
Health Management Department

Title

Evaluating The Compliance with Environmental Safety Standards in Dental Clinic Waste Disposal.

Cross Sectional Study at Zawia City

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تقييم مدى الالتزام بمعايير السلامة البيئية في التخلص من نفايات عيادات طب الأسنان :
دراسة مقطعية في مدينة الزاوية

إعداد الطالب : أسامة حسن الخذراوي

ملخص الدراسة

الخلفية :تُنتج عيادات الأسنان أنواعًا مختلفة من النفايات الخطرة التي تتطلب إدارة آمنة وسليمة للحد من مخاطرها على صحة الإنسان والبيئة. ويُعد الالتزام بمعايير السلامة البيئية عنصرًا أساسيًا لضمان التعامل السليم مع هذه النفايات والتخلص منها بطريقة آمنة. **الهدف :**هدفت هذه الدراسة إلى تقييم مدى الالتزام بمعايير السلامة البيئية في التخلص من نفايات عيادات الأسنان بمدينة الزاوية في ليبيا، ودراسة العوامل المؤثرة في هذا الالتزام، بما في ذلك مستوى الوعي، والتدريب، والممارسات، والبنية التحتية، والرقابة، والمعوقات. **المنهجية :**اعتمدت الدراسة المنهج الكمي باستخدام تصميم وصفي مقطعي. وجُمعت البيانات من (250) من العاملين في عيادات الأسنان باستخدام استبانة منظمة، ثم جرى تحليل البيانات باستخدام برنامج الحزمة الإحصائية للعلوم الاجتماعية (SPSS)، بالاعتماد على الإحصاءات الوصفية، وتحليل الارتباط، واختبار(t) ، وتحليل الانحدار.**النتائج :** أظهرت النتائج انخفاض مستوى الالتزام في معظم أبعاد الدراسة؛ إذ كانت البنية التحتية أضعف الأبعاد بمتوسط حسابي بلغ($M = 1.958$) ، في حين جاءت المعوقات بمستوى متوسط بمتوسط حسابي بلغ .($M = 2.818$) كما أظهرت النتائج وجود فجوة واضحة بين ارتفاع مستوى الالتزام وفق التقييم الذاتي للمشاركين ($M = 3.912$) وانخفاض مؤشر الالتزام الكلي الفعلي .($M = 2.237$) وأظهرت البنية التحتية أقوى ارتباط بالالتزام ($r =$ 0.878)، تلتها عمليات التدريب($r = 0.756$) ، ثم الرقابة .($r = 0.748$) كما كان نموذج الانحدار ذا دلالة إحصائية($F = 6.785, p < 0.001$) ، وتبيّن أن البنية التحتية، والرقابة، والمعوقات تُعد من أهم العوامل المتنبئة بمستوى الالتزام. كذلك أظهرت العيادات الخاصة أداءً أفضل من العيادات العامة في مجالات التدريب، والبنية التحتية، والرقابة، ومستوى الالتزام الكلي، بينما سجلت العيادات العامة مستويات أعلى من المعوقات، وارتفاعًا في مستوى الالتزام وفق التقييم الذاتي. **الخلاصة :**خلصت الدراسة إلى أن مستوى الالتزام بمعايير السلامة البيئية لا يزال ضعيفًا على المستوى التشغيلي والتطبيقي. ويتطلب تحسين هذا الالتزام تبني جهود متكاملة تستهدف تعزيز التدريب، وتطوير البنية التحتية، وتفعيل أنظمة الرقابة، وتحسين ممارسات فرز النفايات، وتعزيز نظم المساءلة؛ بما يسهم في تقليص الفجوة بين مستوى الالتزام المُدرك والممارسة الفعلية. **الكلمات المفتاحية :**معايير السلامة البيئية؛ نفايات عيادات الأسنان؛ الالتزام؛ البنية التحتية؛ الرقابة؛ مدينة الزاوية.

Evaluating The Compliance with Environmental Safety Standards . in Dental Clinic Waste Disposal, Cross sectional study at Zawia city

By: Osama Hasan Al-khadrawi

Abstract

Background: Dental clinics generate hazardous waste requiring safe management to protect health and the environment. Compliance with environmental safety standards is essential for proper waste handling and disposal. Aim: This study evaluated compliance with environmental safety standards in dental clinic waste disposal in Zawia City, Libya, and examined influencing factors including awareness, training, practices, infrastructure, monitoring, and barriers. Methods: A quantitative, cross-sectional descriptive design was used. Data were collected from 250 dental clinic personnel using a structured questionnaire and analyzed using SPSS, including descriptive statistics, correlation, t-test, and regression analysis. Results: Most compliance dimensions were low. Infrastructure was the weakest dimension ($M = 1.958$), while barriers were moderate ($M = 2.818$). A gap emerged between high self-rated compliance ($M = 3.912$) and the low overall compliance index ($M = 2.237$). Infrastructure ($r = 0.878$), training ($r = 0.756$), and monitoring ($r = 0.748$) showed the strongest correlations with compliance. The regression model was significant ($F = 6.785$, $p < 0.001$), with infrastructure, monitoring, and barriers as key predictors. Private clinics outperformed public clinics in training, infrastructure, monitoring, and overall compliance, while public clinics reported higher barriers and higher self-rated compliance. Conclusion: Compliance remains weak at the operational level. Improving it requires integrated efforts to strengthen training, infrastructure, monitoring, segregation practices, and accountability systems to bridge the gap between perception and practice.

Dedication

To the soul of my father, who has returned to his Creator, leaving in my heart a lasting legacy of strength, honor, and wisdom, May Allah grant him His boundless mercy and admit him into His eternal paradise.

To my beloved mother, the source of endless care and unwavering support, whose prayers and sacrifices have been the foundation of my journey, May Allah preserve her, grant her good health, and bless her with a long and happy life.

To my family, whose encouragement and presence have been a constant source of strength and motivation throughout this journey.

To all those who supported me, believed in me, and stood by me during the completion of this work.

This work is dedicated to you all, with sincere appreciation and gratitude.

Allah is the best guide to the right path.

Table of Contents

CHAPTER ONE: INTRODUCTION 1

1.2 Introduction 2

1.3 Statement of the Problem 2

1.4 Research Gap 3

1.5 Main Research Question 3

1.6 Sub-Questions 3

1.7 Research Objectives 4

1.8 Research Hypotheses 4

1.9 Significance of the Study 5

1.10 Key Terms of the Study 6

1.11 Study Variables 7

1.12 Conceptual Framework 7

1.13 Research Methodology 8

1.13.1 Study Design 8

1.13.2 Study Setting 8

1.13.3 Study Population 9

1.13.4 Sampling Technique and Sample Size 9

1.13.5 Data Collection Instrument 9

1.13.6 Validity and Reliability 10

1.13.7 Pilot Study 10

1.13.8 Data Collection Procedures 10

1.13.9 Data Analysis Methods 10

1.13.10 Ethical Considerations 10

CHAPTER TWO: LITERATURE REVIEW 11

2.2 Environmental Safety Standards in Healthcare Waste Management 12

2.2.1 Concept and Definition 15

2.2.2 Types of Healthcare and Dental Waste 17

2.2.3 Classification of Hazardous and Non-Hazardous Waste 21
2.2.4 International Standards (WHO Guidelines) 25
2.2.5 Importance of Environmental Safety in Dental Clinics 27
2.2.6 Risks of Improper Waste Disposal 29
2.3 Dental Waste Management Practices 32
2.3.1 Waste Segregation Practices 34
2.3.2 Waste Handling and Storage 36
2.3.3 Disposal Methods in Dental Clinics 39
2.3.4 Common Mistakes in Waste Management 42
2.3.5 Challenges in Dental Waste Management 44
2.4 Factors Influencing Compliance 46
2.4.1 Staff Training and Qualification 48
2.4.2 Awareness of Environmental Regulations 50
2.4.3 Availability of Infrastructure and Resources 52
2.4.4 Internal Monitoring and Supervision 54
2.4.5 Barriers and Organizational Challenges 56
2.5 Compliance with Environmental Safety Standards 59
2.5.1 Concept of Compliance 61
2.5.2 Measuring Compliance in Healthcare 63
2.5.3 Indicators of Compliance in Dental Clinics 65
2.5.4 Relationship Between Compliance and Safety Outcomes 66
2.6 Healthcare Context in Libya and Zawiya 69
2.6.1 The Libyan Health System and Healthcare Waste Management: Insights from Previous Studies 70
2.6.2 Dental Clinics in Zawiya City 72
2.6.3 Environmental and Administrative Challenges 74
2.7 Previous Studies 76
2.7.1 Studies on Dental Waste Management 77
2.7.2 Studies on Compliance and Safety Standards 79
2.7.3 Studies on Training and Awareness 83
2.7.4 Commentary on Previous Studies 86

2.8 Chapter Summary 89

CHAPTER THREE: METHODOLOGY 91

3.1 Introduction 92

3.2 Research Design 92

3.3 Study Setting 93

3.4 Study Population and Sample 94

3.4.1 Study Population 94

3.4.2 Sampling Technique 94

3.4.3 Final Valid Sample 94

3.5 Data Collection Tool 95

3.5.1 Questionnaire 95

3.5.2 Questionnaire Structure 96

3.5.3 Validity and Reliability of the Questionnaire 97

3.6 Data Analysis Methods 98

3.7 Ethical Considerations 100

3.8 Chapter Summary 101

CHAPTER FOUR: RESULTS 102

4.1 Introduction 103

4.2 Demographic Characteristics of Participants 104

4.3 Ranking of Study Variables by Mean Score 106

4.4 Analysis of Questionnaire Dimensions 108

4.4.1 Level of Awareness and Knowledge 108

4.4.2 Level of Practices and Segregation 111

4.4.3 Level of Infrastructure and Facilities 113

4.4.4 Level of Challenges and Barriers 117

4.4.5 Final Compliance Level Results 120

4.4.6 Overall Compliance Index 122

4.5 Correlation Analysis and Testing Research Hypotheses 125

4.5.1 Hypothesis One: Awareness and Knowledge 127

4.5.2 Hypothesis Two: Training and Protocols 127

4.5.3 Hypothesis Three: Practices and Segregation 128
4.5.4 Hypothesis Four: Infrastructure and Facilities 128
4.5.5 Hypothesis Five: Internal Monitoring 129
4.5.6 Hypothesis Six: Challenges and Barriers 129
4.5.7 Summary of Hypothesis Testing 130
4.6 Independent Samples T-Test According to Clinic Type 130
4.6.1 Descriptive Statistics by Clinic Type 131
4.6.2 Inferential Analysis: T-Test Results 132
4.7 Multiple Regression Analysis 134
4.8 Summary of Hypothesis Testing 138
4.9 Chapter Summary 140

CHAPTER FIVE: DISCUSSION, CONCLUSION AND RECOMMENDATIONS 143

5.1 Introduction 144
5.2 Overall Compliance Status and Key Dimension Findings 145
5.3 Discussion of Results in Relation to Previous Studies 148
5.3.1 The Role of Awareness in Supporting Compliance 148
5.3.2 The Role of Training in Supporting Compliance 149
5.3.3 Operational Deficiencies in Waste Handling 150
5.3.4 The Central Role of Infrastructure in Waste Management 152
5.3.5 The Role of Monitoring in Sustaining Compliance 153
5.3.6 Obstacles to Effective Waste Management 155
5.3.7 Overall Compliance 156
5.3.8 Hypothesis Testing Results 157
5.3.9 General Interpretation of the Findings 159
5.4 Conclusions 160
5.5 Recommendations 162
5.5.1 Practical Recommendations 162
5.5.2 Policy Recommendations 165
5.6 Study Limitations 166

5.7 Suggestions for Future Research 168

REFERENCES 170

APPENDICES 179

Appendix 1: The Questionnaire 180

Appendix 2: Ethical Approval Letter 184

List of Tables

Table 2-1: Main Types of Healthcare and Dental Waste 20

Table 2-3: WHO-Based Matrix for Safe Healthcare Waste Management 27

Figure 2-1: Dental Waste Management Cycle in Dental Clinics. **41**

Table 2-4: Summary of Previous Studies Related to Dental Waste Management on Compliance and Safety Standards 82

Table 2-5: Summary Table of Major Empirical Studies on awareness, knowledge, attitudes, and practices of dental professionals and healthcare workers 86

Table 3-1: Final Valid Sample 95

Table 3-2: The Structure of the Questionnaire 96

Table 3-3: Cronbach's Alpha Reliability Coefficients for the Questionnaire Dimensions 98

Table 3-5: Statistical Methods Used in the Study 99

Table 3-6: Ethical Considerations of the Study 100

Table 4-1: Demographic and Clinical Characteristics of Respondents 105

Table 4-2: Ranking of Study Variables by Mean Score 106

Table 4-3: Descriptive Statistics of Awareness and Knowledge Items (N=250). ... 108

Table 4-4: Overall Result of the Awareness and Knowledge Dimension 110

Table 4-5: Overall Result of the Practices and Segregation Dimension 112

Table 4-6: Descriptive Statistics of Infrastructure and Facilities Items (n=250) 114

Table 4-7: Overall Result of the Infrastructure and Facilities Dimension 115

Table 4-8: Descriptive Statistics of Challenges and Barriers Items 117

Table 4-9: overall mean of the challenges and barriers dimension 119

Table 4-10: Distribution of Respondents by Final Compliance Level 120

Table 4-11: Overall Result of the Final Compliance Level 121

Table 4-12: Overall Result of the Compliance Index 123

Table 4-13: Pearson Correlation between Study Dimensions and Overall Compliance Index 125

Table 4-14: Group Statistics According to Clinic Type 131

Table 4-16: Variables Entered in the Regression Model 134

Table 4-17: Regression Model Summary 135

Table 4-18: ANOVA Results for the Regression Model 135

Table 4-19: Multiple Regression Coefficients for the Prediction of Final Compliance Score 136

LIST OF FIGURES

Figure 2-2: **Proposed Conceptual Framework of the Study**.....8

Figure 2-1: **Dental Waste Management Cycle in Dental Clinics**.....41

List of Abbreviations

Abbreviation	Full Term
ANOVA	Analysis of Variance
CI	Confidence Interval
DV	Dependent Variable
IV	Independent Variable
M	Mean
MSc	Master of Science
N	Number of Respondents / Sample Size
SD	Standard Deviation
Sig.	Significance
SPSS	Statistical Package for the Social Sciences
WHO	World Health Organization

1 CHAPTER ONE: INTRODUCTION

1.2 Introduction

Environmental safety in healthcare waste management has become an important concern because improper disposal of healthcare waste can harm patients, staff, communities, and the surrounding environment. Dental clinics generate different types of waste, including sharps, contaminated materials, chemical residues, amalgam waste, disinfectants, and radiographic chemicals. These wastes require proper segregation, storage, handling, and disposal according to environmental safety standards and healthcare waste management guidelines.

Although dental clinics are usually smaller than hospitals, they produce waste that may be hazardous if not managed correctly. In practice, the level of compliance may be affected by staff awareness, formal training, available infrastructure, internal monitoring systems, and practical barriers such as cost, time pressure, and lack of equipment. Therefore, evaluating compliance in dental clinics can provide useful evidence for improving safe and sustainable waste management.

This study focuses on dental clinics in Zawia city. It is designed as a quantitative, cross-sectional study using a structured questionnaire. The questionnaire measures demographic and clinic characteristics, awareness and knowledge, training and protocols, waste segregation practices, infrastructure and facilities, internal monitoring systems, challenges and obstacles, and the overall level of compliance.

1.3 Statement of the Problem

Despite the availability of international and national guidelines for healthcare waste management, dental clinics may not always comply fully with environmental safety standards. Non-compliance may appear in the mixing of hazardous and non-hazardous waste, weak use of labeled or color-coded containers, unsafe handling of chemical waste, inadequate management of contaminated liquids, or lack of formal contracts with licensed waste disposal services.

The problem is not limited to individual behavior. It may also be related to institutional and organizational factors, such as insufficient staff training, weak communication of regulations, lack of written protocols, inadequate equipment,

absence of internal audits, and unclear accountability. These factors can reduce compliance even when staff members are aware of the risks associated with dental waste.

Accordingly, this study seeks to evaluate the level of compliance with environmental safety standards in dental clinic waste disposal in Zawia city and to identify the main factors and challenges that influence this compliance.

1.4 Research Gap

Previous studies on dental and healthcare waste management have often highlighted deficiencies in segregation, training, infrastructure, and monitoring. However, there is a need for a locally focused quantitative assessment in Zawia city that links compliance with the practical dimensions measured in the questionnaire. This study addresses that gap by examining the relationship between compliance and the following dimensions: awareness and knowledge, training and protocols, waste segregation practices, infrastructure and facilities, internal monitoring systems, and perceived barriers.

1.5 Main Research Question

To what extent do dental clinics in Zawia city comply with environmental safety standards in dental waste disposal, and what factors influence their compliance?

1.6 Sub-Questions

1. What is the level of awareness and knowledge among dental clinic personnel regarding environmental safety regulations and dental waste management standards?
2. To what extent do dental clinic personnel receive training and follow written protocols related to waste disposal?
3. To what extent do dental clinics apply correct practices for waste segregation and safe disposal?
4. How adequate are the infrastructure and facilities available for dental waste management?
5. What is the role of internal monitoring systems in supporting compliance with environmental safety standards?

6. What are the most important challenges and obstacles that limit full compliance?

7. What is the overall level of compliance with environmental safety standards in dental clinic waste disposal?

1.7 Research Objectives

The main research objective is to study the relationship between compliance of healthcare workers in dental clinics and the following dimensions: awareness and knowledge, training and protocols, waste segregation practices, infrastructure and facilities, internal monitoring systems, and perceived barriers. The subobjectives of the study are the following:

1 To assess the level of awareness and knowledge of environmental safety regulations among dental clinic personnel.

2 To examine the availability and effectiveness of training and written protocols for dental waste management.

3 To assess waste segregation and disposal practices in dental clinics.

4 To evaluate the adequacy of infrastructure and facilities used for dental waste management.

5 To determine the role of internal monitoring systems in promoting compliance.

6 To identify the main challenges and obstacles that hinder full compliance.

7 To evaluate the overall level of compliance with environmental safety standards in dental clinic waste disposal in Zawia city.

8 To test the relationships between the study dimensions and the overall level of compliance.

1.8 Research Hypotheses

The following hypotheses are formulated to match the questionnaire dimensions and the proposed statistical analysis:

I. Null hypothesis:

H_{01}: There is no significant relationship between awareness and knowledge and the overall level of compliance with environmental safety standards.

H_{02}: There is no significant relationship between training and protocols and the overall level of compliance with environmental safety standards.

H_{03}: There is no significant relationship between waste segregation practices and the overall level of compliance with environmental safety standards.

H_{04}: There is no significant relationship between infrastructure and facilities and the overall level of compliance with environmental safety standards.

H_{05}: There is no significant relationship between internal monitoring systems and the overall level of compliance with environmental safety standards.

H_{06}: There is no significant relationship between perceived challenges and obstacles and the overall level of compliance with environmental safety standards.

II. Alternative hypothesis

H_{a1}: There is a significant relationship between awareness and knowledge and the overall level of compliance with environmental safety standards.

H_{a2}: There is a significant relationship between training and protocols and the overall level of compliance with environmental safety standards.

H_{a3}: There is a significant relationship between waste segregation practices and the overall level of compliance with environmental safety standards.

H_{a4}: There is a significant relationship between infrastructure and facilities and the overall level of compliance with environmental safety standards.

H_{a5}: There is a significant relationship between internal monitoring systems and the overall level of compliance with environmental safety standards.

H_{a6}: There is a significant relationship between perceived challenges and obstacles and the overall level of compliance with environmental safety standards.

1.9 Significance of the Study

This study is significant because it provides a local assessment of environmental safety compliance in dental clinic waste disposal in Zawia city. The findings can help dental clinic managers, health administrators, environmental health authorities, and policymakers understand the strengths and weaknesses of current waste management practices.

The study may also support the development of targeted training programs, clearer written protocols, better internal monitoring systems, and improved infrastructure for safe waste disposal. Academically, the study contributes to the literature on healthcare waste management by focusing on dental clinics and by linking compliance to practical organizational and behavioral factors.

1.10 Key Terms of the Study

- **Environmental Safety Standards:** Rules, guidelines, and procedures designed to ensure the safe handling, segregation, storage, treatment, and disposal of healthcare and dental waste in a way that protects human health and the environment.
- **Dental Waste:** Waste generated from dental diagnosis, treatment, and clinical services, including sharps, infectious waste, chemical waste, amalgam waste, contaminated materials, and general waste.
- **Compliance:** The degree to which dental clinics follow environmental safety standards and waste disposal procedures.
- **Waste Segregation:** The process of separating hazardous and non-hazardous waste into appropriate containers according to risk category and disposal requirements.
- **Training and Protocols:** Formal instruction, workshops, written guidelines, and procedures that support safe waste management practices among clinic personnel.
- **Internal Monitoring Systems:** Audit, supervision, documentation, and corrective procedures used inside the clinic to ensure adherence to waste management protocols.
- **Challenges and Obstacles:** Factors that limit full compliance, such as cost, lack of staff, lack of equipment, complex regulations, weak training, inconsistent practices, and unclear accountability.

1.11 Study Variables

The study variables are defined according to the questionnaire structure as follows:

Variable Type	Variable / Dimension	Measurement in the Questionnaire
Dependent Variable	Overall compliance with environmental safety standards	Final self-assessment of compliance and compliance-related items across practices, infrastructure, and monitoring.
Independent Variable	Awareness and knowledge	Five Likert-scale items on knowledge of regulations and standards, plus source of information.
Independent Variable	Training and protocols	Five Likert-scale items and two multiple-choice questions on training coverage and frequency.
Independent Variable	Waste segregation practices	Seven Likert-scale items on segregation, color-coded containers, chemical waste, contaminated liquids, sharps, and radiographic chemicals.
Independent Variable	Infrastructure and facilities	Four Likert-scale items on availability of labeled containers, replacement of containers, disposal contracts, and amalgam separators.
Independent Variable	Internal monitoring systems	Four Likert-scale items on internal monitoring, documentation, corrective actions, audits, and self-monitoring.
Independent Variable	Challenges and obstacles	Seven items rated from 1 to 4, plus one open-ended question on the biggest obstacle.
Control / Descriptive Variables	Participant and clinic characteristics	Gender, clinic type, practice model, number of clinical staff, and respondent role.

1.12 Conceptual Framework

The conceptual framework assumes that the level of compliance with environmental safety standards is influenced by several organizational and behavioral factors measured in the questionnaire (see Table 2.2) . Awareness, training, proper practices, adequate infrastructure, and internal monitoring are expected to support higher compliance, while perceived challenges and obstacles are expected to limit compliance.

Awareness + Training + Practices + Infrastructure + Internal Monitoring - Obstacles -> Compliance Level



Figure 1-1: **Proposed Conceptual Framework of the Study.**
Compliance with environmental safety standards is influenced by several organizational and professional factors, including training, awareness, infrastructure, monitoring, and barriers, which in turn affect safety outcomes in dental clinics.

1.13 Research Methodology

1.13.1 Study Design

This study used a quantitative, non-experimental, cross-sectional research design. The design is appropriate because data were collected at one point in time from dental clinic personnel to describe the current level of compliance and examine relationships between the study variables.

1.13.2 Study Setting

The study was conducted in dental clinics located in Zawia city. The clinics included public clinics, private clinics, group practices, large institutional clinics, public health clinics, and university clinics.

1.13.3 Study Population

The target population includes dental clinic personnel who are directly or administratively involved in dental practice and waste management. This may include dentists, clinic owners, clinic or office managers, oral health specialists, dental assistants, and other relevant staff members.

1.13.4 Sampling Technique and Sample Size

A convenience sampling technique was used due to the practical difficulty of accessing all dental clinics and all potential participants in Zawia city. When possible, the researcher may attempt to include different clinic types to improve the representativeness of the sample. The final sample size was relayed on the number of accessible clinics and respondents, while ensuring that the sample is sufficient for descriptive statistics and correlation analysis.

1.13.5 Data Collection Instrument

Data were collected using a structured self-administered questionnaire. The questionnaire was designed to match the study objectives, questions, and hypotheses. It consists of the following sections:

Section 1: Participant and clinic profile.

Section 2: Awareness and knowledge.

Section 3: Training and protocols.

Section 4: Practices and waste segregation procedures.

Section 5: Infrastructure and facilities.

Section 6: Internal monitoring systems.

Section 7: Challenges and obstacles.

Final item: Overall self-assessment of compliance.

Most questionnaire items use a five-point Likert scale ranging from strongly disagree to strongly agree. The challenges and obstacles section uses a four-point rating scale ranging from not a barrier to a major barrier. The final compliance item uses categorical response options ranging from fully compliant to non-compliant.

1.13.6 Validity and Reliability

Content validity was established by presenting the questionnaire to a panel of specialists in health management, environmental health, dentistry, or research methodology. Their comments were used to improve the clarity, relevance, and coverage of the questionnaire items. Reliability was tested using Cronbach's Alpha for the Likert-scale dimensions. A coefficient of 0.70 or higher considered acceptable for internal consistency.

1.13.7 Pilot Study

A pilot study was conducted with a small number of dental clinic personnel to test the clarity of the questionnaire, the time required to complete it, and any difficulties in understanding or answering the items.

1.13.8 Data Collection Procedures

After obtaining the necessary approvals, the questionnaire was distributed to eligible participants either electronically or in printed form. Participants were informed that their participation is voluntary, anonymous, and confidential. Completed questionnaires were checked for completeness before statistical analysis.

1.13.9 Data Analysis Methods

Data were analyzed using SPSS statistical package. Descriptive statistics were used to summarize demographic and clinic characteristics and to describe responses to each dimension. Means, standard deviations, frequencies, and percentages were used according to the type of variable. Inferential statistics were used to test relationships between dimensions and the overall compliance level.

1.13.10 Ethical Considerations

The researcher obtained the required academic and institutional approval for data collection. Participation was voluntary, and respondents were having the right to refuse participation or withdraw at any time. No names or identifying information were required in the questionnaire. Data were used only for academic research purposes and kept confidential.

2 CHAPTER TWO:
LITERATURE REVIEW

This chapter reviews the existing body of research and published literature on environmental safety and its management in dental clinics. Dental practice generates a wide range of environmental and occupational hazards, including infectious and clinical waste, sharps, dental amalgam and mercury residues, radiographic chemicals and lead foils, chemical disinfectants and sterilant, aerosols and bioaerosols produced during treatment, and the consumption of water and energy. If these are not properly controlled, they can endanger patients, dental staff, waste handlers, and the wider community.

The chapter first outlines the main sources and categories of risk in dental settings, then examines the guidelines, regulations, and standards that govern their management. It goes on to discuss previous studies assessing the knowledge, attitudes, and practices of dental professionals regarding infection control, waste segregation, storage, treatment, and disposal, and the effectiveness of interventions such as training programs and monitoring systems.

The chapter also identifies the main obstacles that limit effective environmental safety management. These include weak legislation and poor enforcement, limited awareness and training among dental staff, insufficient financial and material resources, a lack of waste treatment and disposal infrastructure, inconsistent adherence to protocols, and low institutional commitment. Challenges are especially pronounced in low- and middle-income settings, where health systems are often under-resourced. Finally, the chapter highlights gaps in the current literature to justify the need for the present study.

2.2 Environmental Safety Standards in Healthcare Waste Management

Environmental safety standards in healthcare waste management represent a fundamental pillar in contemporary health systems, as they are directly linked to the protection of human health, preservation of environmental balance, and enhancement of institutional responsibility in healthcare settings. The increasing volume and diversity of healthcare waste, particularly hazardous waste, has made the issue of safe management no longer a secondary operational matter, but rather a strategic and

regulatory necessity. This is especially important in facilities that generate infectious, chemical, and sharp waste, where improper handling may result in serious occupational, public health, and environmental consequences. Accordingly, the concept of environmental safety standards has emerged as a comprehensive framework governing the generation, segregation, collection, storage, transport, treatment, and final disposal of healthcare waste in accordance with scientific, legal, and sustainability-based principles.

Environmental safety standards in healthcare waste management refer to the set of regulatory, technical, and operational procedures designed to ensure that waste generated by healthcare activities is managed in a manner that minimizes risk to healthcare workers, patients, the community, and the natural environment. These standards do not only address the final stage of disposal, but rather encompass the entire waste management chain from the point of generation to treatment and final elimination. In this regard, Townend and Cheeseman emphasize that sustainable waste management in healthcare facilities requires an evaluative and regulatory framework capable of linking environmental protection with efficient resource use, thus ensuring that waste practices are assessed not only in terms of technical feasibility but also in relation to broader sustainability objectives (Townend & Cheeseman, 2005).

From another perspective, environmental safety standards are closely associated with the principle of safe treatment and disposal alternatives. Alagoz and Kocasoy argue that the management of healthcare waste, particularly in developing countries, must be based on carefully selected treatment and disposal options that are both environmentally acceptable and contextually feasible, since inappropriate technologies or unsafe disposal routes may transfer the hazard from one medium to another instead of eliminating it (Alagoz & Kocasoy, 2007). This means that environmental safety standards must take into account not only compliance with general rules, but also the appropriateness of chosen methods to the institutional and national context in which healthcare facilities operate.

Likewise, the complexity of healthcare waste management requires standards that can respond to the multiplicity of actors, processes, and constraints involved. Healthcare

waste management is characterized by operational and administrative complexity, and therefore needs structured systems that can balance technical requirements, environmental priorities, and institutional capabilities (Chaerul, et al 2008). The effective healthcare waste management cannot be achieved without a coordinated framework capable of resolving conflicts between cost, safety, capacity, and environmental performance (Chaerul, et al, 2008), This view reinforces the notion that environmental safety standards are not limited to isolated technical instructions, but rather function as an integrated managerial and environmental system.

The World Health Organization provides one of the most authoritative formulations of these standards by presenting healthcare waste management as a structured process governed by internationally accepted principles of segregation, color coding, safe storage, transportation, treatment, and final disposal. According to WHO, safe management of healthcare waste is essential to reduce direct exposure to infectious and hazardous materials, prevent environmental contamination, and ensure occupational safety for healthcare workers and waste handlers. The WHO framework also stresses the importance of institutional policies, staff training, monitoring systems, and legislative support in translating standards into effective practice (World Health Organization, 2019). In this sense, environmental safety standards are not merely technical recommendations; they are part of a broader governance model for healthcare risk control.

In recent years, the discussion on environmental safety standards has increasingly been linked to sustainable healthcare and green management. Lee and Lee argue that effective medical waste management is a major component of sustainable green healthcare because it supports environmental responsibility, reduces pollution, and improves the ecological performance of healthcare organizations. They further note that the adoption of environmentally sound waste practices reflects the growing integration between health service delivery and sustainability goals, particularly in systems that seek to reduce waste generation, improve segregation, and ensure safer disposal methods (Lee & Lee, 2022). Thus, environmental safety standards may also be understood as part of the transition from conventional healthcare operations toward more sustainable and environmentally accountable models.

At the institutional level, adherence to environmental safety standards enhances administrative order, regulatory compliance, and operational consistency. A healthcare facility that applies these standards effectively is more capable of organizing waste streams, reducing accidental exposure, improving internal accountability, and demonstrating conformity with public health and environmental expectations. Conversely, weak adherence to such standards often leads to waste mixing, poor storage conditions, unsafe handling, and environmentally harmful disposal practices. Therefore, environmental safety standards in healthcare waste management should be viewed as both a preventive health mechanism and a managerial instrument that supports institutional quality, environmental protection, and public trust.

Based on the above, it can be said that environmental safety standards in healthcare waste management constitute an integrated framework that combines regulatory control, technical procedures, and environmental responsibility. Their importance lies not only in reducing the risks associated with hazardous healthcare waste, but also in promoting sustainable institutional practices and strengthening the ability of healthcare facilities to operate in a safe, organized, and environmentally sound manner. In the context of this study, these standards provide the conceptual foundation for understanding how dental clinics should manage their waste and how compliance with such standards can be evaluated in relation to actual practice.

2.2.1 Concept and Definition

The concept of environmental safety standards in healthcare waste management is rooted in the broader understanding of how healthcare-generated waste is identified, classified, and managed in a way that minimizes its harmful effects on human health and the environment. With the continuous expansion of healthcare services and the increasing complexity of medical procedures, the volume and diversity of healthcare waste have significantly increased, making it essential to clearly define the concept of safe waste management as a structured and regulated process rather than a simple operational activity.

Healthcare waste management can be conceptually understood as the systematic process that involves the collection, segregation, storage, transportation, treatment, and final disposal of waste generated from healthcare activities, with the primary aim of reducing risks associated with hazardous materials. In this regard, Naja and Chalak define medical waste management as an organized set of practices implemented within healthcare institutions to ensure the safe handling of waste in a manner that protects both human health and the surrounding environment, while also improving institutional performance and regulatory compliance (Naja & Chalak, 2015).

From a broader global perspective, the concept of healthcare waste management extends beyond local institutional practices to include international concerns related to environmental sustainability and public health protection. In fact, medical waste management represents a global issue due to the transboundary nature of environmental risks and the shared responsibility of health systems worldwide in managing hazardous waste safely (Pradhan, et al, 2017). Also, improper waste management practices can lead to serious health consequences and environmental degradation, thereby reinforcing the need for a universally accepted conceptual framework (Pradhan, et al, 2017).

Medical waste management is signified as a multidisciplinary concept that integrates environmental science, public health, and regulatory governance. This concept is not limited to technical handling of waste, but rather includes risk assessment, pollution prevention, occupational safety, and compliance with environmental regulations. This integrated perspective underscores that effective waste management requires coordination between policy, practice, and awareness at multiple levels of the healthcare system (Ahmed, et al, 2018).

At the institutional and policy level, the World Health Organization provides a comprehensive conceptual definition of healthcare waste management by framing it as a structured system governed by standardized procedures and guidelines aimed at minimizing exposure to hazardous waste. The WHO defines healthcare waste management as a process that ensures waste is handled in a way that reduces risks to healthcare workers, patients, and the environment, while promoting safe practices

throughout all stages of waste handling (World Health Organization, 2020). This definition also emphasizes the importance of training, infrastructure, and regulatory support in ensuring the effective implementation of waste management systems.

In addition, contemporary perspectives on healthcare waste management have increasingly incorporated the concept of sustainability, particularly in relation to environmental protection and resource efficiency. Health Care Without Harm Europe defines sustainable healthcare waste management as an approach that seeks to reduce waste generation, improve segregation and recycling practices, and minimize environmental impact through the adoption of circular economy principles (Health Care Without Harm Europe, 2020). This conceptualization reflects a shift from traditional waste disposal approaches toward more environmentally responsible and sustainable healthcare systems.

Based on the above definitions, it can be concluded that the concept of environmental safety standards in healthcare waste management is multidimensional in nature, encompassing technical procedures, environmental considerations, regulatory frameworks, and sustainability principles. It is not merely concerned with disposing of waste, but rather with managing it in a systematic and controlled manner that ensures safety, efficiency, and environmental responsibility.

From the researcher's perspective, healthcare waste management can be operationally defined as the set of organized procedures and standards applied within healthcare facilities to ensure the safe and environmentally sound handling of waste throughout all stages of its lifecycle, in a way that minimizes risks, enhances compliance, and supports sustainable healthcare practices.

2.2.2 Types of Healthcare and Dental Waste

Healthcare and dental waste is not homogeneous in nature, composition, or level of risk, but it consists of several categories that differ according to their source, physical form, chemical properties, and potential impact on human health and the environment. For this reason, the classification of healthcare and dental waste is considered a

fundamental step in building an effective waste management system, because proper identification of waste types determines the appropriate method of segregation, storage, treatment, and final disposal. In dental settings in particular, waste types are often more complex due to the coexistence of general waste with infectious, sharp, chemical, and heavy-metal-containing waste.

In general, healthcare and dental waste can be divided into the following main categories:

I. General Non-Hazardous Waste

This category includes waste that does not pose direct biological, chemical, or physical danger and resembles ordinary domestic waste in composition. It may include paper, packaging materials, food remnants, disposable cups, and other non-contaminated items generated in dental clinics. Although this type is considered low-risk, its improper mixing with hazardous waste increases disposal costs and creates unnecessary pressure on waste management systems. Studies on dental waste management indicate that a considerable proportion of waste generated in dental facilities falls under this category, which highlights the importance of proper segregation at source to prevent contamination and reduce the volume of hazardous waste requiring specialized handling (Adewole, et al 2013).

II. Infectious Waste

Infectious waste refers to materials contaminated with blood, saliva, bodily fluids, or microorganisms that may transmit infection to healthcare workers, waste handlers, or the surrounding community. In dental clinics, this type commonly includes cotton rolls, gauze, gloves, masks, suction tips, and disposable items that come into contact with patients during diagnosis or treatment. Because dental procedures frequently involve exposure to oral fluids and invasive interventions, infectious waste represents a significant category in dental practice. Osamong and colleagues note that the management of such waste requires careful separation from ordinary waste due to its potential health risk and the need for specialized disposal methods (Osamong *et al*, 2005).

III. Sharps Waste

Sharps waste includes needles, scalpel blades, orthodontic wires, burs, broken glass, and any object capable of causing cuts or puncture injuries. This type is particularly dangerous because it combines physical injury risk with the possibility of infection transmission if contaminated. In dental settings, sharps are generated routinely during anesthesia, minor procedures, and restorative or surgical interventions. Their management requires puncture-resistant containers and strict handling procedures. Improper disposal of sharps remains one of the most serious operational weaknesses in healthcare waste systems because it directly threatens both occupational safety and infection control (Koolivand *et al*, 2014).

IV. Chemical Waste

Chemical waste in dental clinics includes disinfectants, sterilizing solutions, dental developers and fixers, solvents, cleaning agents, and laboratory chemicals. This category is significant because many dental materials contain compounds that may be hazardous if discharged into sewage systems or discarded with general refuse. Chemical waste may cause toxic reactions, water contamination, and long-term ecological harm when not properly treated. Research on dental waste characteristics has shown that chemical waste requires clear procedural controls due to its environmental sensitivity and the difficulty of managing it through ordinary disposal channels (Adewole, et al 2013).

V. Pharmaceutical Waste

This type includes expired, unused, spilled, or contaminated medications and pharmaceutical preparations used in dental settings. Although the volume of pharmaceutical waste in dental clinics may be lower than in hospitals, it still requires careful management, especially in cases involving anesthetics, antibiotics, and topical medicaments. The significance of this category lies in the fact that pharmaceuticals may enter the environment through improper disposal and contribute to chemical pollution or antimicrobial resistance. Therefore, its classification within healthcare waste systems is essential to safe and environmentally sound practice.

VI. Heavy Metal and Amalgam-Related Waste

One of the most distinctive categories of dental waste is waste containing heavy metals, particularly mercury from dental amalgam. This may include excess amalgam, amalgam capsules, particles collected in filters, and contaminated items associated with restorative procedures. The importance of this category stems from the environmental toxicity of mercury and its capacity to accumulate in ecosystems. Recent materials-based analyses emphasize that dental solid waste cannot be understood adequately without recognizing the environmental burden of metal-containing residues, particularly amalgam waste, which requires special collection and disposal systems to prevent contamination of water and soil (Khanna, et al, 2023).

VII. Recyclable and Recoverable Waste

Some dental waste materials may be recyclable or recoverable when properly separated, such as paper, cardboard, plastics, certain packaging materials, and in some cases metals. Contemporary perspectives in sustainable healthcare increasingly support the distinction between waste that must be destroyed and waste that can be recovered within environmentally safe systems. This reflects a shift from purely disposal-oriented models toward resource-conscious waste management. Mitsika *et al* highlight that a more refined analysis of dental solid waste can support better classification systems and improve opportunities for sustainable recovery and recycling practices within dental facilities (Mitsika et al, 2024). To clarify the major categories of healthcare and dental waste, Table 2.1 was created.

***Table 2-1*:** Main Types of Healthcare and Dental Waste

Type of Waste	**Examples in Dental Clinics**	**Main Risk**
General non-hazardous waste	Paper, packaging, food remnants	Low direct risk
Infectious waste	Gauze, gloves, suction tips, contaminated disposables	Infection transmission
Sharps waste	Needles, blades, burs, broken glass	Injury and infection
Chemical waste	Disinfectants, solvents, fixer/developer solutions	Toxicity and pollution
Pharmaceutical waste	Expired or unused medicines	Chemical contamination
Heavy	Amalgam particles, capsules, mercury-	Environmental

metal/amalgam waste	containing residues	toxicity
Recyclable waste	Paper, cardboard, some plastics and metals	Requires safe recovery

The above classification shows that dental waste management is not limited to identifying dangerous versus non-dangerous materials only, but rather depends on a more detailed understanding of waste characteristics, composition, and disposal implications. The effectiveness of environmental safety standards in dental clinics begins with this classification process, because any error at this stage affects all subsequent steps of waste handling and disposal.

From the researcher's point of view, the classification of healthcare and dental waste represents the cornerstone of safe waste management, as it provides the practical basis upon which segregation, storage, treatment, and disposal decisions are made. The more accurate the classification process is, the greater the clinic's ability to reduce risks, improve compliance, and promote environmental safety in daily practice.

2.2.3 Classification of Hazardous and Non-Hazardous Waste

The classification of healthcare waste into hazardous and non-hazardous categories is one of the most essential steps in building an effective waste management system. This classification is not merely a technical exercise, but rather a practical foundation upon which all subsequent procedures depend, including segregation, storage, transport, treatment, and final disposal. In healthcare and dental settings, inaccurate classification may result in the mixing of general waste with hazardous materials, thereby increasing risks to healthcare workers, waste handlers, patients, and the environment. For this reason, the distinction between hazardous and non-hazardous waste is central to environmental safety standards and compliance practices in healthcare institutions.

In general, healthcare waste can be classified into two broad categories: Non-Hazardous Waste and Hazardous Waste.

I. Non-Hazardous Waste

Non-hazardous waste refers to waste that does not pose direct biological, chemical, or physical harm under normal handling conditions. It usually resembles domestic or

municipal waste in composition and may include office paper, packaging materials, food residues, and other uncontaminated items generated in healthcare facilities. Although this category is considered low-risk, its significance should not be underestimated, because poor segregation may convert otherwise harmless waste into hazardous waste through contamination. Hossain and his colleagues note that a large proportion of waste generated in healthcare facilities is in fact non-hazardous, but unsafe management practices often lead to unnecessary mixing with infectious or dangerous materials, thereby increasing both environmental risk and disposal burden (Hossain *et al*, 2011).

In dental clinics, non-hazardous waste commonly includes paper towels not contaminated with bodily fluids, outer packaging of materials, food containers, and other routine refuse. The proper identification of this waste is important not only for safety purposes, but also for cost efficiency, because non-hazardous waste does not require the same high-cost treatment methods as hazardous waste. Therefore, accurate classification supports both environmental protection and rational resource use.

II. Hazardous Waste

Hazardous waste includes all waste materials that can pose a significant threat to human health or the environment due to their infectious, toxic, sharp, chemical, or otherwise dangerous characteristics. This category is especially critical in healthcare settings because it involves materials generated during diagnosis, treatment, laboratory procedures, and direct patient care. Hazardous waste requires strict handling procedures, specialized storage, and safe treatment or disposal methods.

In literature, hazardous healthcare waste was explained that it may include infectious waste, pathological waste, sharps, pharmaceutical waste, chemical waste, radioactive waste, and waste containing heavy metals, each of which requires a distinct management approach according to its properties and associated risks (Ahmed *et al*, 2018). This indicates that the hazardous category is itself diverse and cannot be treated as a single uniform group.

The main hazardous waste categories may be outlined as follows:

A. Infectious Waste

This includes waste contaminated with blood, saliva, body fluids, cultures, or microorganisms capable of transmitting disease. In dental clinics, gauze, cotton rolls, gloves, suction tips, and other disposable items used during clinical procedures often fall into this category. Infectious waste is particularly dangerous because it may expose healthcare personnel and waste handlers to pathogens if not properly segregated and treated. Muluken et al stress that improper management of infectious waste remains one of the major weaknesses in healthcare facilities and may contribute directly to occupational and environmental health problems (Muluken, et al 2013).

B. Sharps Waste

Sharps waste includes needles, blades, orthodontic wires, burs, broken glass, and any item capable of cutting or puncturing the skin. Its risk lies not only in physical injury but also in the possible transmission of blood-borne infections when contaminated. Because sharps are frequently generated in dental settings, they require puncture-resistant containers and immediate safe disposal. Their classification as hazardous waste is universally recognized due to their high occupational risk.

C. Chemical Waste

Chemical waste consists of discarded disinfectants, sterilizing solutions, solvents, laboratory reagents, developers and fixers, and other chemical substances used in healthcare and dental practice. This type of waste may be toxic, corrosive, flammable, or environmentally damaging, its improper discharge into water systems or ordinary refuse streams may cause long-term pollution and ecological harm. Patwary, O'Hare, and Sarker emphasize that chemical hazards are among the most serious but often under-recognized risks in waste management systems, especially in developing countries where regulatory enforcement may be limited (Patwary, et al 2011).

D. Pharmaceutical Waste

This category includes expired, unused, spilled, or contaminated medicines and medicinal products, although pharmaceutical waste is more common in hospitals than in small clinics. Dental settings may still generate it in relation to anesthetics, antibiotics, and topical treatments. It is classified as hazardous when its contents may cause toxic or chemical harm to humans or ecosystems.

E. Heavy Metal and Dental-Specific Waste

Dental clinics produce a distinctive form of hazardous waste that includes amalgam residues and other materials containing heavy metals, particularly mercury. Such waste requires special handling due to its toxic environmental impact. In dentistry, this aspect is particularly important because improper disposal of amalgam particles or mercury-containing residues can contaminate water and soil. Subramanian highlights that biomedical waste management in dentistry must pay special attention to these dental-specific hazardous materials because of their direct link to environmental safety and regulatory compliance (Subramanian, 2020).

To simplify the classification, the distinction between hazardous and non-hazardous waste is presented in the table (2.2):

Table 2-2: Classification of Hazardous and Non-Hazardous Waste

Classification	**Description**	**Examples in Dental/Healthcare Settings**
Non-hazardous waste	Waste not posing direct biological, chemical, or physical risk under normal handling conditions	Paper, packaging, food waste, uncontaminated plastic
Hazardous waste	Waste capable of causing infection, injury, toxicity, or environmental contamination	Infectious gauze, sharps, chemical solutions, expired medicines, amalgam waste

This classification shows that the main difference between hazardous and non-hazardous waste lies in the degree and nature of risk associated with each type. Non-hazardous waste may be handled through ordinary municipal systems if properly segregated, whereas hazardous waste requires specialized procedures to prevent exposure and contamination. Consequently, accurate classification is not only an administrative requirement but also a preventive health and environmental necessity.

From the researcher's perspective, the classification of healthcare waste into hazardous and non-hazardous categories forms the operational basis for all environmental safety measures in dental clinics. Without accurate classification, segregation becomes ineffective, storage becomes unsafe, and compliance with waste management standards becomes difficult to achieve. Therefore, this classification

should be regarded as the first and most decisive step in the safe management of healthcare and dental waste.

2.2.4 International Standards (WHO Guidelines)

International standards for healthcare waste management represent a globally recognized framework that aims to ensure the safe handling, treatment, and disposal of waste generated from healthcare activities. These standards are not only technical guidelines but also regulatory and operational systems designed to minimize risks to human health and the environment while promoting sustainable practices. Among the most influential international references in this field are the guidelines developed by the World Health Organization (WHO), which have become a cornerstone for national policies and institutional procedures worldwide.

The World Health Organization provides a comprehensive and structured model for healthcare waste management, emphasizing that safe waste handling must be implemented across all stages of the waste lifecycle. According to WHO, healthcare waste should be managed through a sequence of controlled steps including segregation at the point of generation, proper color-coded containment, safe storage, controlled transportation, appropriate treatment, and environmentally sound disposal. These guidelines highlight that failure at any stage of this chain can compromise the entire system and expose healthcare workers, patients, and the surrounding community to serious risks (World Health Organization, 2019).

In addition to WHO guidelines, national policies derived from international frameworks also play a critical role in translating global standards into local practice. For example, the Ministry of Health in Ghana developed a structured policy for healthcare waste management that aligns with international recommendations while considering local institutional capacities. This policy emphasizes the importance of regulatory enforcement, staff training, monitoring mechanisms, and institutional responsibility in ensuring compliance with safe waste management practices (Ministry of Health, 2006). This reflects how international standards are often adapted into national guidelines to suit specific healthcare systems.

Furthermore, recent developments in environmental health have expanded the scope of international standards to include sustainability and circular economy principles. Health Care Without Harm Europe stresses that healthcare waste management should not only focus on safe disposal but also aim at reducing waste generation, promoting recycling where appropriate, and minimizing environmental impact. This perspective introduces a shift from traditional waste management approaches toward more sustainable systems that integrate environmental responsibility into healthcare operations (Health Care Without Harm Europe, 2020).

Similarly, contemporary research has reinforced the link between effective waste management and sustainable healthcare systems. Lee and Lee argue that the implementation of international standards contributes significantly to improving environmental performance and operational efficiency within healthcare institutions. They emphasize that adopting standardized procedures enhances institutional accountability, reduces environmental risks, and supports the transition toward green healthcare systems (Lee & Lee, 2022).

At the technical level, international standards also address specific treatment methods, particularly for hazardous waste such as incineration. Cai, Wang, and Li highlight that modern waste treatment technologies must comply with environmental safety standards to prevent secondary pollution, especially in the case of medical waste incineration. They emphasize that improper treatment methods may lead to the release of toxic emissions, thereby undermining the purpose of safe waste management and creating additional environmental hazards (Cai, et al 2018).

Taken together, international standards—particularly those established by the World Health Organization—provide a comprehensive framework that integrates regulatory control, technical procedures, and sustainability principles, these standards serve as a reference point for healthcare institutions seeking to improve their waste management practices and ensure compliance with environmental safety requirements.

From the researcher's perspective, international standards represent the guiding foundation upon which healthcare waste management systems should be built, as they offer a structured and scientifically grounded approach for reducing risks, improving

compliance, and promoting environmental sustainability within healthcare and dental settings.

A synthesis of the principal global standards for healthcare waste disposal is presented in the following matrix, which systematically maps waste categories to their corresponding containment, storage, treatment, and disposal requirements. Adapted from the WHO (2019) framework, Table 2.3 provides a pragmatic tool for operationalizing environmentally sound practices, emphasizing the critical importance of correctly pairing each waste stream with its specific management protocol.

***Table 2-3**:* WHO-Based Matrix for Safe Healthcare Waste Management

Waste Category	**Recommended Container**	**Color Coding**	**Storage Requirement**	**Treatment Method**	**Final Disposal**
General non-hazardous waste	Strong plastic bag/bin	Black	Stored in a clean designated area	Not required	Municipal disposal
Infectious waste	Leak-proof bag/container	Yellow	Stored separately in a secure place	Autoclaving / Incineration	Controlled final disposal
Sharps waste	Puncture-resistant safety box	Yellow safety box	Stored safely to avoid injury	Disinfection / Incineration	Specialized disposal
Chemical waste	Resistant closed container	Brown	Stored away from general waste and drains	Chemical treatment	Specialized hazardous disposal
Pharmaceutical waste	Labeled secure container	Brown / according to policy	Stored under controlled conditions	Return / specialized treatment	Hazardous waste disposal
Mercury / Amalgam waste	Airtight special container	Specially labeled	Stored separately to prevent leakage	Recovery / specialized treatment	Approved hazardous disposal

2.2.5 Importance of Environmental Safety in Dental Clinics

Environmental safety in dental clinics has become an essential component of modern healthcare systems due to the nature of dental practices, which involve the generation of various types of hazardous and non-hazardous waste. Dental procedures frequently

expose both healthcare workers and patients to biological, chemical, and physical risks, making the application of environmental safety standards a critical requirement rather than an optional practice. The importance of environmental safety in dental settings extends beyond routine hygiene measures to include structured waste management, risk prevention, and compliance with regulatory frameworks.

From a public health perspective, environmental safety plays a crucial role in preventing the transmission of infectious diseases and reducing occupational hazards within dental clinics. Improper handling and disposal of dental waste—particularly infectious materials and sharps—can lead to serious health risks for healthcare workers, patients, and waste handlers. Studies conducted in Libyan dental settings indicate that insufficient awareness and weak implementation of safety measures are directly associated with increased exposure to health risks, highlighting the urgent need for strengthening environmental safety practices within clinics (Elwahaishi, et al 2025).

In addition to health protection, environmental safety in dental clinics is essential for reducing environmental pollution and ecological damage. Dental waste often contains hazardous components such as chemicals, disinfectants, and heavy metals, which may contaminate soil and water if improperly disposed of. Research conducted in dental clinics in Saudi Arabia demonstrates that inadequate waste management practices contribute significantly to environmental contamination, emphasizing the importance of adopting safe disposal methods and adhering to environmental regulations (Sabbahi, et al 2020).

At the institutional level, environmental safety is closely linked to professional responsibility and the quality of healthcare services. The application of safety standards reflects the commitment of dental clinics to maintaining a safe working environment, ensuring patient protection, and complying with health regulations. Evidence from dental clinics in Tripoli shows that the implementation of safety measures, including proper waste handling and infection control practices, contributes to improving overall clinical safety and operational performance (Elzahaf at el, 2022).

Furthermore, awareness and knowledge among dental professionals play a significant role in enhancing environmental safety. Studies conducted in Libya indicate that the level of knowledge, attitude, and practice regarding dental waste management directly influences the effectiveness of safety measures in clinical settings. Higher levels of awareness are associated with better compliance, improved waste segregation, and reduced environmental risks (Buhour & Aljwiw, 2025). This highlights that environmental safety is not only dependent on infrastructure and regulations, but also on the behavior and competence of healthcare personnel.

From an international perspective, the importance of environmental safety in dental clinics is also reflected in efforts to promote sustainable healthcare practices. Research conducted in the Philippines emphasizes that proper waste management in dental clinics contributes to environmental conservation and supports sustainable development goals by reducing pollution and improving resource utilization (Jumau-as & Kristopher, 2017). This broader perspective positions environmental safety as part of a global movement toward environmentally responsible healthcare system.

Overall, the importance of environmental safety in dental clinics can be understood as a multidimensional concept that integrates health protection, environmental preservation, institutional efficiency, and professional responsibility, it is not limited to preventing immediate risks, but also extends to ensuring long-term sustainability and compliance with environmental standards.

From the researcher's perspective, environmental safety in dental clinics represents a fundamental requirement for achieving safe, efficient, and sustainable healthcare delivery, its importance lies in its ability to reduce risks, enhance compliance, and support the development of environmentally responsible practices within dental healthcare settings.

2.2.6 Risks of Improper Waste Disposal

Improper waste disposal in healthcare and dental settings represents one of the most serious challenges facing environmental health and occupational safety. The danger of this issue does not lie only in the existence of hazardous waste itself, but in the way

such waste is handled after generation. Whenever segregation, storage, transport, treatment, or final disposal are performed incorrectly, the waste becomes a direct and indirect source of harm that may extend beyond the boundaries of the healthcare facility to affect workers, patients, waste handlers, communities, and natural ecosystems. For this reason, the risks of improper waste disposal are considered a major justification for the development and enforcement of environmental safety standards in healthcare institutions.

One of the most immediate risks associated with improper waste disposal is occupational exposure. Healthcare workers, cleaners, waste handlers, and even support staff may be injured or infected when hazardous waste is mixed with general waste or left without proper containment. Patwary, O'Hare, and Sarker explain that unsafe waste disposal in developing countries often leads to increased occupational vulnerability because healthcare waste is not always separated, labeled, or handled according to safety procedures. As a result, workers may face direct exposure to infectious materials, sharps injuries, and toxic substances, especially in systems where training and oversight are weak (Patwary, et al 2011).

A closely related risk is the spread of infection and disease transmission. Infectious waste, when improperly discarded, creates a pathway for microorganisms to move from clinical environments into broader community settings. This may occur through contact with contaminated materials, accidental reuse of unsafe items, or exposure during waste collection and disposal. In primary healthcare settings, poor management of solid medical waste has been shown to increase the probability of contamination and weaken the protective function of health facilities themselves. Al-Khatib notes that ineffective waste management measures contribute directly to unsafe environmental conditions in healthcare centers, thereby increasing the burden of health-related risk instead of reducing it (Al-Khatib, 2013).

In addition to occupational and infectious hazards, improper waste disposal creates serious environmental risks. Hazardous healthcare waste may contain chemicals, disinfectants, pharmaceuticals, and metal residues that can enter soil, water, or air if disposed of through uncontrolled dumping, burning, or sewage discharge. Windfeld and Brooks emphasize that medical waste becomes an environmental concern when

management systems fail to isolate hazardous fractions and apply suitable treatment technologies. In such cases, pollution is not merely a possible outcome, but a likely consequence of structural weakness in waste handling systems (Windfeld & Brooks, 2015).

Another important dimension of risk lies in the impact on households and communities, especially in areas where waste management systems are poorly regulated or partially informal. Waste disposed of unsafely may reach open spaces, residential areas, or municipal refuse streams, thereby exposing the public to injury, contamination, or toxic effects. Udofia *et al* found that poor disposal practices are associated with reported harm at the household and community levels, demonstrating that the effects of medical waste are not confined to healthcare institutions but may continue across the wider social environment (Udofia, et al 2017). This means that improper waste disposal transforms a clinical by-product into a broader public health issue.

Within dental practice specifically, improper waste disposal is especially concerning because dental clinics generate a combination of infectious, sharp, chemical, and metal-containing waste. Govan explains that waste management in dental practice requires careful control because many dental materials may present hidden hazards when discarded as ordinary waste. Materials contaminated with blood and saliva, as well as substances such as amalgam residues, can pose health and environmental risks if they are not managed according to defined procedures (Govan, 2014). Therefore, dental waste cannot be treated as routine refuse without creating the possibility of serious downstream consequences.

Improper disposal also carries administrative and legal risks for healthcare institutions. Facilities that fail to manage waste correctly may face regulatory non-compliance, reputational damage, increased operational costs, and loss of public trust. Unsafe disposal practices often indicate deeper institutional problems such as weak monitoring, inadequate training, poor infrastructure, and insufficient policy implementation. Thus, the risks of improper disposal are not only physical or environmental, but also organizational in nature, because they reveal failures in governance and institutional accountability.

It can therefore be said that the risks of improper waste disposal are multidimensional. They include occupational injury, infection transmission, environmental contamination, community exposure, and institutional weakness. These risks are interconnected, meaning that failure in one stage of waste management may trigger a chain of harmful consequences across several levels at once. This is what makes proper waste disposal one of the most essential components of environmental safety in healthcare and dental settings.

From the researcher's point of view, improper waste disposal represents a critical threat because it undermines the protective purpose of healthcare institutions and transforms waste from a manageable by-product into a source of continuous harm. The seriousness of these risks confirms that safe waste disposal is not merely a procedural requirement, but a fundamental condition for protecting health, preserving the environment, and ensuring responsible healthcare practice.

2.3 Dental Waste Management Practices

Dental waste management practices refer to the actual procedures followed within dental clinics for handling, sorting, storing, transporting, and disposing of the waste generated from clinical and administrative activities. These practices reflect the degree to which environmental safety principles are translated into everyday clinical work. In this sense, waste management in dental settings is not limited to the theoretical existence of rules and standards, but is demonstrated through what is actually done by practitioners inside the clinic during routine service delivery.

The importance of dental waste management practices arises from the particular nature of the dental work environment. Dental clinics generate a mixture of general waste, infectious materials, sharps, chemicals, and metal-containing residues, which requires a high degree of procedural control and operational awareness. Hegde, Kulkarni, and Ajantha explain that biomedical waste management is fundamentally practice-oriented, because the effectiveness of any waste management system depends on correct day-to-day implementation more than on policy statements alone. This

means that the practical side of waste handling is the true measure of whether a clinic is managing its waste safely and responsibly (Hegde, et al 2007).

In developing countries, the quality of waste management practices in dental clinics often varies considerably according to the level of institutional organization, available infrastructure, and staff awareness. Al-Khatib at el found that dental clinics may produce both solid and hazardous waste in significant amounts, yet the management practices applied are not always consistent with safety standards. Their findings indicate that gaps in segregation, handling, and disposal procedures may expose both the health sector and the surrounding environment to avoidable risks (Al-Khatib *et al.*, 2009). This confirms that dental waste management practices must be understood as a combination of technical procedure, professional responsibility, and environmental control.

From an applied perspective, dental waste management practices usually begin at the point where waste is generated. This stage includes identifying the type of waste, deciding how it should be separated, and determining the appropriate container or holding system. After this, practices extend to temporary storage, internal handling, and final transfer to disposal or treatment channels. Thus, waste management is not a single act, but a sequence of interrelated practices in which error at one stage can affect the whole system. Hashim, Mahrouq, and Hadi emphasize that evaluating dental waste management requires attention to the entire process rather than to isolated components, since weak performance in one step may undermine all subsequent stages of safe disposal (Hashim, et al 2011).

Another important aspect of dental waste management practices is that they reveal the real relationship between knowledge and behavior. A clinic may claim awareness of waste management principles, but actual practice may still remain weak due to routine negligence, inadequate supervision, or poor operational systems. Arora, Agrawal, Singh, and Reddy show that the management of dental waste in private clinics is strongly linked to the way practitioners translate knowledge into action, particularly in relation to segregation, storage, and disposal methods. Their findings suggest that practical deficiencies often persist even where basic awareness is present (Arora *et al*, 2014).

In the Libyan context, the practical dimension of dental waste management is particularly important because available local evidence indicates the existence of several procedural shortcomings in the handling of medical waste in dental clinics. Elzahaf *at al* found that waste management in dental clinics in Tripoli still faces practical limitations related to segregation, disposal procedures, and compliance with safety requirements. This suggests that the issue is not merely one of policy availability, but also one of practical implementation within the clinical setting itself (Elzahaf *et al*., 2020).

Accordingly, dental waste management practices may be understood as the operational expression of environmental safety standards in clinical reality. They show whether the clinic is able to control the waste it produces in a safe, organized, and sustainable manner. The stronger and more consistent these practices are, the greater the clinic's ability to protect workers, patients, and the environment from the negative effects of improper waste handling.

From the researcher's perspective, dental waste management practices constitute the practical core of environmental safety in dental clinics, because they represent the field in which standards are either applied effectively or weakened by poor implementation. Therefore, studying these practices is essential to understanding the actual level of compliance and identifying the operational gaps that affect safe waste disposal.

2.3.1 Waste Segregation Practices

Waste segregation practices represent the first and most decisive stage in dental waste management, because all subsequent procedures depend on whether waste has been separated correctly at the point of generation. Segregation means that each type of waste is identified and placed in the appropriate container according to its risk level and physical or chemical nature. In dental clinics, this process is particularly important because different categories of waste are produced side by side during the same procedure, including infectious materials, sharps, chemical residues, and general

non-hazardous waste. If these categories are mixed, the entire waste stream may become hazardous and more difficult to manage safely.

Proper segregation is essential because it reduces contamination, supports safe treatment, and limits unnecessary exposure to dangerous materials. Kumar and Samrongthong explain that compliance with healthcare waste management in dental clinics is strongly influenced by the effectiveness of segregation practices, as these practices determine whether hazardous waste is isolated from ordinary refuse and handled according to environmental and safety requirements (Kumar & Samrongthong, 2016). This indicates that segregation is not only a technical step, but also an indicator of the clinic's overall commitment to waste management standards.

The quality of segregation practices is also linked to the awareness and preparedness of dental personnel. Where staff understand the categories of waste and the risks associated with each, they are more likely to separate waste correctly and consistently. Azlan, Sulaiman, and Suhaimi found that biomedical waste management practices among dental students were closely related to their level of knowledge and attitude, suggesting that proper segregation depends not merely on the availability of bins, but also on the awareness and discipline of those who generate the waste (Azlan, *et al*, 2012). Thus, segregation is partly a behavioral issue and not solely a logistical one.

At the private practice level, segregation practices often reflect the degree of attention given to environmental and occupational safety in the clinic. The awareness, knowledge, and actual practice of dental waste management among private practitioners might not always fully aligned, which means that some clinics may possess basic knowledge yet still fail to apply effective segregation procedures in daily work (Abhishek *et al*., 2016). This reinforces the idea that successful segregation requires both understanding and consistent enforcement.

In local Libyan practice, segregation remains one of the key operational concerns in dental waste management. It has been shown that waste management practices in dental clinics in Tripoli revealed shortcomings in the separation of medical waste categories, which may reduce the safety and efficiency of the disposal process

(Shampe *et al*., 2020). Such findings suggest that weak segregation is one of the clearest signs of limited compliance with environmental safety standards

Similarly, evidence from Iran supports the view that waste segregation is closely associated with the overall quality of dental waste management. For instance, Zazouli and Ehsan has noted that the rate of waste generation and the methods of handling it cannot be managed effectively unless segregation is carried out properly from the outset. Without accurate separation, the clinic loses the ability to distinguish between waste that can be treated through ordinary systems and waste that requires special control procedures (Zazouli & Ehsan, 2014).

It can therefore be said that waste segregation practices are the operational foundation of safe dental waste management. Their importance lies in their capacity to reduce risk, improve organization, lower treatment burdens, and enhance compliance with environmental and healthcare regulations. In practical terms, segregation is the point at which environmental safety either begins successfully or fails from the very start.

From the researcher's point of view, waste segregation practices are the most critical practical indicator of proper dental waste management, because they directly determine the quality of all later stages of handling, storage, and disposal. A clinic that performs segregation correctly is more likely to demonstrate real compliance with environmental safety standards, whereas weak segregation practices often signal broader failures in waste management implementation.

2.3.2 Waste Handling and Storage

Waste handling and storage constitute a central stage in the management of healthcare and dental waste, because they represent the link between waste generation and its final treatment or disposal. Even where segregation is performed correctly, weak handling or unsafe storage can still expose workers, patients, and the environment to considerable risk. In dental clinics, this stage is especially important because waste is often generated continuously throughout the working day, and different categories of waste require immediate and controlled movement to appropriate storage locations.

Therefore, the effectiveness of handling and storage practices reflects the practical maturity of the waste management system within the healthcare institution.

I. Safe Internal Handling of Waste

Safe waste handling refers to the procedures used to collect, move, and transfer waste from the point of generation to temporary storage without causing spillage, contamination, or direct exposure. This requires that waste be handled by trained personnel using proper containers and protective measures. Abdulla *et al* emphasize that internal handling practices are among the most sensitive aspects of waste management because mistakes at this stage can quickly undermine all earlier segregation efforts and increase occupational exposure within the facility (Abdulla, et al 2008).

II. Use of Appropriate Containers

One of the key requirements of proper waste handling and storage is the use of suitable containers that match the type of waste being generated. Hazardous waste, infectious materials, and sharps should not be collected in the same way as general waste. Appropriate containers should be durable, leak-proof, clearly marked, and in the case of sharps, puncture-resistant. Marinkovic *et al* explain that the management of hazardous medical waste depends greatly on the adequacy of the containers used during handling and storage, since inappropriate containment increases the risk of injury, leakage, and environmental contamination (Marinkovic *et al*,, 2008).

III. Temporary Storage Conditions

Storage is not merely the act of keeping waste in one place until disposal; rather, it requires a controlled environment that minimizes risk and prevents unauthorized access, odor, leakage, or decomposition. Waste storage areas should therefore be clearly designated, secure, and separated from clinical or public spaces. Nnorom and Ohakwe note that medical waste management practices become ineffective when storage areas are poorly maintained or when waste remains stored beyond safe periods, as this creates serious health and environmental hazards within healthcare institutions (Nnorom & Ohakwe, 2011).

IV. Policy Adherence in Handling and Storage

The quality of waste handling and storage is closely linked to the degree of adherence to institutional waste management policies. Where facilities have clear rules regarding how waste should be moved, where it should be stored, and who is responsible for these tasks, the process becomes more organized and safer. ElMitainy and El-Haggar found that increased adherence to waste management policy contributes significantly to improving waste handling and storage practices in healthcare facilities, showing that operational discipline is strongly influenced by the existence and enforcement of clear management systems (ElMitainy & El-Haggar, 2019).

V. Storage and Handling in the Libyan Context

In the Libyan healthcare context, weaknesses in handling and storage practices reflect broader challenges in the medical waste management system, including infrastructure limitations, inconsistent procedures, and insufficient supervision. Elhadi and Abusitta, in their assessment of medical waste management in Tripoli Central Hospital, indicate that the handling and temporary storage of medical waste remain areas requiring improvement, particularly in relation to safety, organization, and compliance with standard procedures (Elhadi & Abusitta, 2022). Although their study focused on hospital settings, its implications are highly relevant to dental clinics, where safe handling and storage are equally important for environmental safety.

It can therefore be concluded that waste handling and storage are not secondary operational details, but essential protective stages within the waste management process. The safety of these stages depends on proper collection methods, suitable containers, controlled storage conditions, and consistent adherence to policy and supervision.

From the researcher's perspective, waste handling and storage represent a decisive stage in dental waste management because they translate segregation into practical control. If waste is handled unsafely or stored improperly, the clinic loses much of its ability to maintain environmental safety, even if earlier stages of waste classification and separation were correctly performed

2.3.3 Disposal Methods in Dental Clinics

Disposal methods in dental clinics represent the final and most sensitive stage in the waste management process, because they determine whether the waste generated within the clinic will be rendered harmless or will continue to pose risks after leaving the point of care. The importance of this stage lies in the fact that even if waste is correctly segregated, handled, and stored, improper disposal may still result in occupational hazards, environmental contamination, and non-compliance with safety standards. In dental settings, disposal methods are especially significant because the clinic produces different waste streams that cannot all be treated through one uniform method, particularly infectious waste, sharps, chemicals, and amalgam-related waste.

In general, disposal in dental clinics should be based on the principle that each waste category must be directed to the most appropriate treatment or final disposal route according to its level of risk and material characteristics. Allen explains that clinical and dental waste should not be disposed of through routine municipal channels unless it is clearly non-hazardous, and that effective disposal depends on prior classification and the availability of proper disposal arrangements for each type of waste (Allen, 2014). This means that disposal is not an isolated act, but a decision rooted in the earlier stages of waste management.

One of the most widely used disposal-related methods for infectious healthcare waste is chemical disinfection, particularly in contexts where specific infectious materials need to be neutralized before further handling or final disposal. Li, Wang, and Chen note that chemical disinfection can be an effective treatment method when applied appropriately, especially for certain categories of infectious waste, because it reduces microbial load and lowers the immediate hazard posed by contaminated materials. However, they also emphasize that this method requires careful selection of disinfectants and proper operational control to avoid secondary environmental impact from chemical residues (Li, et al 2019). Thus, chemical disinfection is useful, but it must itself be governed by environmental safety considerations.

Another important disposal-related method is autoclaving, which is commonly used for the treatment of infectious waste prior to final disposal. Autoclaving relies on

steam sterilization to inactivate pathogenic microorganisms and is often preferred because it reduces biological risk without the air pollution concerns associated with some thermal destruction techniques. Chen, Wang, and Li explain that autoclaving has become one of the most accepted methods for treating healthcare waste due to its ability to combine safety, practicality, and relatively lower environmental burden when compared with uncontrolled burning or poorly regulated incineration (Chen, et al 2020). In dental settings, this method is especially relevant for contaminated disposables and some infectious waste streams that require treatment before leaving the clinic or being transferred to external waste systems.

A particularly distinctive aspect of disposal methods in dental clinics is the management of mercury and amalgam waste. This category cannot be safely discarded with general refuse or discharged into sewage systems because of the toxic nature of mercury and its capacity to accumulate in the environment. Ramesh, Ramesh, and Krishnan found that the disposal of mercury-containing waste in dental clinics remains a critical issue, especially where practitioners lack consistent systems for separating, storing, and transferring amalgam residues for specialized handling. Their findings show that disposal of such waste requires a more controlled and dedicated approach than ordinary clinical waste because of its long-term environmental consequences (Ramesh, et al 2019).

In the same direction, the FDI World Dental Federation emphasizes that amalgam waste must be managed through safe collection, containment, and transfer procedures that prevent mercury release into the environment. The Federation's guidance reflects a growing international recognition that dental clinics must adopt special disposal pathways for mercury-related waste and should avoid disposal routes that contaminate wastewater, soil, or general municipal streams (FDI World Dental Federation, 2021). This reinforces the idea that dental disposal methods are not only about general waste treatment, but also about addressing the specific environmental profile of dental materials.

Taken together, disposal methods in dental clinics may include safe transfer to licensed waste contractors, chemical disinfection for certain infectious wastes, autoclaving for sterilizable hazardous materials, and specialized collection systems for

mercury- and amalgam-containing waste. The choice of method depends on the type of waste, the level of associated risk, the resources available, and the regulatory framework governing healthcare waste in the relevant context. Therefore, proper disposal is not simply the end of the waste process, but the stage at which the success or failure of the entire waste management system becomes most visible.

From the researcher's perspective, disposal methods in dental clinics are a decisive indicator of environmental responsibility because they reveal whether waste is ultimately neutralized in a safe and compliant manner or merely transferred from the clinic to the wider environment. The appropriateness of the disposal method is therefore essential for reducing health risks, preventing ecological damage, and ensuring that dental waste management is consistent with environmental safety standards.

The management of dental waste may be understood as a continuous process that begins at the point of waste generation and extends through handling, storage, treatment, and final monitoring. This sequence can be summarized in the following flowchart (Figure 2.1).

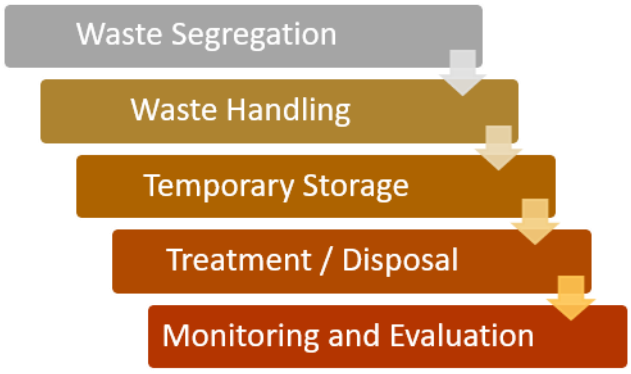


Figure 2-1: **Dental Waste Management Cycle in Dental Clinics.**

Dental waste management is a continuous and interrelated process in which failure at any stage may negatively affect the safety and effectiveness of the whole system. The design was Developed by the researcher based on the reviewed literature

2.3.4 Common Mistakes in Waste Management

Despite the growing emphasis on environmental safety and healthcare waste management standards, many dental clinics still make recurring mistakes in dealing with waste generated from daily clinical activities. These mistakes are often not the result of the absence of waste itself, but rather of weaknesses in how waste is classified, segregated, stored, handled, and finally disposed of. In practice, the repeated occurrence of such errors reflects a gap between what is required by safety standards and what is actually implemented in the clinical setting. For this reason, identifying the common mistakes in waste management is important because it helps explain why compliance often remains partial or inconsistent in dental clinics.

One of the most common mistakes is the mixing of hazardous and non-hazardous waste. When infectious materials, sharps, or chemically contaminated items are discarded together with ordinary waste, the entire waste stream becomes unsafe and more difficult to handle properly. For instance, Darwish and Al-Khatib, in their evaluation of dental waste management in Palestine, showed that weak separation practices are among the most visible failures in dental waste systems, as clinics often do not maintain clear distinctions between different waste categories during disposal (Darwish & Al-Khatib, 2006). This mistake increases both the cost and the risk of waste management because non-hazardous waste becomes unnecessarily treated as dangerous, while hazardous waste may escape proper control.

A second common mistake is the inadequate use of containers and labeling systems. Waste may be placed in inappropriate containers, collected without clear color coding, or stored in receptacles that do not match its level of risk. Such practices make later handling unsafe and create confusion for waste handlers. It has been found that dental waste management among dentists may be weakened by operational shortcomings such as improper container use and inconsistent adherence to recommended handling procedures, which directly undermines the safety of the waste management process (Lakbala, 2020).

Another frequent mistake concerns the failure to translate knowledge into safe practice. Dental professionals may have general awareness of biomedical waste risks,

yet actual practice may still fall short of safe standards. This problem becomes particularly evident under operational pressure or during exceptional conditions such as public health emergencies. It has been shown that safe practices of biomedical and dental waste management depend not only on awareness, but also on consistent behavioral implementation, indicating that professionals may know the correct procedures yet still fail to apply them properly in practice (Mariam, et al 2022). This suggests that waste management errors are often behavioral as well as procedural.

A further mistake is the weak handling of infectious waste in private dental practice, especially where monitoring and formal systems are limited. In such cases, mistakes may include delayed disposal, unsafe temporary storage, or poor handling of contaminated materials. Abdallaoui *et al* showed that infectious healthcare waste management among private dental practitioners is often affected by deficiencies in knowledge, attitudes, and practices, leading to repeated errors that weaken safety and compliance (Abdallaoui Maan, et al 2023). This indicates that mistakes in waste management are not always isolated incidents, but may reflect wider organizational or educational gaps.

In addition, clinics may make mistakes related to recycling and environmental responsibility, particularly when recyclable and hazardous components are not properly distinguished. Poor segregation can prevent safe recovery of recyclable materials and increase the environmental burden of waste disposal. In a survey-based analysis, found that errors in segregation and recycling practices contribute directly to the environmental impact of dental waste, showing that even seemingly small operational mistakes can have broader ecological consequences (Boukhris *et al.*, 2025).

These mistakes reveal that waste management in dental clinics often fails not because standards are conceptually unknown, but because they are inconsistently implemented at the operational level. In many cases, the common errors are interconnected: poor segregation leads to unsafe handling, weak labeling leads to storage problems, and limited supervision allows incorrect practices to continue without correction. Thus, common mistakes in waste management should be viewed as indicators of broader weaknesses in training, infrastructure, oversight, and institutional discipline.

From the researcher's perspective, the common mistakes in dental waste management represent practical warning signs of weak compliance with environmental safety standards. Their importance lies in the fact that they expose the specific operational points at which the system fails, and therefore provide a useful basis for understanding where corrective action is needed in order to improve safety, compliance, and environmental performance in dental clinics.

2.3.5 Challenges in Dental Waste Management

Dental waste management in contemporary healthcare systems is influenced by a wide range of interconnected challenges that extend beyond simple procedural issues. These challenges are not confined to technical limitations alone, but rather reflect a combination of structural, organizational, behavioral, and environmental constraints that collectively affect the effectiveness of waste management practices in dental clinics. In many cases, these challenges are more evident in developing countries, where healthcare systems may struggle with limited resources, inconsistent regulatory enforcement, and varying levels of professional awareness.

At the structural level, one of the most persistent challenges is the inadequacy of waste management infrastructure. Many healthcare and dental facilities lack properly designed systems for waste collection, storage, and treatment, which leads to fragmentation in the management process. Mmereki, et al explain that weaknesses in storage, collection, and disposal systems create operational gaps that prevent waste from being managed in a continuous and controlled manner. These structural deficiencies often result in delays, unsafe handling, and reliance on suboptimal disposal practices (Mmereki, et al 2015). In dental clinics, this problem is particularly critical because waste is generated in small but continuous quantities, requiring efficient and accessible infrastructure at all times.

In addition to infrastructure, economic constraints represent another major challenge in dental waste management. The cost of implementing safe waste management systems—including specialized containers, treatment technologies, and transportation services—can be a significant burden, particularly for small private clinics. Lakbala highlights that the performance of healthcare waste management systems is closely

linked to available financial resources, as limited funding often leads to compromises in safety practices and reduced compliance with recommended standards (Lakbala, 2015). This suggests that even when knowledge exists, financial limitations may prevent its full application in practice.

Organizational and administrative challenges also play a key role in shaping waste management outcomes. In many healthcare settings, there is a lack of clear responsibility, weak monitoring systems, and insufficient enforcement of waste management policies. Madalin, Elena, and Oana note that medical waste management in healthcare facilities is often affected by administrative inefficiencies, including poor coordination between departments and limited institutional oversight. Such conditions create an environment in which unsafe practices may continue without correction or accountability (Madalin, et al 2010). In dental clinics, where operations are often decentralized, these challenges may be even more pronounced.

Another important dimension of the problem lies in behavioral and awareness-related challenges. The effectiveness of waste management systems depends heavily on the knowledge, attitude, and practices of healthcare personnel. Where awareness is limited or inconsistent, even well-designed systems may fail to function properly. Bokhoree *et al* emphasized that environmental and health risks associated with medical waste are often intensified by human factors, including negligence, lack of training, and insufficient understanding of safety procedures (Bokhoree *et al*., 2014). This highlights that waste management challenges are not purely technical, but also deeply linked to human behavior and professional culture.

Furthermore, informal and uncontrolled waste handling practices represent a significant challenge in some contexts, particularly in developing regions. Patwary, O'Hare, and Sarker draw attention to the existence of informal waste economies, where medical waste may be scavenged, reused, or recycled without proper control. Such practices create serious health and environmental risks, as hazardous materials may re-enter circulation outside regulated systems (Patwary, et al 2012). Although this issue may be less visible in formal dental clinics, it reflects a broader systemic weakness that can indirectly affect waste management outcomes.

These challenges are not isolated; rather, they interact in complex ways that make waste management in dental clinics a multifaceted issue. Weak infrastructure may amplify financial constraints, limited funding may reduce training opportunities, and poor supervision may allow unsafe behaviors to persist. As a result, the effectiveness of dental waste management cannot be improved by addressing a single factor in isolation, but requires a comprehensive approach that considers all dimensions simultaneously.

From the researcher's perspective, the challenges in dental waste management represent structural and operational barriers that limit the practical application of environmental safety standards. Understanding these challenges is essential because it allows for identifying the root causes of weak compliance and provides a basis for proposing realistic and context-appropriate improvements in dental waste management practices.

2.4 Factors Influencing Compliance

Compliance with environmental safety standards in healthcare and dental waste management is not determined by a single factor, but rather by a set of interrelated variables that collectively shape how waste management practices are implemented within healthcare facilities. The level of compliance reflects the extent to which institutions and healthcare workers adhere to established procedures, guidelines, and regulatory frameworks governing waste handling, storage, and disposal. In practice, compliance is influenced by organizational structure, resource availability, staff behavior, training, and the broader policy environment.

One of the primary determinants of compliance is the organizational and operational structure of healthcare facilities. Institutions that have clearly defined procedures, designated responsibilities, and structured waste management systems tend to demonstrate higher levels of compliance. The variations in waste management practices across healthcare facilities are often linked to differences in institutional organization and the availability of structured systems for managing waste processes (Debere *et al*., 2013). This suggests that compliance is strongly influenced by how well the waste management system is integrated into the overall functioning of the institution.

In addition to organizational factors, the presence of clear policies and regulatory frameworks plays a significant role in shaping compliance. Proper healthcare waste management practices are closely related to the existence of well-defined guidelines and the extent to which these guidelines are enforced within healthcare facilities. Where policies are unclear or weakly implemented, compliance tends to decline, even if basic awareness exists among staff (Omar *et al*., 2012). This highlights the importance of governance and institutional control in ensuring adherence to environmental safety standards.

Another important factor influencing compliance is the level of awareness and training among healthcare workers. The ability of staff to correctly implement waste management procedures depends on their understanding of risks, their familiarity with guidelines, and their willingness to follow proper practices. It has been shown that training and awareness programs significantly improve compliance levels by enhancing both knowledge and practical skills related to waste management (Gilavand *et al*., 2021). This indicates that compliance is not only a matter of rules, but also of human capacity and behavioral readiness.

At a broader level, economic and infrastructural conditions also affect compliance. Limited resources, lack of equipment, and insufficient access to appropriate waste treatment facilities can restrict the ability of healthcare institutions to follow recommended procedures. Healthcare waste management in developing countries is often constrained by financial and infrastructural limitations, which reduce the feasibility of full compliance with environmental safety standards (Khan *et al*., 2019). Therefore, compliance must be understood within the context of available resources and not only as a matter of policy enforcement.

Moreover, contemporary research highlights that compliance is increasingly influenced by sustainability considerations and evolving healthcare practices. For example, Ranjbari and colleagues show that the transition toward circular economy models and environmentally sustainable systems is shaping how healthcare waste management is approached, which in turn affects compliance patterns. Institutions that adopt sustainability-oriented practices are more likely to integrate waste

management into broader environmental strategies, thereby strengthening compliance with safety standards (Ranjbari *et al*., 2022).

These factors—organizational structure, regulatory frameworks, staff training, resource availability, and sustainability orientation—do not operate independently. Rather, they interact in complex ways to determine the level of compliance within healthcare and dental settings. Weakness in any one factor may undermine the effectiveness of the others, leading to partial or inconsistent adherence to environmental safety standards.

From the researcher's perspective, compliance in dental waste management is a multidimensional outcome that reflects the combined effect of institutional capacity, human behavior, and environmental awareness. Understanding the factors that influencing compliance is therefore essential for identifying the underlying causes of weak implementation and for developing strategies that improve adherence to environmental safety standards in dental clinics.

2.4.1 Staff Training and Qualification

Staff training and qualification represent one of the most critical factors influencing compliance with environmental safety standards in dental waste management. The effectiveness of any waste management system depends largely on the competence of the individuals responsible for implementing it, as even well-designed systems may fail if staff lack the necessary knowledge and skills to apply them correctly. In dental clinics, where waste is generated continuously and in different forms, trained personnel play a central role in ensuring that waste is handled safely and in accordance with established procedures.

Training enhances the ability of healthcare workers to identify different types of waste, apply proper segregation techniques, and follow safe handling and disposal practices. Studies conducted in Libyan dental settings indicate that the level of awareness and understanding among healthcare workers is directly linked to the effectiveness of waste management practices. Elwahaishi *et al* found that environmental awareness significantly influences the way medical waste is managed

in dental clinics, particularly in relation to recognizing health risks and applying safe procedures (Elwahaishi *et al*., 2025).

Similarly, knowledge, attitude, and practice are closely interconnected in determining how healthcare workers deal with hazardous waste. Buhour and Aljwiw demonstrate that dentists who possess higher levels of knowledge and positive attitudes toward waste management are more likely to implement proper safety practices, whereas limited awareness often leads to unsafe or inconsistent behavior (Buhour & Aljwiw, 2025). This suggests that training is not limited to transferring knowledge, but also contributes to shaping professional attitudes toward compliance with environmental standards.

Beyond awareness, formal training programs contribute to improving practical performance in waste management tasks. It has shown that healthcare workers who receive structured training are better able to apply correct sorting and disposal practices, leading to reduced operational errors and improved safety within healthcare facilities (Adu *et al*., 2020). This confirms that training is a key mechanism for translating theoretical knowledge into effective practice.

In addition, the qualification and professional background of healthcare workers influence their ability to manage waste effectively. Differences in knowledge and practice levels among healthcare workers are often associated with variations in educational background and professional training, indicating that academic and professional qualifications play an important role in determining the level of compliance with waste management standards (Mokuolu *et al.*, 2019).

Furthermore, continuous training and awareness programs are necessary to maintain and improve compliance over time. The ongoing education and reinforcement of safety practices help sustain improvements in waste management and prevent the decline of compliance levels due to routine or negligence (Gilavand *et al*., 2021). Therefore, training should not be viewed as a one-time activity, but as a continuous process that supports professional performance within healthcare institutions.

From the researcher's perspective, staff training and qualification represent the cornerstone of effective dental waste management, because they determine how accurately and consistently environmental safety standards are applied in practice. Without adequate training, compliance remains weak even in the presence of clear policies, whereas effective training contributes to enhancing safety, reducing risks, and improving environmental performance in dental clinics.

2.4.2 Awareness of Environmental Regulations

Awareness of environmental regulations is a key determinant of effective healthcare waste management, particularly in dental clinics where different categories of hazardous and non-hazardous waste are generated on a daily basis. Environmental regulations are designed to guide healthcare professionals in managing waste safely, reducing risks, and ensuring compliance with public health and environmental standards. However, the effectiveness of these regulations depends largely on the level of awareness among healthcare workers, as regulations that are not understood or internalized are unlikely to be implemented correctly in practice. The awareness of environmental regulations in dental waste management can be understood through several key dimensions:

I. Knowledge of Waste Management Regulations

Knowledge of regulations refers to the extent to which healthcare workers are familiar with official guidelines, rules, and procedures related to waste management. This includes understanding waste classification, segregation requirements, storage conditions, and disposal protocols. Golandaj and Kallihal found that awareness of biomedical waste management regulations among healthcare staff significantly influences their ability to follow proper practices, as individuals with higher knowledge levels are more likely to comply with safety standards (Golandaj & Kallihal, 2021).

II. Awareness of Environmental and Health Risks

Awareness is not limited to knowing the rules, but also involves understanding the risks associated with improper waste management. Healthcare workers who recognize the environmental and health consequences of unsafe waste disposal are more likely

to adhere to regulations. Awareness of biomedical waste hazards plays a critical role in improving compliance among dental professionals, particularly in relation to infection control and environmental protection (Narang *et al*., 2012).

III. Attitude Toward Environmental Responsibility

The attitude of healthcare workers toward environmental responsibility is another important aspect of awareness. Even when regulations are known, compliance may remain weak if individuals do not perceive environmental safety as a priority. It has been shown that awareness of sustainability issues in dentistry is closely linked to attitudes, as professionals who value environmental responsibility are more likely to adopt safe and sustainable practices (Martin *et al*., 2021). This shows that awareness includes both cognitive and behavioral components.

IV. Awareness of Proper Practices and Procedures

This dimension relates to the practical understanding of how regulations should be applied in daily clinical work. It includes knowledge of correct segregation techniques, safe handling procedures, and appropriate disposal methods. Rao found that awareness of proper waste management practices is essential for ensuring that regulations are implemented effectively in healthcare settings, as lack of practical understanding often leads to incorrect or inconsistent application of safety procedures (Rao, 2008).

V. Awareness of Infection Control and Safety Standards

Environmental regulations in healthcare are closely linked to infection control measures. Awareness of infection prevention practices, such as the safe handling of contaminated materials and the use of protective measures, contributes to better compliance with waste management standards. It has been demonstrated that knowledge of infection control practices among dental professionals is strongly associated with safer waste handling and improved adherence to healthcare regulations (Qudeimat *et al*., 2006).

It can be concluded that awareness of environmental regulations is a multidimensional concept that includes knowledge, risk perception, attitude, and practical understanding. These dimensions work together to influence how healthcare workers

interpret and apply waste management guidelines in real clinical settings. Without adequate awareness, even well-developed regulations may fail to achieve their intended outcomes.

From the researcher's perspective, awareness of environmental regulations represents a fundamental driver of compliance in dental waste management, as it shapes both the understanding and behavior of healthcare workers. Enhancing awareness through education and training is therefore essential for improving adherence to environmental safety standards and ensuring safer waste management practices in dental clinics.

2.4.3 Availability of Infrastructure and Resources

The availability of infrastructure and resources is one of the most decisive factors influencing compliance with environmental safety standards in dental waste management. Even when healthcare workers possess adequate awareness and positive attitudes toward safe waste handling, compliance may still remain weak if the necessary physical facilities, equipment, and operational support are not available. In this sense, infrastructure and resources provide the practical foundation that enables environmental regulations to be translated into daily clinical practice. The role of infrastructure and resources in supporting compliance can be understood through the following dimensions:

I. Availability of Proper Waste Containers

One of the most basic requirements of an effective waste management system is the availability of appropriate containers for different categories of waste. These include leak-proof containers for infectious waste, puncture-resistant boxes for sharps, and clearly marked bags or bins for non-hazardous waste. Without such containers, segregation becomes difficult or impossible to implement correctly. The adequacy of waste containers is a central element in waste management practices, as weak container systems often lead to unsafe handling, mixing of waste categories, and increased occupational risks (Abdulla, et al 2008).

II. Availability of Storage and Collection Facilities

Infrastructure also includes the presence of safe temporary storage areas and organized systems for waste collection within and outside the healthcare facility. If waste storage spaces are not secure, accessible, and properly maintained, even correctly segregated waste may later become a source of contamination or operational disorder. The effectiveness of healthcare waste management depends heavily on the existence of organized storage and collection arrangements, since weak infrastructure at this stage disrupts the continuity of safe waste handling (Shinee *et al.*, 2008).

III. Availability of Financial and Material Resources

The implementation of waste management systems requires continuous financial support for purchasing containers, personal protective equipment, transportation arrangements, and treatment services. Where funding is limited, clinics may be forced to reduce the quality of their waste management practices or rely on unsafe alternatives. It has been shown that financial and material constraints are among the most important obstacles affecting medical waste management systems, particularly in developing contexts where healthcare facilities operate with limited institutional support (Coker *et al.*, 2009). This demonstrates that compliance is often tied not only to willingness, but also to affordability and access to resources.

IV. Availability of Management Strategies and Institutional Support

Infrastructure should not be understood only in a physical sense; it also includes the availability of organized management strategies that guide the use of resources within the facility. This involves having operational plans, procedures, and practical arrangements that help staff use available materials effectively. Effective clinical solid waste management depends on the presence of structured strategies that coordinate how infrastructure and available resources are used across the waste management process (Wiafe *et al*., 2015). Therefore, resources are most effective when they are supported by planning and institutional organization.

V. Availability of Technological Support and Tracking Systems

Modern waste management increasingly benefits from technological tools that improve control, tracking, and accountability. Technologies such as RFID systems can support hazardous waste management by allowing waste to be traced from

generation to final disposal, thereby reducing loss, mismanagement, and unregulated movement of dangerous materials. The technological infrastructure can strengthen hazardous waste management systems by improving monitoring and traceability, which are essential for maintaining compliance and ensuring environmental safety (Namen *et al*., 2014).

It becomes clear, therefore, that the availability of infrastructure and resources is not a secondary issue in waste management, but a core condition for effective compliance. Safe containers, storage spaces, financial support, institutional strategies, and technological systems all contribute to creating an operational environment in which environmental safety standards can be applied consistently and effectively. In their absence, compliance tends to become partial, unstable, or purely formal rather than practical.

From the researcher's perspective, the availability of infrastructure and resources represents the practical capacity of the dental clinic to implement environmental safety standards. The stronger this capacity is, the more likely the clinic is to achieve safe and sustainable waste management. Conversely, weak infrastructure and limited resources often transform compliance from a realistic practice into a difficult or incomplete goal.

2.4.4 Internal Monitoring and Supervision

Internal monitoring and supervision are essential components of effective healthcare waste management systems, as they ensure that environmental safety standards are not only established but also consistently implemented in daily practice. In dental clinics, where waste is generated continuously and handled at multiple stages, the presence of internal control mechanisms plays a crucial role in maintaining compliance, detecting errors, and correcting unsafe practices. Without proper monitoring and supervision, even well-designed waste management systems may gradually deteriorate, leading to weak adherence and increased risk.

Internal monitoring primarily involves the continuous observation and evaluation of waste management practices within the healthcare facility. This includes checking whether waste is properly segregated, handled, stored, and disposed of according to

established guidelines. ElMitainy and El-Haggar emphasize that adherence to waste management policies significantly improves when healthcare facilities implement structured monitoring systems, as these systems reinforce accountability and ensure that procedures are followed correctly (ElMitainy & El-Haggar, 2019). This indicates that monitoring is not only a control mechanism but also a tool for strengthening institutional discipline.

In addition to routine observation, systematic evaluation tools such as waste audits play a critical role in internal monitoring. Waste audits involve analyzing the composition, volume, and handling of waste to assess the effectiveness of management practices and identify areas for improvement. Slutzman and colleagues highlight that waste audits are considered best practices in healthcare waste management because they provide measurable data that supports decision-making and continuous improvement (Slutzman *et al.,* 2023). Through such evaluations, healthcare facilities can move from reactive management to proactive control of waste-related risks.

Supervision, on the other hand, focuses on ensuring that healthcare workers follow correct procedures and maintain safe practices during waste handling. This involves direct oversight, guidance, and feedback provided by supervisors or responsible personnel within the clinic. Monitoring infection control practices, including waste management behaviors, contributes to improving compliance among healthcare workers, particularly when supervision is consistent and supported by awareness initiatives (Mulay *et al.,* 2024). This shows that supervision plays both a corrective and a preventive role in maintaining environmental safety standards.

At a broader level, internal monitoring and supervision are also supported by institutional and regulatory frameworks that define how waste should be managed within healthcare facilities. Guidelines provided by organizations such as the Health and Safety Executive and the National Health Service emphasize the importance of clear internal control systems, regular inspections, and documented procedures for waste management. These frameworks highlight that effective supervision requires structured protocols, defined responsibilities, and continuous review of practices to ensure safety and compliance (Health and Safety Executive, 2023; NHS, 2023).

The relationship between monitoring, supervision, and compliance is therefore dynamic. Monitoring identifies deviations from standard procedures, while supervision ensures that corrective actions are implemented and maintained over time. Together, they create a feedback system that supports continuous improvement and prevents the recurrence of unsafe practices. In dental clinics, where operations are often fast-paced and decentralized, such internal control mechanisms are particularly important to maintain consistency and reduce risk.

From the researcher's perspective, internal monitoring and supervision represent the operational backbone of compliance in dental waste management. Their importance lies in their ability to translate policies into practice, detect weaknesses in real time, and sustain safe behavior within the clinical environment. Without effective monitoring and supervision, compliance with environmental safety standards is likely to remain incomplete, regardless of the availability of regulations or resources.

The relationship between the study variables can be summarized in the following conceptual framework, which illustrates the major factors influencing compliance with environmental safety standards in dental clinics and the expected safety outcomes resulting from such compliance.

2.4.5 Barriers and Organizational Challenges

Barriers and organizational challenges are among the most significant factors that limit effective compliance with environmental safety standards in dental waste management. Even when healthcare workers possess sufficient awareness and clinics attempt to apply safe practices, the presence of structural and organizational obstacles may prevent proper implementation. In dental settings, these challenges may arise from administrative weakness, limited resources, poor planning, technological gaps, or external pressures affecting the healthcare system. Therefore, understanding these barriers is essential for explaining why compliance often remains partial or inconsistent in practice. The main barriers and organizational challenges can be explained as follows:

I. Limited Institutional Capacity

One of the most common organizational barriers is the limited institutional capacity of healthcare facilities to manage waste effectively. This includes weak planning systems, insufficient operational structures, and the absence of integrated management models. In developing contexts, waste management systems are often introduced without adequate institutional readiness, which reduces their practical effectiveness. Fidje, Haddara, and Langseth explain that the adoption of sustainable smart waste management systems in developing countries is often constrained by institutional weaknesses, including poor organizational preparedness and limited administrative capacity (Fidje, et al 2023).

II. Socio-Economic Constraints

Waste management practices are strongly influenced by socio-economic conditions, especially in settings where healthcare institutions face financial pressure and limited public support. In such cases, waste management may receive lower priority compared with other urgent clinical or administrative needs. It has been shown that waste management practices in developing countries are shaped by broader socio-economic realities, including funding limitations, weak public investment, and institutional inequality, all of which restrict the implementation of effective environmental practices (Jagun *et al*., 2022).

III. Crisis-Related and Emergency Challenges

Extraordinary situations such as public health emergencies may intensify organizational difficulties and expose weaknesses in waste management systems. During periods of crisis, clinics may experience increased waste generation, pressure on staff, and disruption of regular control measures. For instance, biomedical waste management in dental clinics during the COVID-19 pandemic was affected by additional burdens related to infection control, operational overload, and the urgent need for adaptive management strategies (Sharma *et al.*, 2021). This suggests that crises often magnify pre-existing weaknesses in organizational systems.

IV. Weak Integration of Sustainability into Practice

Another important barrier lies in the gap between sustainability principles and their practical incorporation into daily dental operations. Although many healthcare

systems increasingly recognize the importance of environmentally responsible waste management, this recognition does not always lead to effective implementation. The sustainable waste management in dental practices is often hindered by limited strategic integration, meaning that environmental goals remain insufficiently embedded within routine clinical and managerial procedures (Alshammari *et al.*, 2021).

V. Complexity of Waste Composition

A further challenge arises from the complex composition of dental waste itself. Dental clinics produce mixed waste streams that may contain infectious materials, contaminated disposables, sharps, chemicals, and recyclable components. This complexity requires a high level of organization and precision in handling procedures. Yeoh and colleagues, in their investigation of contaminated waste composition in a university dental clinic, showed that the nature of dental waste creates practical sustainability challenges, particularly when waste categories are not clearly distinguished or when clinic systems are not sufficiently equipped to manage contaminated materials effectively (Yeoh *et al*., 2024).

These barriers and challenges are interconnected rather than isolated. Limited institutional capacity may worsen the effects of socio-economic constraints, while weak sustainability planning may become more problematic during times of crisis. Similarly, the complexity of dental waste increases the burden on clinics that already lack strong organizational systems. As a result, compliance with environmental safety standards is often shaped as much by organizational realities as by individual knowledge or professional willingness.

From the researcher's perspective, barriers and organizational challenges represent the practical obstacles that stand between environmental safety standards and their effective application in dental clinics. Addressing these barriers requires more than technical guidance alone; it requires institutional strengthening, strategic planning, and the creation of supportive systems that enable clinics to translate environmental standards into sustainable daily practice.

2.5 Compliance with Environmental Safety Standards

Compliance with environmental safety standards in healthcare and dental waste management refers to the extent to which healthcare institutions and professionals adhere to established rules, procedures, and guidelines governing the safe handling, storage, treatment, and disposal of waste. In dental clinics, compliance is especially important because waste management involves multiple stages and categories of waste that require consistent control. The presence of standards alone does not guarantee safety; rather, safety is achieved when those standards are translated into real and continuous practice within the clinical setting.

From an international perspective, compliance is strongly associated with the ability of healthcare facilities to align their internal practices with recognized waste management frameworks. The World Health Organization emphasizes that safe management of healthcare waste depends on the proper implementation of procedures covering segregation, labeling, storage, transport, treatment, and final disposal. According to this perspective, compliance is not a single act but a process of continuous adherence across the entire waste management chain (Chartier *et al.*, 2014). This makes compliance a dynamic and operational concept rather than a purely regulatory one.

In dental clinics, compliance also reflects the degree to which best practices are incorporated into everyday work. For instance, Lopez and his colleague explain that proper waste disposal in dental clinics requires more than awareness of general rules; it depends on the routine application of correct disposal pathways for different categories of waste, particularly sharps, infectious materials, chemicals, and amalgam-related waste. Their discussion shows that compliance becomes visible in how waste is actually managed at the point of care, not merely in written policy or declared intention (Lopez, et al 2021).

Compliance with environmental safety standards is also linked to the broader goal of reducing the environmental burden of healthcare services. The Royal College of Physicians stresses that healthcare institutions must not only manage waste safely but also reduce unnecessary waste generation and improve resource use in ways that

support environmental sustainability. In this sense, compliance includes a preventive dimension, as it encourages institutions to integrate safer and less wasteful practices into their operational systems (Royal College of Physicians, 2018). Thus, compliance is not limited to avoiding harm after waste is produced, but also includes minimizing environmental impact before disposal occurs.

At the level of hazardous dental waste, compliance requires strict observance of specialized disposal procedures. Hazardous dental waste cannot be managed through ordinary disposal routines and that best management practices must be followed carefully to prevent occupational and environmental risks (Naik *et al*., 2011). It has been shown that compliance in dental clinics is especially significant where waste includes sharps, infectious materials, and toxic residues, because mistakes in these categories may produce consequences far more serious than those associated with general waste (Naik *et al*., 2011). The practical value of compliance is also evident in large-scale healthcare systems. For instance, Yong *et al*, in his case study of medical waste management in China, showed that effective waste management depends on how institutions implement and maintain standardized procedures under real operating conditions. Their findings suggested that the compliance is influenced by administrative control, infrastructure, and operational consistency, which means that adherence to environmental safety standards is shaped by both technical requirements and institutional capacity (Yong *et al*., 2009).

Taken together, compliance with environmental safety standards may be understood as the practical realization of environmental and health protection principles within healthcare and dental waste management. It reflects the extent to which institutions are able to convert standards into organized daily action, ensure continuity of safe practice, and maintain accountability throughout the waste management process.

From the researcher's perspective, compliance with environmental safety standards in dental clinics represents the true operational measure of how effectively environmental principles are applied in practice. It is through compliance that waste management shifts from a theoretical requirement to a real protective mechanism for healthcare workers, patients, and the environment.

2.5.1 Concept of Compliance

The concept of compliance is widely used in environmental management, healthcare governance, and public safety to describe the degree to which individuals or institutions act in accordance with established rules, regulations, and standards. In the context of healthcare waste management, compliance refers to adherence to the procedures and requirements designed to ensure the safe handling and disposal of waste in a way that protects both public health and the environment. Because healthcare waste management is a regulated and multi-stage process, the concept of compliance is central to evaluating the effectiveness of waste management systems in clinical and institutional settings.

In regulatory terms, compliance may be understood as alignment with formal policy frameworks and operational requirements. It has been documented that waste management systems are strongly influenced by policy drivers and institutional enforcement mechanisms, indicating that compliance is closely related to the ability of institutions to respond to legal and policy expectations through practical implementation (Guo *et al.,* 2021). This suggests that compliance is not merely voluntary good practice, but a form of regulated institutional behavior.

From a management perspective, compliance also implies the proper use of procedures and resources in accordance with established waste control systems. For example, Tiynmaz and Demir, in their work on improving solid waste management systems, present compliance as part of a broader effort to make management systems more functional, effective, and consistent. In this view, compliance is linked to how far actual practice follows the structure and logic of the designed management system (Tiynmaz & Demir, 2006). This interpretation is particularly relevant to dental clinics, where the effectiveness of waste management depends on how closely daily actions reflect procedural requirements.

In healthcare settings, compliance can also be understood as adherence to safe practice in relation to specific waste streams. In pharmaceutical waste management in public health facilities, it has been shown compliance includes proper handling, control of wastage, and safe disposal according to recognized procedures. Their

discussion indicates that compliance is not simply a legal matter, but an operational and ethical responsibility to manage potentially harmful materials in a safe and accountable manner (Ahmed, et al 2021).

From an environmental safety perspective, compliance is linked to the reduction of harmful outcomes. Poor waste management practices may be associated with toxic effects and unsafe environmental conditions, which implies that compliance can be understood indirectly through the extent to which harmful consequences are prevented or minimized (Tsakona, et al, 2007). In other words, compliance is reflected not only in following procedures, but also in achieving the protective purpose for which those procedures were established.

In the specific context of dental waste, compliance also has a practice-based meaning. Dental waste management involves particular operational requirements due to the diversity of waste generated in dental care settings (Myszograj, 2023). This means that compliance in dental clinics includes the accurate application of waste classification, safe handling, and proper disposal according to the nature of dental waste streams (Myszograj, 2023). Therefore, the concept of compliance in dental waste management is both general, in relation to environmental standards, and specific, in relation to the operational demands of dental practice.

Based on the above, the concept of compliance may be defined as the extent to which healthcare institutions and professionals adhere in a consistent and effective manner to the rules, procedures, and standards governing waste management, with the aim of reducing risks and ensuring environmental and occupational safety. It is therefore a concept that combines legal obligation, institutional discipline, operational performance, and protective outcomes.

From the researcher's perspective, compliance in dental waste management can be operationally understood as the degree to which dental clinics apply environmental safety standards correctly and continuously across all stages of waste handling and disposal. It is this applied dimension of compliance that determines whether environmental standards remain formal requirements or become real practices capable of protecting people and the environment.

2.5.2 Measuring Compliance in Healthcare

Measuring compliance in healthcare waste management is essential for evaluating how effectively environmental safety standards are implemented in practice. Compliance cannot be assessed through assumptions or general observations; instead, it requires structured tools and measurable indicators that reflect actual performance within healthcare facilities. In dental clinics, measuring compliance is particularly important because it helps identify gaps between recommended procedures and real practices, thereby supporting continuous improvement.

Compliance in healthcare waste management can be measured through several key approaches:

I. Policy Adherence Assessment

This approach focuses on evaluating the extent to which healthcare facilities follow established waste management policies and guidelines. It examines whether procedures such as segregation, labeling, storage, and disposal are performed according to institutional or national standards. ElMitainy and El-Haggar demonstrated that measuring adherence to waste management policies provides a clear indication of compliance levels, particularly when supported by structured monitoring systems within healthcare facilities (ElMitainy & El-Haggar, 2019).

II. Waste Audit and Evaluation Methods

Waste audits are among the most effective tools used to measure compliance in healthcare settings. This method involves analyzing the composition, quantity, and handling of waste to determine whether it has been managed according to safety standards. Slutzman and colleagues highlight that waste audits provide objective and data-driven insights into waste management practices, allowing institutions to identify errors, inefficiencies, and areas for improvement (Slutzman *et al*., 2023).

III. Monitoring of Practice and Behavior

Compliance can also be measured by observing the actual behavior of healthcare workers during waste handling processes. This includes evaluating how staff perform segregation, use protective equipment, and follow safety procedures. Mulay, Naik, Wyawahare, Mahajan, and Kulkarni found that monitoring infection control practices,

including waste management behaviors, is an effective way to assess compliance at the operational level, as it reflects real-time adherence to safety standards (Mulay *et al.*, 2024).

IV. Assessment of Waste Management Practices

Another approach involves evaluating overall waste management practices within healthcare facilities, including sorting, collection, and disposal processes. This method provides a broader view of compliance by assessing how well the system functions as a whole. It has been shown that examining waste sorting and management practices across healthcare institutions helps identify variations in compliance levels and highlights operational weaknesses that require improvement (Adu *et al.*, 2020).

V. Measurement Through Waste Generation Indicators

Compliance may also be indirectly assessed by analyzing waste generation rates and patterns. Abnormal or inconsistent waste generation levels may indicate poor segregation or inefficient waste management practices. Measuring healthcare waste generation rates can provide insights into the effectiveness of waste management systems and the level of compliance with proper procedures (Debere *et al*., 2013).

It can be concluded that measuring compliance in healthcare waste management requires a combination of qualitative and quantitative methods. No single approach is sufficient on its own; rather, effective assessment depends on integrating policy evaluation, waste audits, behavioral observation, practice assessment, and data analysis.

From the researcher's perspective, measuring compliance in dental clinics should rely on multiple complementary tools that capture both procedural adherence and actual behavior. This integrated approach allows for a more accurate evaluation of environmental safety practices and provides a solid basis for improving waste management systems in dental healthcare settings.

2.5.3 Indicators of Compliance in Dental Clinics

Compliance with environmental safety standards in dental clinics can be effectively evaluated through a set of measurable indicators that reflect how well waste management practices are implemented in reality. These indicators provide practical evidence of adherence to safety procedures and allow for systematic assessment of performance across different aspects of waste management. In dental settings, where multiple types of waste are generated, the use of clear indicators is essential for identifying strengths and weaknesses in compliance.

The main indicators of compliance in dental clinics can be presented as follows:

I. Proper Waste Segregation

One of the most important indicators of compliance is the extent to which waste is correctly segregated at the point of generation. This includes separating hazardous from non-hazardous waste and using appropriate containers for each category. Effective segregation is a key factor in determining the quality of dental waste management systems, as it directly influences all subsequent stages of handling and disposal (Koolivand *et al.,* 2014).

II. Safe Management of Hazardous Dental Materials

The handling and disposal of hazardous materials, particularly amalgam waste containing mercury, represent a critical indicator of compliance. Improper disposal of such materials may lead to environmental contamination and long-term ecological damage. Incorrect disposal of silver-mercury amalgam reflects a serious failure in environmental safety practices within dental settings (De Souza *et al.,* 2012). Therefore, proper management of hazardous materials is a clear measure of compliance.

III. Adherence to Standard Disposal Procedures

Compliance can also be assessed through the extent to which dental clinics follow recommended disposal methods for different types of waste. This includes using appropriate treatment methods, safe transport, and controlled disposal system. Adherence to best management practices for hazardous dental waste disposal is essential for minimizing risks and ensuring safe outcomes (Naik *et al.,* 2011).

IV. Implementation of Waste Management Practices in Daily Operations

Another key indicator is the consistency of waste management practices in routine clinical work. This includes how regularly and accurately procedures such as segregation, handling, and disposal are applied in everyday practice. Evaluating waste management practices in dental clinics provides insight into the level of practical compliance, as differences in implementation often reveal gaps between knowledge and actual behavior (Arora *et al.*, 2014).

V. Compliance with Infection Control Standards

Environmental safety in dental waste management is closely linked to infection control practices. Proper handling of contaminated materials, use of protective measures, and adherence to hygiene protocols all serve as indicators of compliance. It has been found that knowledge and application of infection control measures among dental professionals are strongly associated with safer waste management practices, indicating that infection control can be used as a proxy indicator for compliance (Qudeimat *et al.*, 2006).

It is clear that compliance in dental clinics cannot be measured through a single indicator, but rather through a combination of interrelated factors that together reflect the overall effectiveness of waste management practices. These indicators provide a practical framework for evaluating performance and identifying areas that require improvement.

From the researcher's perspective, the use of clear and measurable indicators is essential for assessing compliance in dental waste management, as it allows for objective evaluation of practices and supports data-driven decision-making in improving environmental safety within dental clinics.

2.5.4 Relationship Between Compliance and Safety Outcomes

The relationship between compliance with environmental safety standards and safety outcomes in healthcare waste management is both direct and significant. Compliance is not merely an administrative requirement; it is a practical mechanism through

which healthcare facilities reduce risks, protect workers, safeguard patients, and prevent environmental harm. In dental clinics, where hazardous and non-hazardous waste are produced simultaneously, the degree of compliance largely determines whether waste remains under control or becomes a source of danger. Therefore, safety outcomes may be understood as one of the clearest consequences of either strong or weak compliance.

This relationship can be understood through several major outcome areas:

I. Occupational Safety Outcomes

One of the strongest links between compliance and safety outcomes appears in the area of occupational safety. When healthcare workers follow waste segregation, handling, and disposal procedures correctly, the risk of injuries, contamination, and exposure to hazardous materials is significantly reduced. Poor compliance with medical waste disposal standards in developing countries increases occupational risks, especially for workers directly involved in waste handling and transportation (Patwary, et al 2011).

This means that compliance serves as a protective barrier against workplace hazards.

II. Public Health Outcomes

Compliance also affects public health outcomes by limiting the spread of infection and reducing community exposure to unsafe waste. If waste is not managed according to proper standards, hazardous materials may enter public spaces, municipal waste streams, or informal disposal channels. However, weak healthcare waste management practices can negatively affect both human health and the surrounding environment, which indicates that compliance is essential for preventing broader public health consequences (Hossain *et al*., 2011).

III. Household and Community Safety Outcomes

The effects of compliance are not confined to healthcare institutions; they also extend to households and communities. Improper disposal practices may expose waste handlers, nearby residents, and even families to injuries or contamination. Unsafe disposal of solid medical waste was associated with reported harm at the household level, demonstrating that weak compliance within formal healthcare systems can eventually lead to risks beyond the clinical setting (Udofia, et al 2017).

IV. Environmental Safety Outcomes

Environmental safety is one of the most important outcomes influenced by compliance. Proper waste management reduces the release of toxic substances into soil, water, and air, while non-compliance increases the likelihood of environmental contamination. For instance, Tsakona, Anagnostopoulou, and Gidarakos, in their toxicity evaluation study, found that poor hospital waste management may contribute to unsafe environmental conditions and toxic risks, which confirms that compliance is directly related to the protection of environmental systems (Tsakona, et al 2007).

V. Reduction of Health and Environmental Risks

A broader indicator of the relationship between compliance and safety outcomes is the overall reduction of health and environmental risks. Facilities that comply with environmental safety standards are more likely to achieve safer outcomes across multiple dimensions, including worker protection, cleaner surroundings, and lower exposure to hazardous materials. Improper management of medical waste is associated with serious environmental and health risks, which implies that improved compliance has the potential to reduce these risks significantly (Bokhoree *et al.*, 2014).

It is evident that compliance and safety outcomes are closely interconnected. The higher the level of compliance with environmental safety standards, the more likely healthcare facilities are to achieve positive occupational, public health, and environmental outcomes. Conversely, weak compliance increases the probability of injury, contamination, and ecological damage. Thus, safety outcomes may be regarded as the practical results through which the effectiveness of compliance is ultimately judged.

From the researcher's perspective, the relationship between compliance and safety outcomes is fundamental to understanding the importance of environmental safety standards in dental clinics. Compliance gains its true value not simply from adherence to rules, but from its measurable ability to reduce risks and produce safer health and environmental conditions.

2.6 Healthcare Context in Libya and Zawia

The healthcare context in Libya, including cities such as Zawia, is increasingly shaped by concerns related to occupational safety, waste management, environmental health, and the ability of institutions to translate policy into safe practice. Healthcare waste management intersects directly with worker safety, service quality, environmental protection, and institutional performance. This is particularly relevant to dental clinics, where routine activities generate waste streams requiring organized and compliant management.

Occupational exposure risks remain a significant concern in Libyan healthcare settings. Evidence from hospital settings shows that sharps and contaminated material injuries continue to affect healthcare workers, highlighting the importance of safe handling systems and waste control procedures. It has been found that needlestick and sharps injuries among nurses and laboratory technicians in Misrata hospitals reflected practical safety vulnerabilities, reinforcing the need for stronger control over hazardous materials and clinical waste (Karawad, et al 2017).

There is also a growing need to evaluate waste management practices beyond conventional hospital waste. in fact, evaluation of medical waste from wet cupping therapy, showed that healthcare waste management in Libya requires broader institutional awareness and more systematic control across different forms of health service delivery (Elwahaish *et al.,* 2024). This suggests that waste management concerns extend to smaller facilities such as dental clinics.

The problem of improper medical waste disposal also has economic and environmental dimensions. Duong pointed out that unsafe disposal imposes costs not only on the health system but also on the environment, creating burdens beyond the healthcare facility itself (Duong, 2023). This is particularly relevant where healthcare systems face operational pressures, as ineffective waste management may increase both financial strain and environmental damage.

Healthcare systems also need to move from fragmented practices toward organized systems of learning and improvement. McDonald and colleagues argued that effective

healthcare systems require converting operational data into knowledge and practical improvement, which is essential for building learning health systems capable of responding to recurring safety challenges (McDonald *et al*., 2024). In the Libyan context, healthcare waste management requires not only regulation but also continuous institutional learning, monitoring, and adaptation.

From a global perspective, the World Health Organization continues to stress that healthcare waste is a major issue affecting human health, occupational safety, and environmental integrity. The WHO emphasizes that unsafe waste handling exposes workers and communities to preventable harm and underscores the necessity of safe collection, treatment, and disposal systems in all healthcare environments (WHO, 2024). This global framework provides an important benchmark for evaluating local and institutional practices in Libya and Zawia.

Overall, the healthcare context in Libya and Zawia may be described as one where environmental safety and healthcare waste management are increasingly relevant to institutional quality, worker protection, and public health outcomes. Available evidence suggests that the issue is not simply one of technical disposal, but of system capacity, regulatory practice, and the ability of institutions to maintain safe and sustainable operational standards.

From the researcher's perspective, the healthcare context in Libya and Zawia provides an important background for understanding why waste management in dental clinics deserves focused study. The local health environment reflects broader concerns about safety, waste control, and institutional improvement, making compliance with environmental safety standards a particularly relevant issue in dental practice.

2.6.1 The Libyan Health System and Healthcare Waste Management: Insights from Previous Studies

The Libyan health system is a mixed structure composed of public hospitals, primary healthcare facilities, specialized centers, and a growing number of private providers. Its performance is influenced not only by clinical service delivery but also by supporting functions such as infrastructure, regulation, waste management, and

environmental safety. Any overview of the system must therefore include attention to how healthcare facilities manage the waste generated by daily medical activity.

Healthcare waste management reflects the overall organizational quality of health institutions. In many public facilities, waste generation and wastage are linked to broader weaknesses in planning, supervision, and operational control. Ahmed, et al showed that pharmaceutical waste management in public facilities is strongly associated with institutional efficiency and effective control measures (Ahmed, et al 2021). Although not Libyan, this finding is relevant to health systems where resource management and operational oversight remain critical concerns. Environmental impact is another important dimension. Nematollahi and colleagues demonstrated through comparative life cycle assessment that healthcare waste scenarios differ substantially in environmental burden depending on management quality (Nematollahi *et al*., 2024). This highlights that environmental performance is part of the broader institutional profile of healthcare delivery.

Healthcare systems in developing settings often face recurring obstacles including weak infrastructure, limited financial resources, and inconsistent safety procedures. Coker and colleagues found that medical waste management in Ibadan was constrained by multiple systemic barriers, indicating that waste problems are rooted in wider health system challenges (Coker *et al*., 2009). Similarly, Shinee and colleagues found that healthcare waste management in Mongolia depended heavily on organization of collection, storage, and disposal arrangements across the health sector (Shinee *et al.*, 2008). Both observations are highly relevant to Libya.

Awareness and practice among healthcare workers are also central to system effectiveness. Hospital waste management is strongly influenced by staff awareness and practical behavior, showing that performance depends as much on human factors as on material resources (Rao, 2008). In Libya, this implies that improving waste management requires not only infrastructure and policy support but also strengthening professional awareness and routine compliance.

Taken together, the Libyan health system is one in which waste management and environmental safety are increasingly important indicators of institutional quality.

Healthcare waste management should be interpreted not as a peripheral service but as part of broader health system performance, reflecting planning quality, resource use, supervision, and professional practice.

From the researcher's perspective, any overview of the Libyan health system must include attention to environmental and operational dimensions, as these directly affect the safety and sustainability of clinical practice. Dental waste management is not separate from the health system but is one of the practical areas through which its level of organization and compliance can be assessed.

2.6.2 Dental Clinics in Zawia City

Dental clinics in Zawia City can be understood as part of the broader network of primary and private healthcare services that provide daily diagnostic, preventive, and therapeutic dental care. As with similar urban dental settings, these clinics are not only treatment spaces, but also operational environments in which different categories of healthcare waste are generated continuously. For this reason, understanding dental clinics in Zawiyah requires attention not only to their clinical role, but also to the environmental and organizational implications of the waste they produce.

I. Dental Clinics as Continuous Waste-Generating Units

Dental clinics differ from many other small healthcare units because waste is generated regularly through routine procedures such as examinations, restorations, extractions, injections, sterilization, and cleaning. This makes dental practices active waste-producing environments rather than occasional generators of medical refuse. Janakiram explains that private dental practices generate a range of waste materials that require organized disposal systems, indicating that dental clinics must be viewed as structured contributors to healthcare waste streams rather than as minor sources of general refuse (Janakiram, 2008).

II. Diversity of Waste Produced in Dental Clinics

A key characteristic of dental clinics is the diversity of the waste they produce. In addition to ordinary non-hazardous refuse, dental practices generate biomedical waste, sharps, contaminated disposables, chemical residues, and mercury-related materials. This diversity makes the management of dental clinics more complex from an environmental safety perspective. It has been emphasized that dental practitioners frequently deal with mercury and other biomedical waste types that require controlled handling and disposal, which means that the waste profile of dental clinics is more specialized than it may initially appear (Singh *et al*., 2014).

III. Public Health and Ecological Relevance of Dental Clinics

Dental clinics also carry public health and ecological significance because unsafe waste handling within these facilities may create risks that extend beyond the clinic itself. Improper management of waste generated in dental offices may affect workers, patients, waste handlers, and the wider environment. Muhamedagic and his colleague, highlighted that dental office waste should be treated as a matter of public health and ecological concern, since even relatively small facilities may contribute to wider environmental risk if waste is poorly controlled (Muhamedagic *et al*., 2009).

IV. Environmental Sustainability in Dental Practice

Modern dental clinics are increasingly being viewed not only as clinical service providers, but also as institutions whose practices have an environmental footprint. The issue is therefore no longer limited to safe disposal alone, but extends to sustainability, resource use, and waste reduction. Duane and colleagues show that primary dental care contributes to measurable environmental impact through routine service delivery, which highlights the need for more environmentally sustainable approaches in dentistry (Duane *et al.*, 2017). In this sense, dental clinics in Zawiyah may also be considered part of the broader discussion on sustainable healthcare practice.

V. Composition of Waste as an Indicator of Local Management Needs

Another useful way to understand dental clinics in Zawiyah is through the composition of the waste typically generated in dental care settings. The type and proportion of waste produced can provide an indication of the management systems required at the clinic level. Richardson, Grose, Manzi, and colleagues show that examining the content of dental clinical waste helps identify opportunities for better segregation, safer disposal, and reduced environmental impact (Richardson *et al.*, 2016). This perspective is particularly relevant for Zawia City because it suggests that improving dental waste management begins with understanding the nature of waste produced in local clinics.

Overall, dental clinics in Zawia City may be viewed as healthcare units that combine clinical, environmental, and organizational functions. Their importance lies not only in delivering oral health services, but also in managing the waste produced by those services in a way that protects health and the environment.

From the researcher's perspective, dental clinics in Zawia City provide an appropriate and relevant field for studying compliance with environmental safety standards, because they represent everyday clinical settings in which waste generation, handling, and disposal practices can be directly linked to broader issues of safety, sustainability, and institutional responsibility.

2.6.3 Environmental and Administrative Challenges

Environmental and administrative challenges represent a major part of the context within which healthcare waste management is practiced in dental and healthcare facilities. These challenges extend beyond the technical act of disposal to the wider institutional environment where decisions are made, resources are allocated, responsibilities are distributed, and environmental consequences are managed. Waste management is shaped as much by administration and system performance as by the characteristics of the waste itself.

One significant challenge is that improper waste disposal creates a dual burden on both the healthcare system and the environment. Unsafe disposal results not only in

ecological harm but also in additional operational and financial pressure on health services. Duong explained that unsafe disposal increases costs for health systems while expanding environmental damage, weakening both sustainability and institutional efficiency (Duong, 2023). Another administrative challenge is the inability of some healthcare systems to transform operational information into practical improvement. Waste management problems are often repeated because facilities do not build feedback systems capable of identifying errors, analyzing patterns, and correcting weaknesses over time. Effective healthcare systems must move from data collection to knowledge generation and then to performance improvement, a principle highly relevant to waste management (McDonald *et al*., 2024).

Challenges also emerge when stages of waste management are not properly connected. Storage, collection, treatment, and disposal may exist as separate activities without sufficient coordination, leading to weak continuity across the system. Fragmentation between these stages undermines safety and consistency of waste control practices (Mmereki, et al 2015). In many developing healthcare contexts, challenges are intensified by limited resources, weak governance, and inconsistent policy implementation. Khan and colleagues noted that healthcare waste management in developing countries is constrained by insufficient financial support, poor infrastructure, and inadequate administrative oversight, reducing institutional capacity to maintain safe and compliant systems (Khan *et al*., 2019).

A further challenge is that healthcare systems are increasingly expected to move toward sustainable and circular models of waste management, yet this transition requires strategic planning, institutional commitment, and administrative flexibility (Ranjbari *et al*., 2022). In fact, persistent challenges related to implementation, coordination, and system adaptation in current healthcare waste management research. The administrative challenge is no longer only to dispose of waste safely, but also to redesign waste systems to support long-term environmental sustainability.

Taken together, these challenges show that waste management in healthcare and dental settings is a multidimensional issue. The problem is not simply one of disposal technique, but of institutional learning, inter-stage coordination, governance quality,

and environmental strategy. Where these elements are weak, waste management becomes vulnerable to inefficiency, risk, and non-compliance.

From the researcher's perspective, environmental and administrative challenges form the practical background against which compliance with environmental safety standards must be understood. They explain why waste management problems may persist even when general awareness exists, and they demonstrate that improving environmental safety in dental clinics requires both technical control and stronger administrative capacity.

2.7 Previous Studies

Previous studies represent an essential component of the theoretical framework because they provide the empirical background upon which the current research is built. Through reviewing previous research, the researcher can identify the main directions of the literature, understand the dominant methodological approaches, and determine the gaps that still require investigation. In the field of dental waste management, previous studies are especially important because they reveal how environmental safety standards are applied in different healthcare and dental contexts, and they help explain the factors that influence compliance in practice.

The literature reviewed in this study covers research conducted in different geographical contexts, including Palestine, Libya, Saudi Arabia, and other developing settings. These studies address several dimensions related to dental waste management, such as segregation practices, hazardous waste handling, staff awareness, environmental safety, and the general level of compliance with proper waste management procedures. Together, they provide a useful foundation for understanding the current state of dental waste management and for situating the present study within a broader empirical context.

From the researcher's perspective, reviewing previous studies is not only important for summarizing earlier findings, but also for identifying the methodological and contextual space in which the current study can make a meaningful contribution. In this sense, the reviewed literature helps clarify what is already known about dental

waste management and what still needs to be explored, particularly in the context of dental clinics in Zawia City.

2.7.1 Studies on Dental Waste Management

The literature on dental waste management has been shaped by a growing body of empirical research conducted across diverse geographical and institutional settings. These studies have collectively contributed to understanding the composition of dental waste, the level of awareness and practice among dental professionals, the administrative and infrastructural barriers to safe disposal, and the broader environmental and health implications of improper waste handling. Together, they provide a comprehensive empirical foundation that informs current research and highlights persistent gaps requiring further investigation.

One of the earliest and most influential contributions to the field was the study by (Hashim, et al 2011), which evaluated dental waste management practices across 49 dental clinics in the Emirate of Ajman, United Arab Emirates. Employing a descriptive survey design with interviews and survey-based data collection, the researchers found that while all clinics segregated infectious waste from general waste, considerable variation existed in handling, storage, and disposal measures. This study was instrumental in drawing attention to the operational inconsistencies that persist even where basic segregation is practiced, and it emphasized the need for more systematic improvements in hazardous waste management across all stages of the waste chain.

Building on this foundation, (Sudhakar and Janakiram 2008) shifted the focus toward the behavioral and educational dimensions of dental waste management. Their cross-sectional survey of 389 private dental practitioners in Bangalore City, India, revealed alarmingly low levels of segregation practice, with 64.3% of respondents failing to segregate waste before disposal and 47.6% relying on street garbage collectors for waste removal. The study identified the absence of waste management agency services (42.1%) and lack of knowledge (16.9%) as major barriers, thereby influencing subsequent research by demonstrating that technical guidelines are ineffective without corresponding improvements in practitioner awareness and

infrastructure access. This study has been widely cited as evidence that behavioral and systemic factors are as critical as regulatory frameworks in determining waste management outcomes.

The quantitative dimension of dental waste management was significantly advanced by (Koolivand et al 2014), who conducted an analytical descriptive investigation of waste characteristics in 15 dental centers in Urmia, Iran. Through manual separation and weighing of waste into 31 components, the study provided detailed baseline data on waste generation rates and composition. Total daily waste generation in general offices, specialist offices, and clinics was found to be 58.94 kg, 17.92 kg, and 10.22 kg, respectively, with potentially infectious waste constituting 34.24%, domestic waste 35.46%, toxic waste 11.83%, and chemical and pharmaceutical waste 5.56% of total waste. This study has been particularly influential in establishing that dental waste contains a substantial hazardous fraction requiring specialized management, and its quantitative findings have provided a critical reference point for waste management planning and policy development.

The gap between knowledge and practice was further explored by (Lakbala 2020), whose cross-sectional study of 133 dentists in Bandar Abbas, Iran, revealed persistent and serious deficiencies in awareness and disposal practices. Only 12.0% of dentists knew the correct disposal container color for human anatomical waste, while the majority disposed of x-ray film lead foils (52.6%), orthodontic wires (48.9%), and outdated drugs (60.2%) in ordinary trash bins. Perhaps most concerning was the finding that dental chemicals and amalgam waste were predominantly poured into municipal sewage systems, creating significant environmental hazards. The study's conclusion that dentists exhibit generally low awareness and substandard disposal practices has been highly influential in directing attention toward the urgent need for targeted educational interventions, stronger regulatory enforcement, and improved waste management infrastructure.

A more recent and integrative perspective was provided by(Myszograj 2023) , who offered an overview of dental waste management from a statistical and environmental standpoint. The study emphasized that the quantity of dental waste varies according to treatment type and prevention measures, and argued that effective management must

extend beyond disposal to include statistical understanding and environmental planning. This review has been influential in reframing dental waste management as an environmental planning issue rather than a purely operational concern, thereby contributing to the growing literature advocating for sustainability-oriented and circular economy approaches in dental healthcare.

Collectively, these studies have shaped the current understanding of dental waste management in several important ways. They have established that dental waste is a significant and complex category of healthcare waste, characterized by a substantial hazardous fraction that includes infectious, toxic, and chemical components. They have demonstrated that awareness and practice levels among dental professionals are often insufficient, and that behavioral, educational, infrastructural, and administrative barriers frequently prevent the translation of guidelines into safe practice. They have also shown that effective waste management requires not only technical procedures but also institutional capacity, regulatory enforcement, and strategic environmental planning. In doing so, these studies have collectively provided a robust empirical foundation for the present research, while also revealing persistent gaps in understanding, particularly in relation to compliance with environmental safety standards in specific local contexts such as dental clinics in Zawia City.

2.7.2 Studies on Compliance and Safety Standards

A substantial body of empirical research has examined dental waste management practices in developing countries and the Middle East, with particular attention to the gaps between regulatory standards and actual implementation (see Table 2.4). These studies have collectively contributed to understanding the systemic, behavioral, and infrastructural barriers that prevent effective waste management in dental settings, and they have provided critical evidence for the need for stronger institutional frameworks, professional training, and regulatory enforcement.

(Al-Khatib, et al 2010) conducted a comprehensive survey of 97 dental clinics in the Nablus district of Palestine, focusing on hazardous waste production, handling, storage, treatment, and disposal measures. Their findings were particularly influential in revealing the systemic nature of non-compliance in developing contexts. The study

found that dental waste was not properly separated according to World Health Organization classification standards, and medical waste was frequently mixed with general waste during generation, collection, and disposal. Most critically, final disposal often occurred in open dumping sites, with waste sometimes burned close to communities, creating direct public health hazards. This study was instrumental in demonstrating that weak waste management in dental settings is not merely a technical failure but a reflection of broader institutional and regulatory deficiencies. The authors' recommendation for stronger cooperation between professional associations and government authorities, alongside training and capacity-building programs, has influenced subsequent policy discussions and research agendas.

In the Libyan context,(Shampe, et al 2020) provided one of the earliest systematic evaluations of medical waste management in dental clinics in Tripoli. Through a cross-sectional descriptive design involving 201 respondents, the study revealed alarmingly low levels of compliance with basic waste management standards. Only 33.8% of clinics segregated medical waste from non-medical waste, and only 39.8% separated blood-contaminated waste specifically. Perhaps most concerning was the finding that a large proportion of clinics (82.1%) improperly disposed of liquid waste such as blood and saliva into the sewage system, creating significant environmental and public health risks. This study has been particularly influential in establishing baseline evidence of weak compliance in Libyan dental settings and has underscored the urgent need for systemic improvements in segregation and disposal practices.

(Sabbahi, et al 2020) extended the geographical scope of the literature by assessing oral healthcare providers' knowledge and behavior in Jeddah, Saudi Arabia. Their cross-sectional study of 314 dental healthcare providers from four dental colleges and 20 private dental clinics revealed concerning deficiencies in both training and practical knowledge. Only 33.4% of participants had received professional training in waste management, and mean knowledge and behavior scores were notably low (1.4 ± 1.3 out of 8 for knowledge, and 3.7 ± 1.3 out of 6 for behavior). The study found that knowledge about waste segregation, collection, transportation, and treatment was weak and substandard, leading the authors to emphasize the urgent need for clearer policies and regulations. This study has been influential in highlighting that formal education and training are critical determinants of safe waste management practices,

and that regulatory frameworks must be accompanied by capacity-building initiatives to be effective.

More recent Libyan research has further elaborated on the knowledge-practice gap identified in earlier studies(. Elwahaishi, et al 2025) evaluated dentists' awareness of medical waste management practices in Misrata, Libya, through a descriptive quantitative design involving 94 private dental practitioners. Their findings were striking: 55.3% of practitioners lacked adequate knowledge about medical waste management, 69.1% admitted disposing of chemical waste through the city's sewer system, and 51.1% continued using amalgam despite its environmental hazards. The study also found that a considerable proportion of practitioners lacked familiarity with local policies and guidelines, a deficiency linked mainly to a lack of vocational training. This study has been particularly influential in demonstrating that environmental awareness and safe practice are closely intertwined, and that inadequate training perpetuates unsafe disposal behaviors that have direct environmental and health consequences.

Complementing these findings, (Buhour and Aljwiw 2025) assessed knowledge, attitudes, and practices related to hazardous dental waste management among 196 dentists in Tripoli, Libya. While 53.6% of respondents showed knowledge regarding infectious and non-infectious waste management, and 95.4% agreed that infectious waste can cause disease, the study found that 81.1% reported using separate trash bins for infectious and non-infectious waste, suggesting a gap between knowledge and consistent implementation. The study concluded that dental hazardous waste management in Tripoli still requires more research and stronger practical attention, particularly regarding hazardous waste. This study has been influential in demonstrating that while awareness of risks may be present, it does not automatically translate into consistent safe practice, and that behavioral and organizational factors must be addressed alongside educational initiatives.

Taken together, these studies have collectively shaped the current understanding of dental waste management in developing and Libyan contexts in several important ways. They have established that non-compliance is widespread and multifaceted, involving deficiencies in segregation, handling, storage, and disposal practices. They

have demonstrated that knowledge and awareness among dental professionals are often insufficient, and that training and education are critical determinants of safe practice. They have revealed that infrastructural and regulatory weaknesses frequently prevent the translation of guidelines into effective implementation, and that hazardous materials such as amalgam, chemical waste, and blood-contaminated waste are often mismanaged in ways that create significant environmental and public health risks. Most importantly, these studies have highlighted the urgent need for stronger institutional frameworks, clearer policies, enhanced professional training, and more rigorous monitoring and enforcement mechanisms. They provide a robust empirical foundation for the present study, while also revealing persistent gaps in understanding, particularly in relation to the specific factors influencing compliance with environmental safety standards in dental clinics in Zawia City.

Table 2-4: Summary of Previous Studies Related to Dental Waste Management on Compliance and Safety Standards

Author (s) / Year	**Country**	**Study Title**	**Sample**	**Methodology**	**Main Findings**
Al-Khatib *et al.* (2010)	Palestine	Dental solid and hazardous waste management and safety practices in developing countries	97 dental clinics	Descriptive survey	Weak segregation and improper disposal practices were observed.
Elzahaf *et al*. (2020)	Libya	Medical waste management in dental clinics in Tripoli/Libya	201 participants	Cross-sectional	Low compliance with segregation and disposal standards was reported.
Elwahaishi *et al.* (2025)	Libya	Environmental awareness and health risks in medical waste management	94 practitioners	Descriptive quantitative	Limited awareness and poor disposal of chemical waste were found.
Buhour & Aljwiw (2025)	Libya	Knowledge, Attitude and Practices	196 dentists	Cross-sectional	Moderate knowledge with gaps in

Author (s) / Year	Country	Study Title	Sample	Methodology	Main Findings
		Towards Dental Hazardous Waste Management			hazardous waste management practices.
Sabbahi *et al*. (2020)	Saudi Arabia	Management of dental waste in dental offices and clinics in Jeddah	314 providers	Cross-sectional	Knowledge and behavior toward dental waste management were below standard.

2.7.3 Studies on Training and Awareness

A significant strand of the literature on dental waste management has focused on the awareness, knowledge, attitudes, and practices of dental professionals and healthcare workers, particularly in relation to biomedical waste management policies, infection control, and occupational safety (see Table 2.5). These studies have collectively contributed to understanding the human and organizational factors that determine compliance with environmental safety standards, and they have highlighted persistent gaps in training, awareness, and practical implementation across different healthcare settings.

(Narang, et al 2012) conducted one of the earlier investigations into awareness of biomedical waste management among dental professionals and auxiliary staff in Amritsar, India. Their descriptive cross-sectional study of 160 staff members (80 dentists and 80 auxiliary staff) revealed significant disparities in awareness levels. Dentists showed significantly higher awareness of biomedical waste management policies than auxiliary staff, and were also significantly more aware of waste collection methods and the use of color-coded bags for disposal. However, the study found a lack of awareness of most aspects of biomedical waste management among auxiliary staff and only partial awareness among dentists. This study was influential in demonstrating that awareness is unevenly distributed within dental settings, and that auxiliary staff—who are often directly involved in waste handling—are particularly underserved by training and education initiatives.

(Golandaj and Kallihal 2021) extended this line of inquiry by assessing awareness, attitudes, and practices related to biomedical waste management among 273 public healthcare workers in Karnataka, India. Using a cross-sectional observational design with questionnaires and checklists, the study revealed a generally poor level of knowledge and awareness among healthcare personnel. Only 43% of participants correctly knew the categorization of biomedical waste and its disposal in proper color-coded bins or bags, and more than half of the participants had not received any training related to biomedical waste management. This study has been particularly influential in highlighting that inadequate training is a pervasive issue across healthcare settings, and that knowledge deficits are not confined to dental professionals but extend to the broader healthcare workforce.

(Mulay, et al 2024) shifted the focus toward infection control practices, which are closely linked to safe waste management. Their prospective observational study of 64 healthcare workers across three primary health centers in India assessed awareness of and adherence to infection control practices using WHO and SIAPS guidelines. The study revealed considerable variation in adherence across centers, with overall compliance scores ranging from 66% in PHC-A to 40% and 38% in PHC-B and PHC-C. Hand hygiene compliance was considerably better in PHC-A than in the other centers, and the study emphasized the importance of ongoing training and targeted interventions to improve awareness and infection control practices. This study has been influential in demonstrating that compliance is not uniform across facilities and that institutional support, supervision, and training are critical determinants of safe practice.

In the Libyan context, (Elwahaishi, et al 2025) evaluated dentists' awareness of medical waste management practices in Misrata, Libya, through a descriptive quantitative design involving 94 private dental practitioners. The findings were striking: 55.3% of practitioners lacked adequate knowledge about medical waste management, 69.1% admitted disposing of chemical waste through the city's sewer system, and 51.1% continued using amalgam despite its environmental hazards. The study also found that a considerable proportion of practitioners lacked familiarity with local policies and guidelines, a deficiency linked mainly to a lack of vocational training. This study has been particularly influential in demonstrating that

environmental awareness and safe practice are closely intertwined, and that inadequate training perpetuates unsafe disposal behaviors that have direct environmental and health consequences in Libyan dental settings.

Complementing these findings,(Buhour and Aljwiw 2025) assessed knowledge, attitudes, and practices related to hazardous dental waste management among 196 dentists in Tripoli, Libya. While 53.6% of respondents correctly identified infectious waste, and 95.4% agreed that infectious waste can cause disease, the study found that 81.1% reported using separate trash bins for infectious and non-infectious waste. The study concluded that hazardous dental waste management in Tripoli still requires stronger practical attention and further research. This study has been influential in demonstrating that while awareness of risks may be present, it does not automatically translate into consistent safe practice, and that behavioral and organizational factors must be addressed alongside educational initiatives.

Taken together, these studies have collectively shaped the current understanding of awareness, knowledge, and infection control in dental waste management in several important ways. They have established that awareness levels are often insufficient and unevenly distributed across professional categories, with auxiliary staff being particularly disadvantaged. They have demonstrated that training and education are critical determinants of safe practice, and that the absence of structured training programs is a major barrier to compliance. They have revealed that knowledge alone is insufficient to ensure safe behavior, as gaps persist between awareness and practical implementation. They have also shown that institutional support, supervision, and monitoring are essential for translating knowledge into consistent practice.

In the Libyan context, these studies have provided critical evidence of weak compliance, limited training, and unsafe disposal practices, underscoring the urgent need for stronger institutional frameworks, clearer policies, and enhanced professional development initiatives. These findings provide a robust empirical foundation for the present study, while also revealing persistent gaps in understanding, particularly in relation to the specific factors influencing compliance with environmental safety standards in dental clinics in Zawia City.

Table 2-5: Summary Table of Major Empirical Studies on awareness, knowledge, attitudes, and practices of dental professionals and healthcare workers

Study	Context	Design	Sample	Major Findings
Narang *et al*. (2012)	Amritsar, India	Descriptive cross-sectional	160 (80 dentists, 80 auxiliary staff)	Dentists showed higher awareness than auxiliary staff; partial awareness among dentists; lack of awareness among auxiliary staff
Golandaj & Kallihal (2021)	Karnataka, India	Cross-sectional observational	273 healthcare workers	Poor knowledge overall; only 43% knew correct categorization; >50% had no training
Mulay *et al*. (2024)	India	Prospective observational	64 healthcare workers	Adherence varied across centers (38%–66%); hand hygiene better with training; ongoing training emphasized
Elwahaishi *et al*. (2025)	Misrata, Libya	Descriptive quantitative	94 private dental practitioners	55.3% lacked knowledge; 69.1% disposed chemicals in sewer; 51.1% used amalgam; lack of training identified
Buhour & Aljwiw (2025)	Tripoli, Libya	Cross-sectional descriptive	196 dentists	53.6% had knowledge; 95.4% aware of infectious waste risks; 81.1% used separate bins; further research needed

2.7.4 Commentary on Previous Studies

A review of the previous studies shows that dental waste management has received increasing attention in different geographical and institutional contexts, particularly in developing countries where healthcare waste systems often face practical and

organizational limitations. The reviewed studies collectively confirm that dental clinics generate different categories of hazardous and non-hazardous waste that require safe segregation, handling, storage, and disposal procedures. They also show that waste management in dental settings is closely linked to environmental safety, occupational health, and institutional compliance with healthcare regulations.

A major point of similarity among the reviewed studies is their emphasis on the existence of weaknesses in actual waste management practices. Several studies found that dental waste is often not managed according to proper standards, particularly in relation to waste segregation, disposal of hazardous materials, and compliance with safety procedures. For example, the studies conducted in Palestine, Tripoli, Misrata, and Jeddah all indicated that improper disposal practices, limited segregation, and weak implementation of guidelines remain recurring problems in dental clinics (Al-Khatib e*t al*., 2010; Elzahaf *et al.*, 2020; Elwahaishi *et al*., 2025; Sabbahi *et al*., 2020). This suggests that the problem is not confined to one country or one healthcare system, but appears to be a wider issue affecting dental waste management in many settings.

Another common feature of the reviewed studies is their focus on the role of awareness, knowledge, and training in shaping waste management performance. A number of studies demonstrated that limited training and insufficient awareness among dental professionals contribute directly to unsafe waste handling and poor compliance with waste management standards. This was evident in the studies conducted in India, Libya, and Saudi Arabia, which showed that awareness does not always translate into proper practice unless it is supported by structured training and operational supervision (Azlan *et al.*, 2012; Buhour & Aljwiw, 2025; Elwahaishi *et al.*, 2025). Therefore, the literature consistently indicates that human factors remain one of the most influential dimensions of waste management effectiveness.

Despite these similarities, the reviewed studies differ in their focus, methodology, and scope. Some studies concentrated mainly on evaluating waste management practices in dental clinics, such as the studies of (Hashim *et al*., 2011 and Janakiram 2008) while others focused more specifically on hazardous waste, environmental awareness, or occupational safety. In addition, some studies used descriptive cross-sectional

survey designs based on questionnaires, whereas others relied on evaluative or observational approaches. These methodological differences are important because they show that the issue of dental waste management has been approached from different perspectives, including behavioral, environmental, and operational ones.

The reviewed studies also differ in the extent to which they address compliance as a measurable concept. While many of them describe weaknesses in waste management practices, not all of them explicitly examine compliance with environmental safety standards as an integrated outcome influenced by multiple factors. Some studies focus on knowledge and awareness, others on waste generation and disposal methods, and others on general safety practices. This indicates that there is still room for research that brings these dimensions together within one comprehensive analytical model.

An additional point that emerges from the review is the relative scarcity of local studies in the Libyan context, especially studies that focus specifically on dental clinics and environmental safety standards. Although recent Libyan studies conducted in Tripoli and Misrata have contributed valuable findings, the available evidence remains limited in geographical scope and does not adequately cover other important local contexts such as Zawia City (Elzahaf *et al.*, 2020; Elwahaishi *et al*., 2025; Buhour & Aljwiw, 2025). This limitation strengthens the importance of the present study, as it seeks to address a local gap in the literature by examining dental waste management practices and compliance in a context that has not yet been sufficiently studied.

The present study benefits from previous studies in several ways. First, it draws on them in identifying the major dimensions of dental waste management, such as segregation, hazardous waste handling, safety practices, training, and awareness. Second, it benefits from their methodological approaches, particularly the use of descriptive and cross-sectional designs with questionnaire-based data collection. Third, it builds on their findings in framing the current problem and in selecting the factors most likely to influence compliance with environmental safety standards in dental clinics.

Based on the above, it can be concluded that previous studies have provided a strong empirical basis for understanding dental waste management as an environmental and healthcare issue. However, they also reveal a number of gaps, particularly the limited integration of compliance-related variables within one study and the shortage of research in the Libyan local context outside major cities. For this reason, the current study seeks to extend the existing literature by investigating compliance with environmental safety standards in dental clinic waste disposal in Zawia City, with a specific focus on the factors influencing adherence and the practical realities of dental waste management in that setting.

2.8 Chapter Summary

This chapter presented the theoretical framework and literature review related to environmental safety standards in healthcare and dental waste management. It began by discussing the concept of environmental safety standards, their meaning, and their importance in healthcare settings, with particular attention to dental clinics as continuous generators of hazardous and non-hazardous waste. The chapter also explained the main types of healthcare and dental waste, the classification of hazardous and non-hazardous waste, the risks associated with improper waste disposal, and the international standards that guide safe waste management practices.

In addition, the chapter examined dental waste management practices through several key dimensions, including waste segregation, handling and storage, disposal methods, common mistakes, and the main challenges facing effective management in dental settings. It further explored the major factors influencing compliance with environmental safety standards, such as staff training and qualification, awareness of environmental regulations, the availability of infrastructure and resources, internal monitoring and supervision, and barriers and organizational challenges.

The chapter also addressed the concept of compliance with environmental safety standards and explained how compliance can be measured in healthcare settings and identified through practical indicators in dental clinics. Moreover, it clarified the relationship between compliance and safety outcomes by showing how adherence to

environmental standards contributes to improving occupational safety, public health, and environmental protection.

Finally, the chapter reviewed the healthcare context in Libya and Zawia, together with a number of previous studies related to dental waste management, compliance, and awareness. These studies provided an empirical foundation for the present research and helped identify the gap that this study seeks to address. Overall, this chapter established the theoretical and empirical background necessary for understanding the issue of compliance with environmental safety standards in dental clinic waste disposal and prepared the basis for the methodological chapter that follows.

3 CHAPTER THREE:
METHODOLOGY

3.1 Introduction

This chapter presents the methodological framework adopted in the current study, which investigates compliance with environmental safety standards in dental clinic waste disposal in Zawia City. It explains the research design, study setting, target population, sampling procedure, data collection instrument, questionnaire structure, validity and reliability procedures, data analysis methods, and ethical considerations.

The methodological procedures were selected in accordance with the nature of the study problem and its objectives. Since the study aimed to assess the current level of compliance and examine the relationships between several factors affecting dental waste disposal, a quantitative descriptive analytical approach was considered appropriate. The study relied mainly on a structured questionnaire designed to measure awareness and knowledge, training and protocols, practices and segregation, infrastructure and facilities, internal monitoring, challenges and barriers, and the overall level of compliance with environmental safety standards.

The statistical analysis was based on 250 valid responses obtained from dental clinic personnel. These responses were analyzed using SPSS-software statistical procedures, including descriptive statistics, reliability analysis, correlation analysis, independent samples t-test, hypothesis testing, and multiple regression analysis.

3.2 Research Design

The current study adopted a quantitative, non-experimental, cross-sectional research design within a descriptive analytical framework. This design was suitable because the study did not involve any experimental intervention or manipulation of variables. Instead, it aimed to describe the existing situation of dental waste management practices and analyze the relationships between the main study variables.

The cross-sectional design allowed the researcher to collect data from participants at one point in time. This was appropriate for assessing the current level of awareness, training, waste segregation practices, infrastructure, internal monitoring, barriers, and compliance in dental clinics in Zawia City.

The study was also descriptive because it used frequencies, percentages, means, and standard deviations to describe the respondents' characteristics and the level of each questionnaire dimension. In addition, it was analytical because it examined relationships and differences among variables using correlation analysis, t-test, and regression analysis.

Accordingly, the design of the study can be described as a quantitative descriptive analytical cross-sectional design.

3.3 Study Setting

The study was conducted in dental clinics located in **Zawia City, Libya**, The participating clinics included both **public** and **private** dental clinics. This distinction was important because the type of clinic may influence the availability of waste management infrastructure, training systems, internal monitoring, and overall compliance with environmental safety standards.

The statistical output showed that the sample included respondents from public and private clinics. This allowed the study to compare some compliance-related dimensions according to clinic type through the independent samples t-test.

Dental clinics were considered an appropriate setting for the study because they generate different types of waste, including general waste, contaminated materials, sharps, chemical waste, amalgam-related waste, and radiographic chemical waste. These types of waste require proper segregation, storage, handling, and disposal in order to reduce environmental and occupational risks.

3.4 Study Population and Sample

3.4.1 Study Population

The target population of the study consisted of personnel working in dental clinics in Zawia City. The population included individuals who were directly or indirectly involved in dental waste generation, handling, segregation, supervision, or disposal procedures. The respondents represented different occupational roles within dental clinics, including dentists or clinic owners, clinic or office managers, dental hygienists, dental assistants, and other staff members. These categories were relevant to the study because dental waste management is not limited to dentists only; rather, it involves all staff who participate in clinical procedures, waste handling, cleaning, monitoring, or administrative supervision.

3.4.2 Sampling Technique

A convenience sampling technique was used due to the practical difficulty of accessing all dental clinics and all potential participants in Zawia city. This technique was considered suitable because obtaining a complete official list of all dental clinic personnel in Zawia City was not practically feasible. Care was taken to include respondents from both public and private clinics in order to reflect variation in organizational conditions, resources, and waste management practices. This allowed the study to examine whether differences existed between public and private clinics in relation to the main study dimensions.

3.4.3 Final Valid Sample

The final valid sample used for statistical analysis consisted of 250 respondents. The SPSS-software output confirmed that the number of valid responses (see Table 3.1). The final sample size was considered adequate for the statistical procedures used in the study, including descriptive statistics, reliability analysis, correlation analysis, t-test, and regression analysis. It provides a sufficient empirical basis for examining the study variables and testing the research hypotheses.

Table 3-1: Final Valid Sample

Item	Frequency	Percentage
Valid responses used in statistical analysis	250	100.0%
Total	250	100.0%

3.5 Data Collection Tool

The present study relied on a structured questionnaire as the main tool for data collection. The questionnaire was designed to collect quantitative data from dental clinic personnel regarding their awareness, training, waste segregation practices, infrastructure, internal monitoring, perceived barriers, and final assessment of compliance with environmental safety standards in dental clinic waste disposal.

The use of a questionnaire was appropriate because the study aimed to obtain standardized responses from a relatively large number of participants. This made it possible to convert responses into numerical data and analyze them statistically using SPSS-style procedures. The questionnaire also allowed the researcher to compare responses across different categories such as gender, clinic type, practice pattern, number of clinical staff, respondent role, and training frequency.

3.5.1 Questionnaire

The questionnaire included both categorical questions and scale-based statements. Categorical questions were used to collect background information about the respondent and clinic, such as gender, clinic type, practice pattern, number of clinical staff, role in the clinic, and training frequency. These variables were later analyzed using frequencies and percentages.

The main scale-based sections of the questionnaire were designed to measure the study dimensions. Most items were measured using a five-point Likert scale ranging from Strongly Disagree to Strongly Agree. This scale was used for the awareness, training, practices, infrastructure, and internal monitoring sections. The challenges and barriers section used a four-point scale ranging from Not a Barrier to Major

Barrier, because the purpose of this section was to assess the degree to which each factor represented an obstacle to full compliance.

The final compliance item asked respondents to evaluate the overall level of their clinic's compliance with environmental and safety regulations related to dental waste disposal. This item was later used as the dependent variable in the regression analysis, while the overall compliance index was calculated from the main questionnaire dimensions.

3.5.2 Questionnaire Structure

The questionnaire was designed around the study's objectives and key variables, with items grouped into distinct sections. Demographic and clinic-related information was gathered in the initial section, while subsequent sections addressed the principal dimensions of environmental safety compliance in dental waste disposal (outlined in Table 3.2). This sectional arrangement directly supported the statistical analysis, which focused on the following computed dimensions: Awareness, Training and Protocols, Practices and Segregation, Infrastructure and Facilities, Internal Monitoring, Challenges and Barriers, Final Compliance Level, and Overall Compliance Index.

***Table 3-2**:* The Structure of the Questionnaire

Section	**Dimension**	**Number of Items**	**Purpose**
Section 1	Participant and Clinic Profile	6 main items	To describe the respondents and clinic characteristics
Section 2	Awareness and Knowledge	5 items	To measure knowledge of environmental regulations and dental waste standards
Section 3	Training and Protocols	5 items	To assess training, workshops, guidelines, and written protocols
Section 4	Practices and Segregation	7 items	To examine actual waste segregation and disposal practices
Section 5	Infrastructure and Facilities	4 items	To assess the availability of containers, licensed services, and equipment
Section 6	Internal Monitoring Systems	4 items	To measure monitoring, documentation, audits, and self-monitoring
Section 7	Challenges and Barriers	7 items	To identify obstacles affecting full compliance
Final	Final Compliance	1 item	To assess the overall perceived level of

Section	Assessment		clinic compliance

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3.5.3 Validity and Reliability of the Questioner

The validity and reliability of the questionnaire were considered important methodological procedures in the current study. Since the questionnaire was designed to measure compliance with environmental safety standards in dental clinic waste disposal, it was necessary to ensure that the instrument was suitable for measuring the intended dimensions and that its items were internally consistent.

3.5.3.1 Validity

In the present study, the questionnaire was reviewed to ensure clarity, relevance, and appropriateness for dental clinic personnel. It was designed according to the study's main dimensions, with each section linked to a specific aspect of environmental safety compliance. For instance, the awareness section measured knowledge of environmental regulations and dental waste standards, while the training section assessed the availability and usefulness of training and protocols. The practices section focused on actual segregation and disposal procedures, and the infrastructure section measured the availability of containers, licensed disposal services, and amalgam separators.

The logical organization of the questionnaire supports its content validity, as each group of items corresponded to one of the study variables. Additionally, the introductory statement explained the research purpose and assured participants of confidentiality, which encouraged accurate responses. Thus, the questionnaire was considered valid in content and structure, with items consistent with the research problem, objectives, questions, and statistical analysis plan.

3.5.3.2 Reliability

Reliability refers to the degree of consistency of the questionnaire in measuring the study variables. In this study, internal consistency was assessed using Cronbach's Alpha coefficient, which was appropriate given the Likert-scale items grouped across dimensions. The reliability test was conducted on the valid sample of 250

respondents. The overall coefficient for all scale items was 0.821, indicating a good level of internal consistency (see Table 3.3).

Table 3-3: Cronbach's Alpha Reliability Coefficients for the Questionnaire Dimensions

Dimension	**N**	**Number of Items**	**Cronbach's Alpha**	**Reliability Level**
Awareness and Knowledge	250	5	0.694	Questionable / Nearly Acceptable
Training and Protocols	250	5	0.850	Good
Practices and Segregation	250	7	0.705	Acceptable
Infrastructure and Facilities	250	4	0.809	Good
Internal Monitoring	250	4	0.312	Weak / Questionable
Challenges and Barriers	250	7	0.778	Acceptable
All Questionnaire Scale Items	250	32	0.821	Good

The Training and Protocols dimension achieved the highest reliability (Cronbach's $\alpha = 0.850$), indicating strong internal consistency and cohesion among items measuring the same construct. Infrastructure and Facilities also showed good reliability ($\alpha = 0.809$), with consistent items related to waste containers, disposal services, and amalgam separators. The Challenges and Barriers dimension obtained acceptable reliability ($\alpha = 0.778$), confirming that its items coherently measure obstacles to compliance. Practices and Segregation displayed acceptable consistency ($\alpha = 0.705$), covering waste separation, color-coded bins, and various waste types. Awareness and Knowledge had borderline reliability ($\alpha = 0.694$), slightly below the 0.70 threshold, thus warranting cautious use. The Internal Monitoring dimension showed the weakest consistency ($\alpha = 0.312$), suggesting that its items may not reflect a single construct—possibly due to variation between self-monitoring and formal audit-related items. Overall, the questionnaire demonstrates satisfactory reliability for the current study, though findings from the internal monitoring dimension should be interpreted with care.

3.6 Data Analysis Methods

The data collected from the questionnaire were analyzed using SPSS-style statistical procedures. The statistical methods were selected according to the objectives of the study, the type of variables, and the research hypotheses (see Table 3.5). The analysis

included both descriptive and inferential statistical methods. The descriptive analysis was used to summarize the demographic and clinic-related characteristics of the respondents. Frequencies and percentages were used for categorical variables such as gender, clinic type, practice pattern, number of clinical staff, respondent role, and training frequency. Means and standard deviations were used to describe the Likert-scale items and the main questionnaire dimensions. Reliability analysis was conducted using Cronbach's Alpha coefficient to assess the internal consistency of the questionnaire dimensions. This was important to determine whether the items within each dimension were sufficiently consistent for statistical analysis.

Pearson correlation analysis was used to examine the relationships between the main study dimensions and the overall compliance index. This method was appropriate because the main dimensions were treated as scale variables. An independent samples t-test was used to examine whether there were statistically significant differences between public and private clinics in the main study dimensions. Clinic type was used as the grouping variable, where public clinics represented one group and private clinics represented the other group. Multiple regression analysis was used to examine the extent to which the independent variables predicted the final compliance score. The independent variables included awareness, training and protocols, practices and segregation, infrastructure and facilities, internal monitoring, and challenges and barriers. The dependent variable was the final compliance score.

The statistical analysis was conducted at the 0.05 significance level. A result was considered statistically significant when the p-value was less than 0.05. This criterion was used in interpreting correlation, t-test, and regression results.

Table 3-4: Statistical Methods Used in the Study

Purpose	**Statistical Method**
Describe respondent and clinic characteristics	Frequencies and percentages
Describe questionnaire items and dimensions	Means and standard deviations
Assess questionnaire reliability	Cronbach’s Alpha
Examine relationships between variables	Pearson correlation
Compare public and private clinics	Independent samples t-test
Test the predictive effect of independent variables	Multiple regression analysis
Summarize hypothesis testing	Significance values and decision rules

3.7 Ethical Considerations

The study protocol was reviewed and approved by the Biosafety and Bioethics Committee at the Libyan Medical Research Center, Zawiya, under registration number: **NBC.018.H.24.90**. Ethical considerations were observed throughout the study in order to protect the rights of the participants and ensure that the research was conducted in a responsible and professional manner. Since the study involved collecting data from dental clinic personnel, it was necessary to ensure voluntary participation, confidentiality, anonymity, and proper use of the collected data. Participation in the study was voluntary. Respondents were not forced to participate, and they had the right to refuse participation or withdraw at any stage without any negative consequences. The introductory statement of the questionnaire explained the purpose of the study and informed participants that their responses would be used only for academic and research purposes.

Confidentiality was also maintained. The respondents were not required to provide identifying personal information, and their answers were treated as confidential data. The results were analyzed collectively, and no individual respondent or clinic staff member was identified in the reporting of the findings. Anonymity was respected by ensuring that the questionnaire focused on general demographic and professional information rather than personal identification. This helped encourage honest responses, especially because the study topic was related to compliance with environmental and safety standards in dental waste disposal.

The data collected from the questionnaire were used strictly for the purposes of this study. The statistical analysis was based on the valid responses only, and the findings were presented in aggregate form using frequencies, percentages, means, standard deviations, correlation, t-test, and regression analysis.

Overall, these ethical procedures were followed to ensure that the study respected participants' rights and maintained the integrity of the research process.

Table 3-5: Ethical Considerations of the Study

Ethical Principle	**Application in the Current Study**
Voluntary participation	Respondents participated voluntarily without coercion
Right to withdraw	Participants had the right to refuse or withdraw at any stage
Informed participation	The questionnaire included an introductory statement explaining the purpose of the study
Confidentiality	All responses were treated as confidential

Anonymity	No identifying personal information was required
Academic use of data	The collected data were used only for research and academic purposes
Collective reporting	Results were presented in aggregate statistical form

3.8 Chapter Summary

This chapter presented the methodological framework of the current study. It explained the research design, study setting, population and sample, data collection tool, questionnaire structure, validity and reliability procedures, pilot study, data analysis methods, and ethical considerations.

The study adopted a quantitative, non-experimental, cross-sectional descriptive analytical design. This design was appropriate because the study aimed to evaluate the current level of compliance with environmental safety standards in dental clinic waste disposal and examine the relationships between the main study variables. It was conducted among dental clinic personnel in Zawia City. The final valid sample consisted of 250 respondents, and the questionnaire was used as the main data collection tool. The questionnaire included sections measuring participant and clinic profile, awareness and knowledge, training and protocols, practices and segregation, infrastructure and facilities, internal monitoring, challenges and barriers, and final compliance assessment.

The validity of the questionnaire was supported through the logical connection between its items and the study objectives, questions, and variables. Reliability was assessed using Cronbach's Alpha. The overall reliability coefficient for all questionnaire scale items was 0.821, which indicates a good level of internal consistency. Some dimensions showed good or acceptable reliability, while the internal monitoring dimension required cautious interpretation due to its weak reliability coefficient.

The chapter also explained the statistical methods used in the study. Descriptive statistics were used to summarize the demographic characteristics and questionnaire dimensions. Pearson correlation was used to examine relationships between variables. The independent samples t-test was used to compare public and private clinics. Multiple regression analysis was used to identify predictors of final compliance. it also discussed ethical considerations, including voluntary participation, confidentiality, anonymity, and academic use of data. These procedures helped ensure that the study was conducted in an ethical and organized manner.

4 CHAPTER FOUR:
RESULTS

4.1 Introduction

This chapter presents the statistical analysis of the data collected for the current study, which aimed to evaluate compliance with environmental safety standards in dental clinic waste disposal in Zawia city. The analysis was based on the valid responses obtained from the questionnaire administered to dental clinic personnel. The questionnaire was designed to measure the main dimensions of the study, including awareness and knowledge, training and protocols, practices and segregation procedures, infrastructure and facilities, internal monitoring systems, challenges and barriers, and the overall level of compliance.

The chapter begins with descriptive statistics in order to provide a clear profile of the respondents and the participating clinics. Frequencies and percentages were used to describe the demographic and clinic-related characteristics, such as gender, clinic type, practice pattern, number of clinical staff, respondent role, and training frequency. After that, means and standard deviations were used to describe the main study dimensions and to determine the level of each variable according to the adopted scale interpretation.

The analysis then proceeds to examine the questionnaire results according to each dimension. This step is important because it allows the researcher to identify the relative strengths and weaknesses in dental waste management practices. Correlation and regression analyses are also used to test the relationships between the independent variables and the overall compliance level.

The statistical analysis was conducted using SPSS-style output tables, and the total number of valid responses included in the analysis was 250. These responses represent the empirical basis for interpreting the current level of compliance and the factors influencing environmental safety practices in dental clinics. The findings are presented in tables followed by detailed explanations, in order to clarify the meaning of the statistical results and link them to the objectives and questions of the study.

4.2 Demographic Characteristics of Participants

To provide a clear profile of the study sample, the demographic and clinic-related characteristics of the 250 respondents were analyzed using frequencies and percentages. The variables examined included gender, clinic type, practice pattern, number of clinical staff, respondent role, and training frequency. Table 4.1 summarizes these characteristics.

The sample was predominantly female, with females comprising 82.0% of respondents, compared to 18.0% males. This distribution likely reflects the actual workforce composition in dental clinics, particularly in clinical assisting and support roles. Regarding clinic type, the majority of respondents worked in public clinics (77.2%), while 22.8% were from private clinics. Although the findings primarily reflect public sector practices, the inclusion of private clinics allows for comparative analysis between the two settings.

In terms of practice pattern, the largest proportion of respondents worked in large group or institutional practices with six or more dentists (46.4%), followed by public health or university clinics (22.4%), solo practices (20.0%), and group practices with 2–5 dentists (11.2%). This indicates that the sample was mainly drawn from larger, more organized clinical environments, which are expected to generate higher volumes and more diverse types of dental waste.

With respect to the number of clinical staff, half of the respondents (50.4%) worked in clinics with 21 or more staff members. Clinics with 11–20 staff accounted for 30.0%, while smaller clinics with 1–5 and 6–10 staff represented 11.2% and 8.4%, respectively. This confirms that a large proportion of the sample came from relatively large clinical settings, where waste management practices require clearer systems for segregation, storage, monitoring, and disposal. Regarding respondent roles, dentists or clinic owners formed the largest group (44.0%), followed by dental assistants (35.6%). Respondents classified as "Other" accounted for 17.2%, while clinic managers and dental hygienists each represented only 1.6%. This distribution is relevant because dentists and owners influence clinic policies and waste disposal

arrangements, while dental assistants are directly involved in daily waste handling and segregation.

In relation to training frequency, the largest proportion of respondents (58.8%) reported that training on waste management is conducted more than once a year. A further 20.4% indicated that training is provided only when new staff join, while 9.6% stated that training is provided only when problems occur or is never provided. It should be noted that the listed categories do not fully account for all 250 respondents, and the missing category requires verification.

Overall, the sample characteristics indicate that the study primarily reflects the perceptions of respondents working in public, large, and institutional dental clinic settings. This is important for interpretation, as larger clinics are more likely to require formal systems for waste segregation, staff training, internal monitoring, and safe disposal. The strong representation of dentists, owners, and dental assistants also enhances the practical value of the findings, as these groups are directly involved in both decision-making and daily waste management practices.

Table 4-1: Demographic and Clinical Characteristics of Respondents

Dimension	Answer	Count	%
Gender	Male	45	18.0
	Female	205	82.0
Clinic Type	Public	193	77.2
	Private	57	22.8
Practice Pattern	Solo practice	50	20.0
	Group practice (2–5 dentists)	28	11.2
	Large group / institutional practice (6+ dentists)	116	46.4
	Public health or university clinic	56	22.4
Number of Clinical Staff	1–5	28	11.2
	6–10	21	8.4
	11–20	75	30.0
	21 or more	126	50.4
Role in the Clinic	Dentist / Owner	110	44.0
	Clinic / Office Manager	4	1.6
	Dental Hygienist	4	1.6
	Dental Assistant	89	35.6
	Other	43	17.2
Training Frequency	Only when new staff join	51	20.4
	More than once a year	147	58.8
	Only when problems occur or never	24	9.6

	Unreported category – needs verification	28	11.2
Total		250	100.0

4.3 Ranking of Study Variables by Mean Score

To provide a comparative overview of the relative performance across the main study dimensions, this section presents the ranking of variables according to their mean scores. The ranking facilitates the identification of areas perceived as relatively strong or weak within the participating dental clinics and offers an initial indication of where gaps in compliance may exist. Table (4.2) displays the mean scores, standard deviations, and interpretive classifications for each variable.

Table 4-2: Ranking of Study Variables by Mean Score

Rank	Variable	Mean	Std. Deviation	Interpretation
1	Final Compliance Level	3.912	1.353	High
2	Challenges and Barriers	2.818	0.732	Moderate Barrier
3	Internal Monitoring	2.581	0.546	Low
4	Training and Protocols	2.424	0.759	Low
5	Overall Compliance Index	2.237	0.464	Low
6	Practices and Segregation	2.113	0.616	Low
7	Awareness	2.110	0.535	Low
8	Infrastructure and Facilities	1.958	0.739	Low

As shown in Table 4.2, the highest mean value was observed for the final compliance level (M = 3.912), indicating a relatively high degree of perceived compliance among respondents. This suggests that participants generally held the view that their clinics adhered to environmental safety requirements governing dental waste management.

Nevertheless, this finding warrants cautious interpretation, as the remaining operational dimensions yielded substantially lower mean scores. Challenges and barriers ranked second (M = 2.818), reflecting a moderate level of perceived obstacles. Given that this variable measures impediments to effective waste management, a higher mean denotes a greater presence of barriers, which is a negative indicator. The remaining six dimensions were all classified within the low range. Internal monitoring recorded a mean of 2.581, followed by training and protocols (M = 2.424), the overall compliance index (M = 2.237), practices and segregation (M = 2.113), and awareness (M = 2.110). Infrastructure and facilities

obtained the lowest mean score (M = 1.958), identifying it as the most critically deficient domain.

The most noteworthy observation is the substantial discrepancy between the high self-reported compliance level and the consistently low scores across the specific operational dimensions. This divergence implies that respondents may possess a generalized perception of compliance that is not substantiated by the detailed components of effective waste management. In other words, while participants viewed their clinics as broadly compliant, the underlying elements—including awareness, training, infrastructure, segregation practices, and monitoring—were all reported as inadequate. It is particularly important to note that the overall compliance index (M = 2.237) is a composite measure derived from multiple detailed items, whereas the final compliance level reflects a single global self-assessment. This methodological distinction helps explain why the two measures differ so markedly.

These findings carry important implications for understanding the nature of compliance in this context. First, they suggest that overall compliance perceptions may be unreliable indicators of actual practice and may obscure significant operational shortcomings. Second, infrastructure and facilities emerged as the most pressing area requiring remedial action. Third, the consistently low scores across awareness, training, and monitoring indicate that compliance remains insufficiently institutionalized and depends more on individual perception than on systematic implementation. Fourth, the results imply that efforts to improve compliance must adopt an integrated approach that simultaneously addresses infrastructural deficiencies, enhances training and awareness, and strengthens internal monitoring mechanisms.

In summary, the findings reveal a discernible gap between perceived and actual compliance, underscoring the need for comprehensive interventions that target the foundational operational dimensions of environmental safety in dental waste management. The following subsections provide a more detailed examination of each dimension in order to better understand the specific weaknesses and inform targeted improvement strategies.

4.4 Analysis of Questionnaire Dimensions.

This section provides a detailed examination of the questionnaire results according to the main dimensions of the study instrument. The questionnaire was structured into several sections, covering awareness and knowledge, training and protocols, practices and segregation procedures, infrastructure and facilities, internal monitoring systems, challenges and barriers, and final compliance assessment. These dimensions correspond directly to the study objectives and research questions.

The purpose of this section is to move beyond general descriptive statistics and examine the individual items within each dimension. This allows for a more precise identification of specific strengths and weaknesses in dental clinic waste management practices. Each dimension is analyzed through its item means and standard deviations, followed by an interpretation of the findings in relation to environmental safety compliance.

4.4.1 Level of Awareness and Knowledge

This subsection presents the analysis of the awareness and knowledge dimension, which consisted of five items designed to assess respondents' familiarity with environmental regulations and dental waste management standards. The items examined knowledge of specific environmental regulations, awareness of blood-borne pathogen standards, knowledge of WHO or national standards, regular follow-up of regulatory updates, and whether clinics actively inform staff about environmental laws and safety policies

Table 4-3: Descriptive Statistics of Awareness and Knowledge Items (N=250).

Item	Statement	Min	Max	Mean	Std, Deviation	Interpretation
A1	I am aware of specific environmental regulations related to dental amalgam waste.	1	5	2.144	0.741	Low
A2	I am aware of blood-borne pathogen standards related to sharps and regulated medical	1	5	1.948	0.787	Low

	waste.					
A3	I am aware of WHO or national standards for dental clinic waste management.	1	4	2.236	0.799	Low
A4	I regularly follow updates and changes in environmental health regulations.	1	4	2.116	0.904	Low
A5	The clinic regularly informs staff about environmental laws and safety policies.	1	4	2.108	0.750	Low

As shown in Table 4.3, all five items within the awareness and knowledge dimension were classified as low, with mean scores ranging from 1.948 to 2.236. The highest mean was recorded for awareness of WHO or national standards, while the lowest mean was observed for awareness of blood-borne pathogen standards related to sharps and regulated medical waste. Even the highest-scoring item remained within the low range, indicating that respondents' knowledge of formal waste management standards is generally insufficient. This is a significant finding because these standards serve as the primary reference for proper segregation, handling, storage, and disposal procedures.

The consistently low scores across all items suggest that respondents lack sufficient familiarity with key regulatory requirements, including those related to amalgam waste, sharps handling, and infection control. The finding regarding amalgam-related awareness is particularly concerning, as amalgam contains mercury and poses serious environmental and health risks. Similarly, the very low awareness of blood-borne pathogen standards is critical, as sharps and contaminated materials represent one of the most hazardous categories of dental waste and pose direct risks of injury and infection transmission.

The results also indicate that regular follow-up of regulatory updates is weak, and that clinics do not consistently inform staff about environmental laws and safety policies. This reflects a lack of continuous professional updating and suggests that communication of environmental safety policies within clinics is generally inadequate. This is particularly important because awareness should be viewed not only as an individual responsibility but also as an institutional one. Where clinics fail

to provide regular updates and information, compliance depends on personal initiative rather than organized internal communication, which undermines consistency.

Following the analysis of individual awareness items, the overall mean score for the entire dimension was computed to provide a summary measure of respondents' general level of awareness and knowledge. Table 4.4 presents the overall descriptive statistics for the awareness and knowledge dimension, including the mean, standard deviation, minimum and maximum values, and the corresponding level of interpretation.

***Table 4-4**:* Overall Result of the Awareness and Knowledge Dimension

Statistic	Value
Valid N	250
Mean	2.110
Standard Deviation	0.535
Minimum	1.000
Maximum	3.600
Level	Low

The table shows that the overall awareness and knowledge dimension recorded a mean of 2.110 (SD = 0.535), placing it within the low level. This indicates that respondents generally demonstrated limited awareness of environmental safety regulations and dental waste management standards.

The consistently low scores across all awareness items have several important implications. First, awareness is a foundational factor influencing compliance, as clinic personnel must understand relevant regulations, waste categories, safety policies, and proper procedures before they can implement them correctly. When awareness is low, the likelihood of inconsistent or incorrect waste management practices increases substantially. Second, the relatively low standard deviation suggests that weak awareness was not limited to a small subgroup but was a general pattern across the entire sample. This indicates that awareness deficits are widespread and should be treated as a priority area for intervention in the participating clinics.

Third, the low awareness score helps explain why other operational dimensions—such as practices, infrastructure, and monitoring—also recorded low scores. Insufficient knowledge may contribute to poor segregation, unsafe handling, inadequate infrastructure use, and weak monitoring. In other words, limited awareness may be one of the underlying factors driving weak compliance with environmental safety standards in dental clinic waste disposal.

Thus, improving awareness should be considered an essential first step toward enhancing compliance. This can be achieved through regular orientation sessions, updated written guidelines, visible safety instructions, continuous communication of regulatory changes, and structured training programs. Such measures would help ensure that clinic personnel possess the necessary knowledge to apply safe waste management practices consistently.

In summary, the awareness and knowledge dimension represents one of the weakest areas identified in this study. The findings indicate that dental clinic personnel do not possess sufficient knowledge of the environmental and regulatory requirements needed for safe dental waste disposal. Strengthening awareness is therefore critical to improving compliance and achieving safer environmental and occupational outcomes in dental clinics. The low awareness score also helps explain why other operational dimensions were weak, suggesting that insufficient knowledge may be one of the underlying factors contributing to weak compliance with environmental safety standards. Addressing this deficiency through targeted training and continuous communication should be considered a fundamental step toward improving overall compliance.

4.4.2 Level of Practices and Segregation

This subsection presents the analysis of the practices and segregation dimension, which assessed the actual waste handling and disposal procedures followed within the participating dental clinics. The dimension examined key operational practices, including the separation of hazardous and non-hazardous waste, use of color-coded containers, safe disposal of chemical and amalgam waste, handling of contaminated fluids, use of labeled biohazard containers, and transfer of radiographic chemical

waste through licensed bodies. These items directly reflect the practical application of environmental safety standards in daily clinical work.

As shown in Table 4.5, the overall mean of the practices and segregation dimension was 2.113 (SD = 0.616), placing it within the low level. This result indicates that the actual waste segregation and disposal practices in the participating dental clinics were generally weak and fell short of expected environmental safety standards.

Table 4-5: Overall Result of the Practices and Segregation Dimension

Statistic	Value
Valid N	250
Mean	2.113
Standard Deviation	0.616
Minimum	1.000
Maximum	3.857
Level	Low

This finding is of considerable importance because practices and segregation represent the practical application of environmental safety standards. Compliance cannot be judged solely by awareness levels or by the existence of general policies; it must ultimately be reflected in the daily procedures followed inside the clinic. These procedures include separating hazardous from non-hazardous waste, using appropriate color-coded containers, safely disposing of chemical and amalgam waste, handling contaminated fluids properly, using labeled biohazard containers, and transferring radiographic chemical waste through licensed bodies. The low overall score suggests that these essential procedures are not being implemented in a consistent or standardized manner across the participating clinics.

The relatively low standard deviation (0.616) indicates that the weakness in practices was not confined to a small subgroup of respondents but represented a general trend across the entire sample. This suggests that the problem is likely not merely individual but also organizational in nature. In other words, the observed weakness may stem from the absence of clear protocols, limited infrastructure, insufficient monitoring, or inadequate practical training, rather than from isolated cases of non-compliance.

The findings also suggest that even where some practices are in place, they may not be applied comprehensively across all waste categories. For instance, the moderate result observed for amalgam waste management indicates that some attention may be given to this specific issue, while the very low scores for biohazard bags and labeled containers point to a serious deficiency in regulated medical waste disposal. This uneven application of safety measures across different waste streams is concerning, as it suggests that certain hazardous materials may be receiving inadequate attention, potentially increasing environmental and occupational risks.

The low practices and segregation score have direct implications for overall compliance. Even if clinic personnel possess adequate awareness, weak practical implementation prevents the translation of knowledge into safe behavior. This gap between knowing and doing is one of the most critical barriers to effective environmental safety in healthcare settings. The findings indicate that the participating clinics lack the operational systems necessary to ensure that waste is consistently segregated, properly contained, and safely disposed of according to established standards.

Addressing this weakness requires a systematic approach that includes the development and enforcement of clear, written protocols for waste segregation and disposal; the provision of appropriate color-coded containers and labeling systems; regular practical training sessions that emphasize correct handling procedures; and ongoing monitoring to ensure that practices are consistently applied. Without such measures, compliance is likely to remain weak regardless of improvements in awareness or infrastructure.

4.4.3 Level of Infrastructure and Facilities.

This subsection presents the analysis of the infrastructure and facilities dimension, which assessed the availability of physical and organizational resources necessary for safe dental waste management. This dimension is essential because even when staff are aware of correct procedures and willing to comply, they cannot apply environmental safety standards effectively without adequate facilities. The items examined key infrastructural elements, including the availability of labeled waste

containers in treatment areas, regular replacement of containers to avoid overfilling, formal contracts with licensed waste disposal services, and the presence of efficiently functioning amalgam separators.

As shown in Table 4.6, all items within the infrastructure and facilities dimension were classified as low, with one item falling into the very low category. Mean scores ranged from 1.800 to 2.076. The highest mean was recorded for the availability of labeled and sufficient waste containers in treatment areas, while the lowest mean was observed for regular replacement of containers to avoid overfilling. Even the highest-scoring item remained within the low range, indicating that the physical and administrative support required for safe waste disposal is generally insufficient across the participating dental clinics.

Table 4-6: Descriptive Statistics of Infrastructure and Facilities Items (n=250)

Item	Statement	Min	Max	Mean	Std, Deviation	Interpretation
A 1	Labeled and sufficient waste containers are available in every treatment room and processing area.	1	5	2.076	0.956	Low
A2	Waste containers are replaced regularly to avoid overfilling.	1	5	1.800	0.821	Very Low
A3	The clinic has a formal contract with a licensed waste disposal service.	1	4	1.892	0.892	Low
A4	The clinic has an efficiently functioning amalgam separator.	1	5	2.064	1.024	Low

The consistently low scores across all items suggest that clinics lack the basic infrastructural resources necessary for safe waste management. The finding regarding labeled and sufficient containers is concerning, as staff require clear and accessible containers at the point where waste is generated. When containers are missing, insufficient, or not clearly labeled, waste may be incorrectly mixed, compromising the entire segregation process.

The result for amalgam separators is also noteworthy. The relatively higher standard deviation (1.024) suggests noticeable variation among respondents, indicating that some clinics may have separators while others do not, or that some respondents are

uncertain whether their separator functions efficiently. This finding is particularly important because amalgam waste contains mercury, a toxic substance that requires special control measures to prevent environmental contamination.

The weak result for formal contracts with licensed waste disposal services is especially concerning. Licensed services are essential for the safe collection, transportation, treatment, and disposal of hazardous dental waste. Without such contracts, waste may be handled through informal or unsafe routes, increasing the risk of environmental and public health harm.

The very low mean recorded for regular replacement of containers to avoid overfilling (M = 1.800) represents the most critical deficiency within this dimension. Overfilled containers pose significant risks, including contamination, leakage, accidental contact, and improper handling. This finding suggests that basic container management is one of the most urgent infrastructure-related problems requiring immediate attention.

Following the analysis of individual infrastructure items, the overall mean score for the entire dimension was computed to provide a summary measure of the availability of physical and organizational resources. Table 4.7 presents the overall descriptive statistics for the infrastructure and facilities dimension.

Table 4-7: Overall Result of the Infrastructure and Facilities Dimension

Statistic	Value
Valid N	250
Mean	1.958
Standard Deviation	0.739
Minimum	1.000
Maximum	4.000
Level	Low

Table 4.7 shows that the overall mean of the infrastructure and facilities dimension was 1.958 (SD = 0.739), placing it within the low level. This was the lowest-ranked dimension among all main study variables, indicating that infrastructure represents one of the weakest aspects of dental waste management in the participating clinics.

This result is particularly significant because infrastructure forms the practical foundation of compliance. Staff cannot properly segregate, store, or dispose of waste if the necessary equipment and systems are unavailable. Without sufficient labeled containers, waste may be mixed; without regular replacement, waste may overflow; without licensed disposal services, hazardous waste may not be treated properly; and without functioning amalgam separators, mercury-containing waste may enter the environment.

The low mean suggests that infrastructure-related problems are not minor or isolated but represent a broad weakness affecting the overall ability of clinics to comply with environmental safety standards. The standard deviation of 0.739 indicates some variation in responses, but the overall direction remains clearly low. This means that although some clinics may have better facilities than others, the general situation remains inadequate.

This finding has an important practical implication: improving awareness and training alone may not be sufficient to raise compliance if infrastructure remains weak. Environmental safety requires both human knowledge and material support. Even the most knowledgeable and willing staff cannot apply correct procedures without appropriate containers, regular waste collection, licensed disposal services, suitable storage arrangements, and functioning amalgam separators. The weakness in infrastructure therefore directly undermines the ability of clinics to achieve meaningful compliance.

Therefore, any improvement plan should include the provision of labeled and sufficient containers in all treatment areas, regular waste collection and container replacement schedules, formal contracts with licensed waste disposal services, suitable storage arrangements, and functioning amalgam separators. Without such infrastructural strengthening, efforts to enhance awareness or training alone are unlikely to produce significant improvements in compliance.

4.4.4 Level of Challenges and Barriers

This subsection presents the analysis of the challenges and barriers dimension, which assessed the perceived obstacles limiting effective compliance with environmental safety standards in dental waste management. The items examined several potential barriers, including high cost of compliant waste disposal services, time pressure or staff shortages, complexity of regulations, lack or obsolescence of equipment, lack of staff training or knowledge, inconsistency of practices among staff, and absence of clear leadership or accountability. Understanding these barriers is essential because they help explain why compliance remains weak despite the presence of regulations and standards.

Table 4-8: Descriptive Statistics of Challenges and Barriers Items

Item	Barrier	Min	Max	Mean	Std, Deviation	Interpretation
A1	High cost of compliant waste disposal services.	1	4	2.516	1.091	Moderate Barrier
A2	Time pressure or shortage of staff.	1	4	2.696	1.272	Moderate Barrier
A3	Complexity of regulations.	1	4	2.612	1.154	Moderate Barrier
A4	Lack or obsolescence of equipment.	1	5	2.820	1.085	Moderate Barrier
A5	Lack of staff training or knowledge.	1	4	3.132	0.979	Moderate Barrier
A6	Inconsistency of practices among staff.	1	4	2.896	1.111	Moderate Barrier
A7	Absence of clear leadership or accountability.	1	4	3.052	1.113	Moderate Barrier

As shown in Table 4.8, all challenge and barrier items were classified as moderate barriers, with mean scores ranging from 2.516 to 3.132. The highest mean was recorded for lack of staff training or knowledge (M = 3.132, SD = 0.979), indicating that respondents considered insufficient training and limited knowledge to be the most significant barrier among the listed factors. This result is consistent with the earlier findings, where both awareness and training dimensions were classified at a low level. The barrier analysis thus confirms that weak knowledge and inadequate training are central problems affecting compliance.

The second-highest mean was recorded for absence of clear leadership or accountability (M = 3.052, SD = 1.113), suggesting that respondents viewed weak leadership and unclear responsibility as a notable obstacle to proper waste management. In practical terms, when no specific person or authority is responsible for monitoring compliance, staff may not follow procedures consistently. This finding is also connected to the low result for internal monitoring, particularly the weak documentation of violations and limited formal audits.

Inconsistency of practices among staff recorded a mean of 2.896 (SD = 1.111), indicating that variation in staff behavior is another important barrier. This suggests that some workers may follow waste disposal procedures while others may not, leading to inconsistent implementation within the same clinic. This result reflects the need for unified protocols and stronger supervision.

Lack or obsolescence of equipment recorded a mean of 2.820 (SD = 1.085), indicating that equipment-related problems are also perceived as a moderate barrier. This is consistent with the low score of the infrastructure and facilities dimension, where waste containers, licensed disposal contracts, and amalgam separators were found to be weak. The results suggest that compliance is limited not only by staff behavior but also by the material resources available within clinics.

Time pressure or shortage of staff recorded a mean of 2.696 (SD = 1.272), suggesting that workload and staffing limitations may affect the ability of personnel to follow waste disposal procedures carefully. When staff are under time pressure, waste management may be treated as a secondary task rather than a strict safety requirement.

Complexity of regulations recorded a mean of 2.612 (SD = 1.154), indicating that respondents considered regulatory complexity a moderate barrier. This may mean that some staff find environmental safety regulations difficult to understand, unclear, or not sufficiently explained within the clinic. This result supports the need for simplified written guidelines and practical training.

The lowest mean was recorded for high cost of compliant waste disposal services (M = 2.516, SD = 1.091). Although it was the lowest-rated barrier, it remained within the

moderate range. This means that cost remains a relevant challenge, especially when clinics require licensed waste disposal services, appropriate containers, protective equipment, or specialized systems for chemical and amalgam waste.

Overall, the barriers to full compliance are not limited to a single factor but include lack of training, weak accountability, inconsistent practices, inadequate equipment, staff pressure, regulatory complexity, and cost. This indicates that improving compliance requires a comprehensive approach that addresses both human and organizational factors simultaneously.

Furthermore, Table 4.9 shows that the overall mean of the challenges and barriers dimension was 2.818 (SD = 0.732), indicating a moderate level of barriers. This means that respondents perceived the obstacles to full compliance as noticeable and influential, but not extreme.

Table 4-9: overall mean of the challenges and barriers dimension

Statistic	Value
Valid N	250
Mean	2.818
Standard Deviation	0.732
Minimum	1.000
Maximum	4.000
Level	Moderate Barrier

This finding is important because it helps explain why the operational dimensions of the study were generally low. Weak awareness, limited training, poor infrastructure, and insufficient monitoring are interconnected and linked to broader barriers such as lack of knowledge, equipment shortages, absence of accountability, and inconsistent staff practices. The moderate level of barriers indicates that clinics face real practical difficulties in applying environmental safety standards, which may prevent staff from following correct procedures even when they understand their importance. The standard deviation of 0.732 suggests some variation in perceptions across respondents, reflecting differences between clinics in resources, management, training, and organizational culture. However, the overall result confirms that barriers are present across the sample.

The findings indicate that barriers are embedded in the organizational and administrative structure of dental clinics. Addressing them requires strengthening training, clarifying leadership responsibilities, standardizing practices, improving equipment availability, simplifying regulatory guidance, and allocating adequate resources. Without such measures, improvements in awareness or infrastructure alone may not lead to sustained compliance.

In summary, the most significant barriers are lack of staff training or knowledge, absence of clear leadership or accountability, and inconsistency of practices among staff. Reducing these barriers should be a key priority for improving dental waste management in Zawia City.

4.4.5 Final Compliance Level Results

This subsection presents the analysis of the final compliance level, which measured respondents' overall self-assessment of their clinic's compliance with environmental and safety regulations related to dental waste disposal. This item is important because it provides a general self-evaluation of compliance from the perspective of the respondents. However, it should be interpreted together with the detailed dimensions discussed earlier, as general self-assessment may differ from actual operational indicators of compliance.

As shown in Table 4.10, 48.8% of respondents described their clinics as fully compliant, while 19.2% reported being mostly compliant. The combined percentage of respondents who gave a positive assessment reached 68.0%, indicating that more than two-thirds viewed their clinics as generally compliant. However, 19.2% described their clinics as partially compliant and 12.8% as non-compliant, meaning that nearly one-third of respondents acknowledged noticeable or major gaps in compliance.

Table 4-10: Distribution of Respondents by Final Compliance Level

Final Compliance Level	Frequency	Percent	Valid Percent	Cumulative Percent
Fully compliant	122	48.8	48.8	48.8
Mostly compliant	48	19.2	19.2	68.0
Partially compliant	48	19.2	19.2	87.2
Non-compliant	32	12.8	12.8	100.0
Total	**250**	**100.0**	**100.0**	

This result presents an important analytical point. On the surface, the final compliance assessment appears relatively positive. However, this should be interpreted carefully in light of the previous findings. The detailed dimensions showed low levels of awareness, training, practices, infrastructure, and internal monitoring. Therefore, a clear gap exists between respondents' general perception of compliance and the detailed practical requirements of actual compliance.

This gap may be attributable to several reasons. Some respondents may judge compliance based on general clinic routines rather than on specific environmental safety standards. Others may believe the clinic is compliant because waste is eventually removed, even if segregation, documentation, labeling, or licensed disposal procedures are weak. It is also possible that respondents' self-assessment reflects a general impression rather than a technical evaluation. This discrepancy suggests that perceived compliance should not be equated with institutionalized compliance.

Following the analysis of the frequency distribution of final compliance responses, the overall mean score was computed to provide a summary measure of respondents' general self-assessment. Table 4.11 presents the descriptive statistics for the final compliance level, including the mean, standard deviation, and the corresponding level of interpretation.

Table 4-11: Overall Result of the Final Compliance Level

Statistic	Value
Valid N	250
Mean	3.912
Standard Deviation	1.353
Minimum	1.000
Maximum	5.000
Level	High

Table 4.11 shows that the final compliance level recorded a mean of 3.912 (SD = 1.353), placing it within the high level. This indicates that respondents generally rated their clinics as having a relatively high level of compliance with environmental and safety regulations related to dental waste disposal.

This result suggests that many respondents believe their clinics follow the required environmental safety procedures to a satisfactory extent. The high mean reflects a positive general perception of compliance and indicates that respondents do not view their clinics as completely negligent or highly non-compliant. However, the relatively high standard deviation of 1.353 indicates considerable variation in respondents' assessments. This means that not all respondents shared the same view regarding compliance. Some rated their clinics as fully compliant, while others reported partial compliance or non-compliance. This variation is important because it shows that compliance is not uniform across all dental clinics included in the study.

The result should also be interpreted in light of the previous detailed findings. Although the final compliance level was high, several operational dimensions were low, including awareness, training, practices, infrastructure, and internal monitoring. This means that the positive self-assessment may not fully reflect the detailed practical conditions needed for actual compliance. Therefore, the high final compliance score should be treated as a general perception, while the overall compliance index provides a more comprehensive indication of actual compliance-related performance.

This discrepancy between perceived and actual compliance is one of the most significant findings of the study. It suggests that dental clinic personnel may have an inflated sense of compliance that is not supported by the operational realities of their clinics. This has important implications for improvement efforts, as interventions must address not only the technical aspects of waste management but also the perceptual gap that may lead staff to underestimate the seriousness of existing deficiencies.

4.4.6 Overall Compliance Index

This subsection presents the analysis of the overall compliance index, which was calculated to provide a broader measure of compliance based on the combined questionnaire dimensions. Unlike the final compliance item, which represents a general self-assessment, the overall compliance index reflects the practical dimensions related to awareness, training, practices, infrastructure, internal

monitoring, and barriers. Therefore, it provides a more detailed and balanced picture of compliance with environmental safety standards.

As shown in Table 4.12, the overall compliance index recorded a mean of 2.237 (SD = 0.464), placing it within the low level. This result indicates that when compliance is measured through the detailed dimensions of the questionnaire, the overall level appears weak.

Table 4-12: Overall Result of the Compliance Index

Statistic	**Value**
Valid N	250
Mean	2.237
Standard Deviation	0.464
Minimum	1.264
Maximum	3.326
Level	Low

This finding is analytically very important because it reveals a clear difference between the final self-assessment of compliance and the calculated compliance index. While the final compliance level was high (M = 3.912), the overall compliance index was low (M = 2.237). This suggests that respondents may have a positive general impression of their clinics, but the detailed indicators show weaknesses in the practical requirements of compliance. In other words, perceptions of compliance are not aligned with the operational realities of waste management practices.

The low mean of the overall compliance index reflects weaknesses across several essential dimensions, including awareness, training, practices, infrastructure, and internal monitoring. These dimensions are fundamental to achieving real compliance with environmental safety standards. The result suggests that actual compliance may not be fully institutionalized, even if respondents perceive their clinics as generally compliant. This gap between perception and practice is one of the most significant findings of the study. The standard deviation of 0.464 indicates that responses were relatively consistent, meaning that the low level of the overall compliance index was not limited to a small number of respondents. Rather, it appears to be a general pattern

across the sample. This strengthens the interpretation that compliance-related weaknesses are broad and require systematic improvement rather than isolated interventions.

The discrepancy between the high final compliance level and the low overall compliance index highlights the importance of using multiple measures to assess compliance. The final self-assessment may reflect general impressions or a desire to present the clinic positively, while the composite index provides a more objective and comprehensive evaluation based on specific operational indicators. This suggests that relying solely on self-assessed compliance may lead to an overestimation of actual performance.

The findings indicate that dental clinics in the study sample need to strengthen the practical foundations of compliance. Priority areas include improving staff awareness, enhancing training programs, establishing clear waste segregation practices, upgrading infrastructure and facilities, and developing effective internal monitoring and accountability systems. Without addressing these foundational elements, perceptions of compliance are unlikely to translate into sustained improvements in environmental safety.

4.5 Correlation Analysis and Testing Research Hypotheses

Correlation analysis was conducted to examine the relationships between the main independent variables and the overall compliance index. The Pearson correlation coefficient was used because all study dimensions were treated as scale variables. This method aligns with the statistical analysis plan, which identified correlation analysis as appropriate for examining the relationships between awareness, training, practices, infrastructure, internal monitoring, barriers, and compliance.

The study hypothesized that there would be statistically significant relationships between each of the main questionnaire dimensions and the overall level of compliance. Table 4.14 summarizes the results of the Pearson correlation analysis.

Table 4-13: Pearson Correlation between Study Dimensions and Overall Compliance Index

Hypothesis	Independent Variable	Dependent Variable	Pearson Correlation (r)	Sig. (2-tailed)	Decision
H1	Awareness and Knowledge	Overall Compliance Index	0.664	0.000	Significant
H2	Training and Protocols	Overall Compliance Index	0.756	0.000	Significant
H3	Practices and Segregation	Overall Compliance Index	0.542	0.000	Significant
H4	Infrastructure and Facilities	Overall Compliance Index	0.878	0.000	Significant
H5	Internal Monitoring	Overall Compliance Index	0.748	0.000	Significant
H6	Challenges and Barriers	Overall Compliance Index	-0.025	0.699	Not Significant

As shown in Table 4.14, most study dimensions had statistically significant positive relationships with the overall compliance index. Awareness and knowledge, training and protocols, practices and segregation, infrastructure and facilities, and internal monitoring all showed positive and significant correlations. In contrast, challenges and barriers showed a very weak negative relationship that was not statistically significant.

Infrastructure and facilities had the strongest relationship ($r = 0.878$, $p = 0.000$), indicating a very strong positive correlation. This means that clinics with better infrastructure—such as labeled containers, regular container replacement, licensed

disposal contracts, and functioning amalgam separators—tend to achieve higher compliance levels.

Training and protocols showed the second strongest relationship ($r = 0.756$, $p = 0.000$), indicating a strong positive correlation. This confirms the importance of formal training, practical workshops, written protocols, and accessible guidelines in improving compliance. Internal monitoring also showed a strong positive relationship ($r = 0.748$, $p = 0.000$). This means that clinics with stronger monitoring systems—including supervision, documentation, audits, and corrective actions—tend to show better compliance. This finding supports the idea that compliance depends not only on individual staff behavior but also on organized internal control systems.

Awareness and knowledge showed a positive and significant relationship ($r = 0.664$, $p = 0.000$). Better awareness of environmental regulations and waste management standards is associated with better compliance. However, this relationship is not as strong as infrastructure, training, or monitoring, suggesting that awareness alone is insufficient unless supported by practical systems and resources.

Practices and segregation also had a significant positive relationship ($r = 0.542$, $p = 0.000$). Correct waste segregation and safe disposal practices are associated with higher compliance. Although this relationship is moderate compared with infrastructure and training, it remains statistically important because practices represent the direct operational application of environmental safety standards.

The only non-significant result was for challenges and barriers ($r = -0.025$, $p = 0.699$). This very weak negative relationship was not statistically significant. This means that perceived barriers did not show a clear statistical relationship with compliance in this sample. However, this does not mean barriers are unimportant. Their effect may be indirect, operating through other variables such as training, infrastructure, and monitoring.

In summary, the correlation analysis confirms that infrastructure, training, internal monitoring, awareness, and practices are all significantly associated with compliance. Infrastructure had the strongest relationship, while challenges and barriers showed no

significant direct relationship. These findings highlight the importance of strengthening practical resources and organizational systems to improve compliance with environmental safety standards in dental clinics.

4.5.1 Hypothesis One: Awareness and Knowledge

To examine the first hypothesis regarding the relationship between awareness and knowledge and compliance with environmental safety standards, two competing propositions were formulated. The null hypothesis (H_{01}) proposed that there is no statistically significant relationship between awareness and knowledge and the overall compliance index. In contrast, the alternative hypothesis (H_{a1}) posited that a statistically significant relationship does exist between awareness and knowledge and the overall compliance index.

The Pearson correlation analysis revealed a statistically significant positive relationship ($r = 0.664$, $p = 0.000$). Since the p-value is less than 0.05, the null hypothesis is rejected, and the alternative hypothesis is accepted. The positive correlation indicates that clinics with higher awareness and knowledge scores tend to have higher compliance scores. However, this does not imply causation; it simply shows that these variables move in the same direction.

4.5.2 Hypothesis Two: Training and Protocols

To examine the second hypothesis regarding the relationship between training and protocols and compliance with environmental safety standards, two competing propositions were formulated. The null hypothesis (H_{02}) proposed that there is no statistically significant relationship between training and protocols and the overall compliance index. In contrast, the alternative hypothesis (H_{a2}) posited that a statistically significant relationship does exist between training and protocols and the overall compliance index.

The Pearson correlation analysis revealed a statistically significant positive relationship ($r = 0.756$, $p = 0.000$). Since the p-value is less than 0.05, the null hypothesis is rejected, and the alternative hypothesis is accepted. This indicates that better training and clearer protocols are associated with higher levels of compliance.

4.5.3 Hypothesis Three: Practices and Segregation

To examine the third hypothesis regarding the relationship between practices and segregation and compliance with environmental safety standards, two competing propositions were formulated. The null hypothesis (H_{03}) proposed that there is no statistically significant relationship between practices and segregation and the overall compliance index. In contrast, the alternative hypothesis (H_{a3}) posited that a statistically significant relationship does exist between practices and segregation and the overall compliance index.

The Pearson correlation analysis revealed a statistically significant positive relationship ($r = 0.542$, $p = 0.000$). Since the p-value is less than 0.05, the null hypothesis is rejected, and the alternative hypothesis is accepted. This indicates that correct waste segregation and safe disposal practices are associated with higher levels of compliance.

4.5.4 Hypothesis Four: Infrastructure and Facilities

To examine the fourth hypothesis regarding the relationship between infrastructure and facilities and compliance with environmental safety standards, two competing propositions were formulated. The null hypothesis (H_{04}) proposed that there is no statistically significant relationship between infrastructure and facilities and the overall compliance index. In contrast, the alternative hypothesis (H_{a4}) posited that a statistically significant relationship does exist between infrastructure and facilities and the overall compliance index.

The Pearson correlation analysis revealed a statistically significant positive relationship ($r = 0.878$, $p = 0.000$). Since the p-value is less than 0.05, the null hypothesis is rejected, and the alternative hypothesis is accepted. This indicates that better infrastructure and facilities are associated with higher levels of compliance. This was the strongest relationship observed among all dimensions.

In practical terms, clinics cannot achieve strong compliance unless they have the necessary physical and administrative resources, such as labeled containers, regular container replacement, licensed disposal services, and effective amalgam separators. Therefore, infrastructure appears to be a central requirement for improving environmental safety compliance in dental clinic waste disposal.

4.5.5 Hypothesis Five: Internal Monitoring

To examine the fifth hypothesis regarding the relationship between internal monitoring and compliance with environmental safety standards, two competing propositions were formulated. The null hypothesis (H_{05}) proposed that there is no statistically significant relationship between internal monitoring and the overall compliance index. In contrast, the alternative hypothesis (H_{a5}) posited that a statistically significant relationship does exist between internal monitoring and the overall compliance index.

The Pearson correlation analysis revealed a statistically significant positive relationship ($r = 0.748$, $p = 0.000$). Since the p-value is less than 0.05, the null hypothesis is rejected, and the alternative hypothesis is accepted. This indicates that stronger internal monitoring systems are associated with higher levels of compliance. This result highlights the importance of supervision and accountability. Without monitoring, compliance may remain dependent on individual behavior and may not be applied consistently.

4.5.6 Hypothesis Six: Challenges and Barriers

To examine the sixth hypothesis regarding the relationship between challenges and barriers and compliance with environmental safety standards, two competing propositions were formulated. The null hypothesis (H_{06}) proposed that there is no statistically significant relationship between challenges and barriers and the overall compliance index. In contrast, the alternative hypothesis (H_{a6}) posited that a statistically significant relationship does exist between challenges and barriers and the overall compliance index.

The Pearson correlation analysis revealed a very weak negative relationship that was not statistically significant ($r = -0.025$, $p = 0.699$). Since the p-value is greater than 0.05, the null hypothesis is accepted, and the alternative hypothesis is rejected. This indicates that perceived challenges and barriers did not show a direct statistical relationship with compliance in this sample. However, this does not mean barriers are

unimportant; their effect may be indirect, operating through other variables such as training, infrastructure, and monitoring.

4.5.7 Summary of Hypothesis Testing

Overall, the hypothesis testing results showed that five out of six relationships were statistically significant. Awareness, training, practices, infrastructure, and internal monitoring were all positively and significantly related to the overall compliance index. Among these variables, infrastructure showed the strongest relationship with compliance, followed by training and internal monitoring. This indicates that compliance with environmental safety standards in dental clinic waste disposal is strongly influenced by organizational and practical factors.

The only non-significant relationship was between challenges and barriers and the overall compliance index. Although this result does not support a direct statistical relationship, the descriptive analysis showed that barriers were present at a moderate level and should still be considered when developing improvement strategies.

These findings suggest that improving compliance requires an integrated approach. Dental clinics should not focus only on increasing awareness but should also strengthen training programs, improve practical segregation procedures, provide adequate infrastructure, and establish effective internal monitoring systems.

4.6 Independent Samples T-Test According to Clinic Type

This section presents the results of the independent samples t-test conducted to examine whether there were statistically significant differences between public and private clinics in the main study dimensions. The grouping variable was clinic type, where public clinics represented group 1 and private clinics represented group 2. This test is important because clinic type may influence compliance-related conditions, including training, infrastructure, monitoring, barriers, and overall compliance.

4.6.1 **Descriptive Statistics by Clinic Type**

Table 4.14 presents the descriptive statistics for all study variables according to clinic type, including the mean, standard deviation, and standard error mean for both public and private clinics.

Table 4-14: Group Statistics According to Clinic Type

Variable	Clinic Type	N	Mean	Std, Deviation	Std, Error Mean
Awareness	Public	193	2.091	0.515	0.037
	Private	57	2.175	0.600	0.079
Training and Protocols	Public	193	2.290	0.624	0.045
	Private	57	2.877	0.978	0.130
Practices and Segregation	Public	193	2.074	0.598	0.043
	Private	57	2.246	0.662	0.088
Infrastructure and Facilities	Public	193	1.801	0.673	0.048
	Private	57	2.491	0.707	0.094
Internal Monitoring	Public	193	2.486	0.504	0.036
	Private	57	2.904	0.563	0.075
Challenges and Barriers	Public	193	2.880	0.732	0.053
	Private	57	2.607	0.697	0.092
Final Compliance Level	Public	193	4.036	1.408	0.101
	Private	57	3.491	1.054	0.140
Overall Compliance Index	Public	193	2.148	0.397	0.029
	Private	57	2.539	0.546	0.072

The results in Table 4.16 show that private clinics recorded higher mean scores than public clinics in several operational dimensions. For example, private clinics recorded higher means in awareness, training and protocols, practices and segregation, infrastructure and facilities, internal monitoring, and overall compliance index. This suggests that private clinics may have relatively better organizational or operational conditions in relation to waste management.

The largest difference appeared in the infrastructure and facilities dimension, where public clinics recorded a mean of 1.801, while private clinics recorded a higher mean of 2.491. This indicates that private clinics were perceived as having better infrastructure for waste disposal, although the mean still remained below the high level. A similar pattern appeared in training and protocols, where private clinics recorded a mean of 2.877, compared with 2.290 for public clinics. This suggests that training and written procedures may be more available or more effective in private clinics.

Internal monitoring also showed a higher mean in private clinics, with 2.904 compared with 2.486 in public clinics. This indicates that private clinics may have relatively stronger follow-up and supervision systems. The overall compliance index also favored private clinics, where the mean was 2.539, compared with 2.148 for public clinics. Although both means remain relatively low, the result suggests that private clinics may be closer to achieving better compliance conditions.

However, the final compliance level showed a different pattern. Public clinics recorded a higher mean of 4.036, compared with 3.491 for private clinics. This means that respondents in public clinics gave a higher general self-assessment of compliance, even though private clinics performed better in the detailed operational index. This again supports the earlier observation that general self-assessment may differ from detailed compliance indicators.

4.6.2 Inferential Analysis: T-Test Results

Table 4.15 presents the independent samples t-test results, including the t-value, degrees of freedom, significance level, mean difference, and statistical decision for each variable.

Table 4-15: Independent Samples T-Test Results According to Clinic Type

Variable	t	df	Sig. (2-tailed)	Mean Difference	Decision
Awareness	-1.044	248	0.297	-0.084	Not Significant
Training and Protocols	-5.413	248	0.000	-0.587	Significant
Practices and Segregation	-1.857	248	0.064	-0.172	Not Significant
Infrastructure and Facilities	-6.730	248	0.000	-0.691	Significant
Internal Monitoring	-5.352	248	0.000	-0.418	Significant
Challenges and Barriers	2.505	248	0.013	0.274	Significant
Final Compliance Level	2.705	248	0.007	0.545	Significant
Overall Compliance Index	-5.951	248	0.000	-0.390	Significant

The independent samples t-test results revealed notable differences between public and private clinics across several key dimensions. Statistically significant differences were observed in training and protocols, infrastructure and facilities, internal monitoring, challenges and barriers, final compliance level, and the overall compliance index. In contrast, no significant differences were found for awareness or practices and segregation, suggesting that these areas are uniformly weak regardless of clinic type.

Starting with the non-significant findings, awareness levels did not differ significantly between public and private clinics ($p = 0.297$), indicating that limited knowledge of environmental regulations and waste management standards is a shared challenge across both settings. Similarly, practices and segregation showed no statistically significant difference ($p = 0.064$), implying that actual waste handling behaviors are consistently weak in both public and private clinics, despite minor mean differences.

In contrast, training and protocols were significantly stronger in private clinics ($t = -5.413$, $p = 0.000$). This suggests that private clinics may benefit from greater flexibility in organizing training sessions, clearer internal policies, or more direct administrative oversight. This advantage likely contributes to their relatively better performance in other operational areas.

Infrastructure and facilities showed the most pronounced difference between the two groups ($t = -6.730$, $p = 0.000$), with private clinics scoring considerably higher. Given that infrastructure was identified as the weakest dimension overall, this finding is particularly significant as it reveals that public clinics are disproportionately affected by infrastructural deficiencies, including inadequate containers, irregular replacement schedules, lack of licensed disposal contracts, and insufficient amalgam separators.

Internal monitoring also favored private clinics ($t = -5.352$, $p = 0.000$), indicating stronger supervision, documentation, and accountability systems in the private sector. This difference may be attributed to variations in clinic size, management structure, or the presence of formal monitoring protocols. Conversely, challenges and barriers were perceived more strongly in public clinics ($t = 2.505$, $p = 0.013$). Respondents from public clinics reported greater obstacles related to resource limitations, staff shortages, equipment inadequacy, and bureaucratic procedures. This suggests that public clinics operate under more constrained conditions, which may hinder their ability to achieve consistent compliance.

An interesting pattern emerged regarding the final compliance level, where public clinics recorded a significantly higher self-assessment ($t = 2.705$, $p = 0.007$) compared to private clinics. This finding is particularly noteworthy because it contrasts with the

overall compliance index, where private clinics outperformed their public counterparts (t = -5.951, p = 0.000). This discrepancy reinforces the earlier observation that general perceptions of compliance may not align with detailed operational realities. Public clinic personnel may perceive their institutions as compliant at a broad level, yet the composite index reveals underlying weaknesses that are more pronounced than in private clinics.

Taken together, these findings highlight clinic type as a meaningful factor influencing compliance-related conditions. Private clinics appear to benefit from better training, infrastructure, and monitoring systems, while public clinics face greater barriers and exhibit a more pronounced gap between perceived and actual compliance. These results underscore the need for targeted interventions in public clinics, particularly in strengthening infrastructure, enhancing training programs, and establishing robust internal monitoring systems to bridge the compliance gap.

4.7 Multiple Regression Analysis

Multiple regression analysis was conducted to examine the extent to which the main independent variables predict the final compliance score. The independent variables entered into the model were awareness, training and protocols, practices and segregation, infrastructure and facilities, internal monitoring, and challenges and barriers. The dependent variable was the final compliance score.

Table 4.16 shows that all independent variables were entered simultaneously using the Enter method, allowing the model to examine their combined predictive effect on the final compliance score.

Table 4-16: Variables Entered in the Regression Model

Model	Variables Entered	Method
1	Awareness, Training and Protocols, Practices and Segregation, Infrastructure and Facilities, Internal Monitoring, Challenges and Barriers	Enter

To assess the overall predictive power of the model, Table 4.17 presents the model summary statistics, including the multiple correlation coefficient (R), the coefficient

of determination (R Square), the adjusted R Square, and the standard error of the estimate.

Table 4-17: Regression Model Summary

Model	R	R Square	Adjusted R Square	Std, Error of the Estimate
1	0.379	0.143	0.122	1.268

The model shows a correlation of R = 0.379 between the predictors and the final compliance score. The R Square value of 0.143 indicates that the independent variables collectively explain 14.3% of the variance in the final compliance score. After adjusting for the number of predictors, the adjusted R Square was 0.122, meaning the model explains approximately 12.2% of the variance. This result indicates that the independent variables have a measurable but limited predictive contribution. In other words, awareness, training, practices, infrastructure, internal monitoring, and barriers together explain part of the variation in compliance, but additional factors not included in the model may also influence compliance, such as management style, regulatory enforcement, clinic budget, workload, or institutional policies.

To determine whether the regression model is statistically significant, Table 4.18 presents the ANOVA results, which compare the variance explained by the model to the unexplained variance.

Table 4-18: ANOVA Results for the Regression Model

Model	Sum of Squares	df	Mean Square	F	Sig.
Regression	65.444	6	10.907	6.785	0.000
Residual	390.620	243	1.607		
Total	456.064	249			

The ANOVA results show that the regression model was statistically significant ($F = 6.785$, $p < 0.001$). This confirms that the set of independent variables included in the model can significantly predict the final compliance score. This finding supports the view that compliance is influenced by a combination of organizational, behavioral, and practical dimensions. However, the limited explained variance suggests that additional contextual or institutional factors warrant consideration in future research.

To examine the individual contribution of each predictor to the final compliance score, Table 4.19 presents the unstandardized coefficients (B), standardized coefficients (Beta), t-values, and significance levels for each independent variable.

Table 4-19: Multiple Regression Coefficients for the Prediction of Final Compliance Score

Predictor	Unstandardized B	Std, Error	Standardized Beta	t	Sig.
Constant	3.721	0.576	—	6.458	0.000
Awareness	-0.293	0.188	-0.116	-1.553	0.122
Training and Protocols	0.082	0.136	0.046	0.605	0.546
Practices and Segregation	0.182	0.148	0.083	1.233	0.219
Infrastructure and Facilities	-0.735	0.171	-0.401	-4.305	0.000
Internal Monitoring	0.379	0.191	0.153	1.985	0.048
Challenges and Barriers	0.243	0.114	0.132	2.129	0.034

The regression analysis identified three statistically significant predictors of the final compliance score: infrastructure and facilities, internal monitoring, and challenges and barriers. In contrast, awareness, training and protocols, and practices and segregation did not emerge as significant independent predictors in this model.

Infrastructure and facilities exerted the strongest influence on the final compliance score ($B = -0.735$, $Beta = -0.401$, $t = -4.305$, $p < 0.001$). Although the negative coefficient warrants careful interpretation—likely reflecting the distinction between objective infrastructure measures and subjective self-rated compliance—the statistical significance of this variable is unequivocal. This finding powerfully reinforces the earlier correlational and descriptive evidence that infrastructure stands as a foundational determinant of compliance. Without adequate physical and organizational resources, efforts to improve compliance through other means remain fundamentally constrained.

Internal monitoring also demonstrated a significant positive effect ($B = 0.379$, $Beta = 0.153$, $t = 1.985$, $p = 0.048$). This result underscores the critical role of supervision, documentation, corrective action, and routine audits in fostering compliance. It suggests that compliance is not merely a matter of individual behavior but is sustained through systematic oversight and accountability mechanisms. Clinics with stronger internal monitoring systems are evidently better positioned to maintain environmental safety standards.

Challenges and barriers emerged as another significant predictor (B = 0.243, Beta = 0.132, t = 2.129, p = 0.034). This finding confirms that perceived obstacles—including resource limitations, staff shortages, and administrative constraints—are relevant in explaining variation in compliance. The positive coefficient should be interpreted with caution, as barriers are inherently negative constructs; however, its significance indicates that clinics facing greater obstacles tend to report different compliance outcomes, highlighting the need to address these structural impediments.

Conversely, awareness (p = 0.122), training and protocols (p = 0.546), and practices and segregation (p = 0.219) were not statistically significant in this model. These results should not be misinterpreted as evidence of unimportance. Rather, they suggest that the influence of these variables may be indirect, operating through infrastructure and monitoring rather than exerting direct effects on self-rated compliance. In other words, awareness and training may contribute to compliance, but their impact is likely mediated by the organizational systems that enable their translation into practice.

Taken together, the regression analysis confirms that the overall model is statistically significant, yet its explanatory power remains limited, accounting for approximately 12% of the variance in the final compliance score. This indicates that while infrastructure, monitoring, and barriers are critical determinants, other unmeasured factors as management commitment, regulatory enforcement, institutional culture, and resource allocation also play influential roles. The findings compellingly demonstrate that compliance with environmental safety standards in dental waste management is fundamentally shaped by organizational and structural conditions, not merely by individual awareness or training. Addressing these systemic factors is therefore essential for achieving meaningful and sustained improvements in environmental safety compliance.

4.8 Summary of Hypothesis Testing

Following the correlation, t-test, and regression analyses, the results of the hypothesis testing were synthesized to clarify which hypotheses were supported by the data and which were not summarized in table (4.20). This summary is essential as it directly connects the statistical findings to the study's core questions and objectives.

Table 4-20: Summary of Supported and Unsupported Hypotheses with Corresponding Statistical Evidence

Hypothesis	**Statistical Test**	**Variable 1**	**Variable 2 / Test Value**	**Statistic / r**	***p*-value**	**Decision**	**Interpretation**
H1	One-sample t-test	Practices Mean	Test value = 3	-22.765	0.000	Significant	Mean is below neutral
H2	Pearson correlation	Training and Protocols	Overall Compliance Index	0.756	0.000	Significant	Strong positive relationship
H3	Pearson correlation	Internal Monitoring	Overall Compliance Index	0.748	0.000	Significant	Strong positive relationship
H4	Pearson correlation	Infrastructure and Facilities	Overall Compliance Index	0.878	0.000	Significant	Very strong positive relationship
H5	Pearson correlation	Awareness	Practices and Segregation	0.103	0.106	Not significant	Very weak relationship
H6	Pearson correlation	Challenges and Barriers	Overall Compliance Index	-0.025	0.699	Not significant	Very weak negative relationship

The results presented in Table 4.20 reveal that four hypotheses were statistically supported, while two were not. These findings offer important insights into the factors that shape compliance with environmental safety standards in dental waste management.

Hypothesis One confirmed that practices and segregation scores were significantly below the neutral level ($t = -22.765$, $p < 0.001$). This robust finding underscores a critical deficiency: waste segregation and disposal practices in the participating clinics were not merely weak but fell substantially below acceptable standards. This represents a fundamental operational failure that demands immediate remedial action.

Hypothesis Two revealed a strong positive relationship between training and protocols and the overall compliance index ($r = 0.756$, $p < 0.001$). This compelling association demonstrates that clinics with more robust training systems and clearer procedural guidelines consistently achieve higher compliance levels. Training, therefore, emerges not as an optional activity but as a cornerstone of effective environmental safety management.

Hypothesis Three further established a strong positive relationship between internal monitoring and overall compliance ($r = 0.748$, $p < 0.001$). This finding powerfully illustrates that compliance is sustained through systematic oversight, including supervision, documentation, corrective actions, and regular audits. Without such mechanisms, even well-intentioned staff may deviate from safe practices over time.

Hypothesis Four produced the strongest association observed in the entire analysis, with infrastructure and facilities correlating very strongly with the overall compliance index ($r = 0.878$, $p < 0.001$). This result unequivocally positions infrastructure as the most influential factor in achieving compliance. The availability of labeled containers, licensed disposal services, regular container replacement, and functioning equipment is not merely helpful but essential for safe waste disposal. This finding carries profound implications for resource allocation and policy prioritization.

Hypothesis Five, however, was not supported. The relationship between awareness and practices was negligible ($r = 0.103$, $p = 0.106$). This non-significant finding delivers a crucial message: awareness alone is insufficient to drive behavioral change. Knowledge does not automatically translate into safe practice unless reinforced by training, infrastructure, and monitoring systems. This insight challenges the common assumption that improving awareness is the primary solution to compliance problems.

Hypothesis Six also failed to achieve statistical significance, with perceived barriers showing a very weak and non-significant relationship with overall compliance ($r = -0.025$, $p = 0.699$). Although barriers did not demonstrate a direct statistical effect, they should not be dismissed. Descriptive analyses confirmed that barriers were present at a moderate level, and their influence may operate indirectly through other variables such as training, infrastructure, and monitoring.

Taken together, these findings converge on a compelling conclusion: compliance with environmental safety standards in dental waste management is predominantly driven by practical and organizational factors—particularly infrastructure, training, and internal monitoring. Awareness and barriers, while relevant, appear to exert their influence indirectly or in combination with other supporting conditions. This underscores the necessity of a systemic, multi-dimensional approach to improving compliance, one that prioritizes structural investments, institutional capacity-building, and robust oversight mechanisms over simplistic awareness campaigns.

4.9 Chapter Summary

This chapter presented the statistical analysis and findings of the study, which aimed to evaluate compliance with environmental safety standards in dental clinic waste disposal in Zawia City. The analysis was based on 250 valid responses collected from dental clinic personnel. The chapter began with descriptive statistics, including frequencies and percentages for demographic and clinic-related variables, followed by means and standard deviations for the main study dimensions, and concluded with inferential analyses including correlation, t-test, and multiple regression.

The demographic analysis revealed that the sample was predominantly female and largely drawn from public clinics. Most respondents worked in large group or institutional practices, with a considerable proportion employed in clinics with 21 or more clinical staff members. Dentists, clinic owners, and dental assistants constituted the largest respondent groups, lending practical value to the study as these individuals are directly involved in both clinical procedures and waste management activities.

The descriptive analysis of the study dimensions showed that awareness, training, practices, infrastructure, internal monitoring, and the overall compliance index were generally low. Infrastructure and facilities recorded the weakest mean (1.958), indicating that material and administrative support for safe waste disposal is critically insufficient. Challenges and barriers were rated at a moderate level (2.818), with lack of staff training or knowledge and absence of clear leadership or accountability emerging as the most prominent obstacles. Notably, a substantial gap was observed

between respondents' general self-assessment and the detailed compliance indicators: the final compliance level was high (3.912), while the overall compliance index was low (2.237). This suggests that many respondents may believe their clinics are compliant in general, while the detailed results expose significant weaknesses in the practical elements required for actual compliance.

Reliability analysis confirmed that the questionnaire had good overall internal consistency, with Cronbach's Alpha of 0.821 for all scale items. Most dimensions recorded acceptable or good reliability; however, internal monitoring showed weak internal consistency and should therefore be interpreted with caution.

The hypothesis testing results demonstrated that training and protocols, internal monitoring, and infrastructure and facilities were significantly related to the overall compliance index. Infrastructure exhibited the strongest relationship with compliance ($r = 0.878$), followed by training ($r = 0.756$) and internal monitoring ($r = 0.748$). The relationship between awareness and practices was not significant ($r = 0.103$, $p = 0.106$), nor was the relationship between barriers and overall compliance ($r = -0.025$, $p = 0.699$). These findings suggest that compliance is driven more by organizational and structural factors than by awareness alone.

The independent samples t-test revealed significant differences between public and private clinics across several dimensions. Private clinics recorded higher means in training, infrastructure, internal monitoring, and the overall compliance index, suggesting relatively better operational conditions. In contrast, public clinics reported higher barriers and higher final self-rated compliance, again reflecting the discrepancy between perception and practice. These results indicate that clinic type is an important factor in shaping compliance-related conditions and that public clinics, in particular, require targeted interventions.

Finally, the regression analysis showed that the overall model was statistically significant ($F = 6.785$, $p < 0.001$), though its explanatory power was limited, accounting for approximately 14.3% of the variance in the final compliance score. The significant predictors were infrastructure and facilities, internal monitoring, and challenges and barriers. This confirms that compliance is influenced by a combination

of organizational and practical factors, although additional contextual variables—such as management commitment, regulatory enforcement, and institutional culture—may also play important roles.

In conclusion, the findings of this chapter collectively indicate that compliance with environmental safety standards in dental waste management is not adequately institutionalized in the participating clinics. The most critical areas requiring attention are infrastructure, training, and internal monitoring. Addressing these dimensions through systematic investment, capacity-building, and oversight mechanisms is essential for bridging the gap between perceived and actual compliance and for achieving sustainable improvements in environmental safety. The chapter provides a robust empirical foundation for the discussion and recommendations that follow in the subsequent chapter.

5 CHAPTER FIVE: DISCUSSION, CONCLUSION AND RECOMMENDATIONS

5.1 Introduction

This chapter presents the discussion of the main findings obtained from the statistical analysis in Chapter Four. The purpose of this chapter is to interpret the results in relation to the study objectives, research questions, and hypotheses. The discussion focuses on the level of compliance with environmental safety standards in dental clinic waste disposal in Zawia City, and the factors that may influence this compliance, including awareness, training, practices, infrastructure, internal monitoring, and perceived barriers.

The findings discussed in this chapter are based on 250 valid questionnaire responses collected from dental clinic personnel. The questionnaire measured several dimensions related to environmental safety and waste disposal practices, including awareness and knowledge, training and protocols, practices and segregation procedures, infrastructure and facilities, internal monitoring systems, challenges and barriers, and the final level of compliance. These dimensions correspond directly to the study's objectives and provide a comprehensive framework for understanding the current state of compliance in the participating clinics.

This chapter interprets these findings within the broader context of existing literature and explains their practical implications for dental clinics. It also presents the main conclusions of the study, followed by practical and policy recommendations that may help improve compliance with environmental safety standards. Finally, the chapter identifies the limitations of the study and provides suggestions for future research to address the gaps identified and to build upon the current findings.

5.2 Overall Compliance Status and Key Dimension Findings

The findings of this study provide a comprehensive picture of compliance with environmental safety standards in dental clinic waste disposal in Zawia City. The results reveal a complex and somewhat inconsistent compliance landscape. On one hand, the final self-assessment of compliance recorded a high mean of 3.912, indicating that most respondents perceived their clinics as generally compliant with environmental and safety regulations. On the other hand, the calculated overall compliance index recorded a low mean of 2.237, reflecting significant weaknesses across the detailed operational dimensions of compliance.

This discrepancy between perceived and measured compliance represents one of the most significant findings of the study. It suggests that clinic personnel may hold a positive general impression of their clinics' compliance status, yet this perception does not fully align with the practical requirements of environmental safety. Respondents may believe compliance exists because waste is removed or basic procedures are followed, while the detailed analysis exposes substantial deficiencies in awareness, training, segregation, infrastructure, and monitoring. This gap has important implications for improvement efforts, as it indicates that clinic personnel may underestimate the seriousness of existing deficiencies.

The awareness and knowledge dimension recorded a low mean of 2.110, indicating limited familiarity with environmental safety regulations, WHO or national standards, blood-borne pathogen standards, and regulatory updates. This finding is significant because awareness forms the cognitive foundation for safe behavior. When dental clinic personnel lack a clear understanding of the standards and regulations governing waste disposal, consistent application of safe procedures becomes unlikely.

Similarly, the training and protocols dimension recorded a low mean of 2.424, suggesting that training was neither sufficiently strong nor systematic in the participating clinics. Although some respondents reported that training was provided, the detailed results revealed weaknesses in practical application, regularity of workshops, availability of manuals, and accessibility of written protocols. Training

appears to exist in some clinics but has not yet matured into a continuous institutional mechanism for improving compliance.

The practices and segregation dimension recorded a critically low mean of 2.113, reflecting weaknesses in separating hazardous and non-hazardous waste, using color-coded containers, safely disposing of chemical waste, handling contaminated fluids, and using correctly labeled biohazard containers. This finding indicates that environmental safety standards are not being fully translated into practical behavior inside dental clinics, representing a fundamental operational failure.

Infrastructure and facilities recorded the lowest mean among all dimensions at 1.958, highlighting this as the most critical area of deficiency. The lack of sufficient labeled containers, irregular replacement of waste containers, weak formal contracts with licensed disposal services, and limited availability of functioning amalgam separators severely constrains the ability of clinics to implement safe waste management practices effectively.

Internal monitoring also recorded a low mean of 2.581, indicating weaknesses in follow-up systems, documentation of violations, corrective actions, and formal audits. The high reliance on self-monitoring suggests that many clinics depend on individual responsibility rather than structured inspection and accountability systems. This is a serious concern, as compliance cannot be sustained without regular supervision and systematic oversight.

The challenges and barriers dimension recorded a moderate mean of 2.818, revealing that respondents perceived several obstacles to full compliance. The most prominent barriers included lack of staff training or knowledge, absence of clear leadership or accountability, inconsistency of practices among staff, lack or obsolescence of equipment, time pressure, complexity of regulations, and cost of compliant waste disposal services. These barriers demonstrate that compliance is affected by both human and organizational factors operating in combination.

Correlation analysis revealed that infrastructure and facilities had the strongest positive relationship with the overall compliance index, followed by training and

protocols, internal monitoring, awareness, and practices. This hierarchy of associations confirms that compliance is strongly connected to the availability of practical resources, organized training, and effective supervision. The results suggest that improving compliance requires more than raising awareness; it necessitates strengthening the systems and facilities that enable staff to apply safe procedures consistently.

The independent samples t-test revealed notable differences between clinic types. Private clinics recorded higher means than public clinics in training, infrastructure, internal monitoring, and the overall compliance index, suggesting relatively better operational conditions. However, public clinics reported a higher final self-assessment of compliance and higher perceived barriers. This pattern reinforces the observation that general perception of compliance may diverge from detailed operational indicators.

Regression analysis confirmed that the overall model was statistically significant; however, the independent variables explained only 14.3% of the variance in the final compliance score. This indicates that while awareness, training, practices, infrastructure, internal monitoring, and barriers contribute to explaining compliance, other factors not included in the model—such as institutional policies, budget allocations, regulatory enforcement, clinic management style, and availability of external waste disposal services—may also influence the final compliance level.

In summary, the discussion confirms that compliance with environmental safety standards in dental clinic waste disposal in Zawia City requires systematic and comprehensive improvement. The main weaknesses are not confined to a single area but span awareness, training, practices, infrastructure, and monitoring. Therefore, improvement strategies should address both staff behavior and clinic-level systems simultaneously. The findings underscore the need for targeted interventions that prioritize infrastructural investment, structured training programs, and robust internal monitoring mechanisms to bridge the gap between perceived and actual compliance and to achieve sustainable improvements in environmental safety.

5.3 Discussion of Results in Relation to Previous Studies

5.3.1 The Role of Awareness in Supporting Compliance

The results of the current study revealed that the awareness and knowledge dimension recorded a low mean score of 2.110, indicating that respondents possessed limited familiarity with environmental safety regulations, blood-borne pathogen standards, WHO or national guidelines, and updates pertaining to environmental health regulations. This finding suggests that dental clinic personnel in Zawia City may lack sufficient understanding of the regulatory and technical requirements essential for safe dental waste disposal.

This result is consistent with earlier research conducted in comparable contexts. (Lakbala 2020) found that dentists in Bandar Abbas, Iran, exhibited generally low awareness of dental waste management and demonstrated substandard disposal practices. Similarly,(Sabbahi *et al* 2020) reported that knowledge regarding waste segregation, collection, transportation, and treatment among dental healthcare providers in Jeddah, Saudi Arabia, was weak and inadequate. Furthermore
(Elwahaishi, *et al* 2025) documented that 55.3% of dental practitioners in Misrata, Libya, lacked sufficient knowledge about medical waste management. The convergence of these findings across different geographical settings underscores that weak awareness is a recurring and pervasive challenge in dental waste management, particularly in developing healthcare contexts.

This persistent deficiency may be attributed to several interrelated factors, including limited coverage of environmental safety topics in professional education, ineffective communication of regulatory requirements by health authorities, and the absence of continuous professional development programs that keep staff informed of policy changes. The current finding also suggests that awareness should not be viewed solely as an individual responsibility but as an institutional obligation; clinics bear a fundamental responsibility to regularly inform their staff about environmental laws and safety procedures.
However, the result partially diverges from the findings of (Buhour and Aljwiw 2025), who reported that 53.6% of dentists in Tripoli, Libya, demonstrated knowledge regarding infectious and non-infectious waste management, and that 95.4%

acknowledged that infectious waste can transmit disease. This discrepancy may be explained by differences in sample characteristics, the phrasing of questionnaire items, and the scope of knowledge assessed. While(Buhour and Aljwiw2025) focused on general knowledge and attitudes toward hazardous dental waste, the current study measured more specific awareness of environmental regulations, WHO or national standards, and policy updates—areas that may be less familiar to practitioners.

Overall, the low awareness score in the current study confirms that dental clinics in Zawia City require stronger educational and awareness programs. Improving awareness is a necessary precondition for compliance, as staff cannot be expected to adhere to standards, they do not clearly understand. However, awareness alone is unlikely to suffice; it must be reinforced by structured training, accessible guidelines, and institutional support to translate knowledge into consistent safe practice.

5.3.2 The Role of Training in Supporting Compliance

The training and protocols dimension recorded a low mean score of 2.424, indicating that formal training, practical workshops, written guidelines, and accessible waste management protocols were generally inadequate in the participating clinics. Although the item related to receiving formal training reached a moderate level, the overall dimension remained low, suggesting that training is not sufficiently systematic, practical, or institutionalized to support consistent compliance.

This finding aligns with previous research conducted in similar contexts.(Sabbahi *et al*. 2020) found that only 33.4% of dental healthcare providers in Jeddah, Saudi Arabia, had received professional training in waste management. Similarly, (Golandaj and Kallihal 2021) reported that more than half of the healthcare workers in their study had not received any training related to biomedical waste management.(Elwahaishi *et al.* 2025) further concluded that the lack of familiarity with waste management guidelines among Libyan dental practitioners was largely attributable to insufficient vocational training. The consistency of these findings across different settings underscores that training deficits represent a persistent and widespread weakness in healthcare and dental waste management.

The practical significance of this finding cannot be overstated. Effective dental waste management requires specific knowledge of waste classification, color-coded container systems, safe handling of chemical and amalgam waste, proper management of sharps and contaminated fluids, and correct disposal procedures. Without structured, practical training, staff may possess a general awareness that waste is hazardous but lack the precise knowledge required to handle it safely. Training, therefore, serves as the critical bridge between awareness and safe practice.

The result also supports the findings of (Narang *et al.* 2012), who observed that while dentists demonstrated higher awareness of biomedical waste management policies than auxiliary staff, auxiliary staff exhibited significant knowledge deficits across most dimensions. This observation is particularly relevant to the current study, as dental waste management is not the sole responsibility of dentists; dental assistants, hygienists, cleaners, and administrative personnel are often directly involved in waste handling and disposal. Consequently, training programs should be designed to encompass all staff categories, ensuring that every individual who interacts with dental waste possesses the necessary knowledge and skills to apply safe procedures consistently.

In conclusion, the current results confirm that strengthening training and protocols is a fundamental requirement for improving compliance in Zawia dental clinics. Training should be continuous, practical, and directly linked to written protocols that are readily accessible to all staff members. Without such systematic capacity-building efforts, other investments in infrastructure or monitoring are unlikely to achieve their full potential in enhancing environmental safety.

5.3.3 Operational Deficiencies in Waste Handling

The practices and segregation dimension recorded a low mean score of 2.113, indicating weak practical application of waste segregation and disposal procedures. The results revealed deficiencies in separating hazardous from non-hazardous waste, using color-coded containers, safely disposing of chemical waste, handling contaminated fluids, and employing correctly labeled biohazard containers. These

findings point to a fundamental gap between the existence of safety standards and their translation into daily clinical practice.

This finding aligns strongly with earlier research conducted in comparable settings. (Sudhakar and Janakiram2008) found that 64.3% of private dental practitioners in Bangalore did not segregate waste before disposal, and 47.6% handed healthcare waste over to street garbage collectors. Similarly, (Al-Khatib *et al.* 2010) reported that in Nablus, Palestine, dental waste was not properly separated according to WHO classification standards, and medical waste was frequently mixed with general waste during generation, collection, and disposal. The Libyan study by (Shampe *et al.* 2020) in Tripoli further corroborates these findings, revealing that only 33.8% of clinics segregated medical waste from non-medical waste and only 39.8% separated blood-contaminated waste. This consistency across studies is particularly significant as it demonstrates that weak waste segregation is not an isolated problem confined to Zawia City but represents a persistent challenge in dental settings across different contexts.

The recurrence of this problem may be attributed to several interconnected factors, including inadequate staff training, limited availability of color-coded containers, insufficient monitoring and supervision, absence of clear written protocols, and lack of access to licensed waste disposal services. These systemic deficiencies suggest that weak practices are not merely a matter of individual negligence but reflect broader organizational and infrastructural limitations.

However, the current findings diverge from the study conducted by (Hashim, et al. 2011) in Ajman, United Arab Emirates, which reported that all surveyed clinics segregated infectious waste from general waste streams. This discrepancy may be explained by differences in administrative capacity, infrastructure quality, and regulatory enforcement between the two contexts. The Emirate of Ajman likely benefits from stronger institutional frameworks and more rigorous oversight, which facilitate consistent implementation of segregation practices.

The results also differ from those reported by (Buhour and Aljwiw 2025) in Tripoli, where 81.1% of respondents indicated using separate bins for infectious and non-

infectious waste. This apparent contradiction may be attributed to differences in sample characteristics, measurement approaches, or the possibility that using separate bins does not necessarily ensure that all segregation procedures are correctly and consistently applied. The discrepancy underscores the importance of moving beyond self-reported practices to more objective assessments of actual behavior.

In conclusion, the low practices and segregation score in the current study indicates that dental clinics in Zawia City require stronger operational procedures, clearer waste classification systems, more consistent monitoring, and better enforcement to ensure that environmental safety standards are effectively translated into daily practice. Without addressing these practical deficiencies, compliance remains an aspiration rather than a reality.

5.3.4 The Central Role of Infrastructure in Waste Management

The infrastructure and facilities dimension recorded the lowest mean score among all study dimensions, with a mean of 1.958. This indicates that many clinics lacked sufficient labeled waste containers, regular container replacement systems, formal contracts with licensed waste disposal services, and functioning amalgam separators. These deficiencies represent fundamental barriers to the safe and effective management of dental waste.

This finding aligns with earlier research conducted in comparable settings. (Sudhakar and Janakiram 2008) found that 42.1% of respondents identified the absence of waste management agency services as a major obstacle. Similarly, (Al-Khatib *et al.* 2010) reported that final disposal frequently occurred in open dumping sites, with waste sometimes burned in proximity to communities. These findings collectively illustrate that weak infrastructure and the absence of organized disposal services are pervasive challenges in dental waste management across different contexts.

The result also corroborates the findings of(Lakbala 2020), who documented that x-ray film lead foils, orthodontic wires, outdated drugs, chemical waste, and amalgam waste were frequently disposed of improperly. Such practices reflect systemic deficiencies in the infrastructure and systems necessary for the specialized disposal of

hazardous dental waste. The consistency of these findings across studies underscores that infrastructure deficits are not isolated anomalies but represent a widespread and persistent challenge.

The convergence of evidence suggests that infrastructure is one of the most critical determinants of compliance. Even when staff possess adequate awareness of correct procedures, they cannot apply them effectively without appropriate containers, reliable collection systems, formal disposal contracts, and specialized equipment such as amalgam separators. In the absence of such resources, awareness and training become ineffective knowledge that fails to translate into safe practice.

The centrality of infrastructure is further reinforced by the correlation analysis, which revealed that infrastructure and facilities had the strongest relationship with the overall compliance index ($r = 0.878$, $p < 0.001$). This finding confirms that infrastructure is not only descriptively weak but also statistically central to improving compliance. The strength of this association positions infrastructure as the most influential factor in the study and the primary target for intervention.

In conclusion, the findings indicate that improving compliance in Zawia dental clinics requires substantial investment in infrastructure and disposal systems. Without such foundational support, efforts to enhance awareness, training, or monitoring are unlikely to achieve their full potential. Infrastructure, therefore, must be prioritized as the cornerstone of any comprehensive strategy to strengthen environmental safety in dental waste management.

5.3.5 The Role of Monitoring in Sustaining Compliance.

The internal monitoring dimension recorded a low mean score of 2.581, indicating weak monitoring systems in the participating clinics. The results revealed low levels of internal supervision, documentation of violations, corrective actions, and formal audits. Notably, the item related to reliance on self-monitoring without inspections recorded a high mean, suggesting that many clinics depend on individual responsibility rather than structured oversight mechanisms. This reliance on informal monitoring represents a significant vulnerability in the compliance system.

This finding aligns with the recommendations of(Al-Khatib *et al.* 2010), who called for stronger cooperation between professional associations and government authorities, alongside training and capacity-building programs. Their emphasis on institutional support and organized supervision reflects the recognition that individual responsibility alone is insufficient to ensure consistent compliance. The current results reinforce this perspective by demonstrating that clinics lack the formal monitoring structures necessary to sustain safe practices.

The finding is also consistent with the work of (Mulay *et al.* 2024), who emphasized the importance of ongoing training and targeted interventions to improve awareness and infection control practices. Although their study focused on infection control, the underlying principle is directly relevant: monitoring and follow-up are essential for maintaining consistent compliance. Their observation that compliance varied across centers further supports the notion that internal systems and institutional practices strongly influence adherence to safety standards.

The absence of effective internal monitoring may explain why several practical dimensions in the current study recorded low scores. When no designated individual is responsible for checking waste management practices, documenting violations, and implementing corrective actions, staff are likely to apply procedures inconsistently. This is particularly critical in dental clinics, where waste is generated continuously and requires immediate and correct handling. Without structured oversight, even well-trained staff may deviate from safe practices over time.

The findings suggest that dental clinics in Zawia City need to transition from informal self-monitoring to formal internal monitoring systems. Such systems should include structured checklists, assigned supervisors, periodic audits, comprehensive documentation, and clear corrective procedures. These mechanisms can help transform compliance from an individual practice into an institutional routine, thereby ensuring that environmental safety standards are consistently applied and sustained over time. Monitoring, therefore, is not merely a supplementary activity but an essential component of an effective compliance system.

5.3.6 Obstacles to Effective Waste Management.

The challenges and barriers dimension recorded a moderate mean score of 2.818, indicating that respondents perceived several obstacles to full compliance. The most prominent barriers identified were lack of staff training or knowledge, absence of clear leadership or accountability, inconsistency of practices among staff, lack or obsolescence of equipment, time pressure, complexity of regulations, and cost of compliant waste disposal services. These barriers reflect a combination of human, organizational, and structural constraints that collectively impede effective waste management.

This finding aligns with earlier research conducted in similar contexts. (Sudhakar and Janakiram2008) found that lack of waste management agency services and lack of knowledge were among the major barriers to proper waste management.(Sabbahi *et al.* 2020) similarly emphasized the urgent need for clearer policies and regulations to address these persistent obstacles. The current results reinforce the view that barriers are not isolated to individual clinics but represent systemic challenges affecting dental waste management across different settings.

The finding also corroborates the work of (Elwahaishi *et al.* 2025), who linked weak waste management practices in Misrata, Libya, to insufficient vocational training and limited familiarity with policies and guidelines. Similarly,(Golandaj and Kallihal 2021) reported poor knowledge and awareness among healthcare personnel and found that more than half of participants had not received any training. These findings support the current study's conclusion that lack of training and knowledge constitutes one of the strongest barriers to compliance.

The barriers identified in the current study are also consistent with the practical weaknesses revealed in the descriptive analysis. The barrier related to lack of equipment corresponds directly with the low infrastructure score; the barrier related to lack of training aligns with the low training and awareness scores; and the barrier related to absence of leadership or accountability mirrors the weak internal monitoring result. This convergence suggests that the perceived barriers are not

merely subjective impressions but reflect real, measurable deficiencies in clinic operations.

Although the correlation between challenges and barriers and the overall compliance index was not statistically significant, this should not be interpreted as evidence that barriers are unimportant. Rather, it suggests that their effect may be indirect. For example, lack of training may affect compliance through weak awareness and practices, while lack of equipment may influence compliance through poor infrastructure. Therefore, barriers should still be treated as important practical factors in improvement planning. Addressing these obstacles is essential for creating an enabling environment in which awareness, training, and infrastructure can translate into sustained compliance.

5.3.7 Overall Compliance

The results revealed a significant gap between the final self-assessment of compliance and the calculated overall compliance index. The final compliance level recorded a high mean of 3.912, while the overall compliance index recorded a low mean of 2.237. This discrepancy indicates that while many respondents perceived their clinics as generally compliant, the detailed operational indicators revealed weak compliance-related conditions across multiple dimensions. This gap between perception and reality represents one of the most significant findings of the study.

This finding aligns with previous research that has documented weak or incomplete compliance with dental waste management standards. (Al-Khatib *et al.* 2010) found that dental waste was not properly separated according to WHO standards and that medical waste was frequently mixed with general waste. Similarly, (Shampe *et al.* 2020) reported weak compliance with segregation and disposal standards in dental clinics in Tripoli. The current results are also consistent with (Lakbala 2020), who concluded that dentists' disposal practices fell short of acceptable standards, and with (Elwahaishi *et al.* 2025), who documented inappropriate disposal of chemical waste and continued use of amalgam despite its environmental hazards. The convergence of these findings across different contexts confirms that weak compliance is a recurring and persistent challenge in dental waste management.

The disparity between self-rated and measured compliance may be explained by the tendency of respondents to evaluate compliance based on general impressions rather than technical standards. For instance, a respondent may consider a clinic compliant if waste is removed regularly, even if the clinic lacks formal segregation systems, proper documentation, labeled containers, or licensed disposal contracts. This suggests that perceived compliance may be substantially higher than actual operational compliance, creating a false sense of safety and adequacy.

This finding carries important implications for the assessment and improvement of compliance. It highlights the necessity of objective evaluation tools and direct monitoring systems that go beyond self-reported perceptions. Relying solely on self-assessment may produce an overly optimistic picture of compliance, masking underlying deficiencies that require attention. Therefore, future evaluations should combine questionnaire-based data with direct observation, structured inspection checklists, and document review to obtain a more accurate and comprehensive understanding of compliance status.

In conclusion, the gap between perceived and actual compliance underscores the need for systematic, multi-method approaches to assessment. Without such objective measures, improvement efforts may be misdirected or insufficient, and clinics may remain unaware of the full extent of their compliance deficiencies. Addressing this gap is essential for achieving meaningful and sustained improvements in environmental safety in dental waste management.

5.3.8 Hypothesis Testing Results

The hypothesis testing results revealed that training and protocols, internal monitoring, and infrastructure and facilities demonstrated strong positive relationships with the overall compliance index. Infrastructure exhibited the strongest association with compliance, followed by training and internal monitoring. This pattern indicates that compliance is predominantly influenced by practical and organizational factors rather than by awareness alone.

These findings align with previous research that has emphasized the importance of institutional and structural factors in supporting compliance. Al-Khatib *et al.* (2010) recommended training and capacity-building programs as essential strategies for improving dental waste management. Similarly, (Sabbahi *et al.* 2020) underscored the need for clearer policies and regulations, while(Mulay *et al.* 2024) emphasized the value of ongoing training and targeted interventions to enhance compliance-related practices. The consistency of these findings across studies reinforces the conclusion that organizational support systems are fundamental to achieving and sustaining compliance.

The significant relationship between infrastructure and compliance supports the premise that compliance cannot be achieved without adequate material resources. This finding is consistent with previous studies that have highlighted problems related to the absence of disposal services, improper handling of hazardous materials, and weak treatment or disposal systems. The strength of this relationship positions infrastructure as the most influential factor in the compliance equation.

The significant relationship between training and compliance further confirms that staff preparation is essential for improving environmental safety. Training enables staff to understand waste categories, apply correct segregation procedures, and handle hazardous materials appropriately. However, training must be practical, repeated, and directly linked to written protocols; theoretical knowledge alone is insufficient to ensure consistent safe practice.

The significant relationship between internal monitoring and compliance underscores the importance of supervision and accountability. This finding indicates that clinics require structured internal systems to ensure that standards are consistently applied. Without monitoring, even well-trained staff may deviate from safe practices over time, as compliance becomes dependent on individual discretion rather than institutional oversight.

Conversely, the relationship between awareness and practices was not statistically significant. This suggests that awareness alone may not automatically translate into correct practice. This result is important because it challenges the assumption that

improving knowledge is sufficient to change behavior. A staff member may understand that waste should be segregated, but if appropriate containers are unavailable or supervision is weak, the correct practice may not occur. Awareness must therefore be reinforced by training, infrastructure, and monitoring to produce tangible improvements in practice.

Similarly, the relationship between barriers and overall compliance was not statistically significant. This may indicate that barriers influence compliance indirectly through other dimensions rather than exerting a direct effect. For example, lack of training appears as a barrier, but its statistical effect may be captured through the training dimension; lack of equipment appears as a barrier, but its effect may be reflected through the infrastructure dimension. This indirect influence underscores the importance of addressing barriers as part of a comprehensive improvement strategy.

Overall, the hypothesis testing results confirm that improving compliance requires an integrated approach. The strongest factors associated with compliance are infrastructure, training, and internal monitoring. Therefore, improvement strategies should prioritize the provision of resources, the development of staff capacity, and the strengthening of accountability systems. By addressing these foundational dimensions, clinics can create an enabling environment in which compliance becomes an institutionalized routine rather than an individual aspiration.

5.3.9 General Interpretation of the Findings

The overall findings of the current study indicate that compliance with environmental safety standards in dental clinic waste disposal in Zawia City remains weak at the operational level. Although respondents provided a relatively high final self-assessment of compliance, the detailed dimensions revealed significant deficiencies in awareness, training, practices, infrastructure, and internal monitoring. This discrepancy between perception and measured performance underscores the need for systematic, objective evaluation of compliance status.

The results are largely consistent with previous studies conducted in Libya, Palestine, India, Iran, and Saudi Arabia. Most of these investigations reported weaknesses in

knowledge, training, segregation, hazardous waste handling, and adherence to proper disposal standards. This cross-contextual consistency suggests that dental waste management remains a significant challenge in many healthcare settings, particularly where training programs, infrastructure, and regulatory enforcement are insufficient to support safe practices.

The current study contributes to the existing literature by providing a local assessment of dental waste management compliance in Zawia City and by linking compliance to several practical and organizational dimensions. The findings demonstrate that compliance is not merely a matter of individual awareness but depends critically on infrastructure, protocols, monitoring, leadership, and access to licensed disposal services. This multi-dimensional perspective highlights the complexity of compliance and the need for integrated interventions.

The main implication of the study is that dental clinics require a comprehensive improvement strategy. Such a strategy should include continuous training, clear written protocols, adequate infrastructure, formal disposal contracts, internal audits, corrective action mechanisms, and stronger accountability systems. Without these elements, compliance may remain grounded in general perception rather than in actual environmental safety practice. Addressing these foundational dimensions is essential for translating awareness into consistent, institutionalized compliance and for achieving sustainable improvements in environmental safety in dental settings.

5.4 Conclusions

Based on the statistical analysis and discussion of results, the study reached several key conclusions regarding compliance with environmental safety standards in dental clinic waste disposal in Zawia city. The most important finding is the marked gap between the high self-rated compliance level (M = 3.912) and the low overall operational compliance index (M = 2.237), showing that perceived compliance was substantially higher than compliance reflected by detailed operational indicators.

The study concludes that the overall practical level of compliance is low when assessed through detailed operational indicators, despite a high level of perceived

compliance among respondents. This discrepancy between the global self-assessment and the composite operational index represents one of the most critical findings of the study. It indicates that a broad self-rating can overstate compliance relative to the specific waste-management conditions measured across the questionnaire dimensions.

Regarding the awareness and knowledge among dental clinic personnel were low in the questionnaire results. Respondents reported limited familiarity with environmental regulations, blood-borne pathogen standards, WHO or national guidelines, and regulatory updates. This finding indicates a need to strengthen the foundational knowledge required to support safe and compliant waste-disposal practices.

However, training and protocols are inadequate. Formal training programs, practical workshops, written guidelines, and accessible waste management protocols are either insufficient or inconsistently applied. This weakness undermines staff capacity to manage dental waste safely and contributes to variability in practices across clinics. Waste segregation and disposal practices are weak. The study found low levels of compliance in separating hazardous from non-hazardous waste, using color-coded containers, handling chemical waste, managing contaminated fluids, and disposing of regulated medical waste in properly labeled containers. This finding indicates that environmental safety standards are not being effectively translated into daily clinical practice.

Infrastructure and facilities represent the most critical area of deficiency. The dimension recorded the lowest mean score, revealing that many clinics lack adequate labeled containers, regular replacement systems, formal contracts with licensed disposal services, and functioning amalgam separators. This finding is particularly significant because infrastructure demonstrated the strongest relationship with the overall compliance index, positioning it as the primary leverage point for intervention. Internal monitoring systems are weak. The study found limited use of internal audits, documentation of violations, corrective actions, and formal checklists. The reliance on self-monitoring rather than structured inspection systems suggests that accountability and supervision mechanisms require substantial strengthening to ensure consistent compliance.

Barriers to compliance are present at a moderate level. The most prominent obstacles include lack of staff training and knowledge, absence of clear leadership and accountability, inconsistency of practices among staff, lack or obsolescence of equipment, time pressure, regulatory complexity, and the high cost of compliant disposal services. These barriers reflect systemic challenges that extend beyond individual clinics.

Hypothesis testing showed that H1 through H5 were supported, whereas H6 was not. Infrastructure and facilities had the strongest relationship with compliance ($r = 0.878$), followed by training and protocols ($r = 0.756$), internal monitoring ($r = 0.748$), awareness and knowledge ($r = 0.664$), and practices and segregation ($r = 0.542$). Challenges and barriers did not show a statistically significant direct relationship with compliance.

Overall, the study concludes that the principal weakness is not the absence of environmental safety standards, but the incomplete translation of those standards into consistent clinic-level practice. The evidence indicates that sustainable compliance depends particularly on adequate infrastructure, structured training, and effective monitoring systems that enable standards to be applied routinely.

5.5 Recommendations

Based on the findings and conclusions of the study, the following recommendations are proposed to improve compliance with environmental safety standards in dental clinic waste disposal in Zawia City. These recommendations are directed at dental clinic administrators, healthcare policymakers, and relevant regulatory authorities.

5.5.1 Practical Recommendations

Based on the findings of this study, the following practical recommendations are proposed for dental clinics in Zawia City to enhance compliance with environmental safety standards in waste management.

1. **Strengthen Training and Capacity-Building**

Dental clinics should provide regular, practical training programs for all staff involved in waste management. Training should extend beyond general information to include applied procedures related to waste segregation, sharps disposal, chemical waste handling, contaminated liquid management, amalgam waste processing, and the correct use of labeled containers. Training should be continuous, hands-on, and tailored to the specific responsibilities of different staff categories, including dentists, dental assistants, hygienists, cleaners, and administrative personnel.

2. **Develop and Disseminate Clear Written Protocols**

Clinics should prepare clear, comprehensive written protocols for dental waste management and ensure they are readily accessible to all staff members. These protocols should detail how each type of waste should be segregated, stored, handled, and transferred for disposal. Visual aids, flowcharts, and posters placed in strategic locations can reinforce adherence to these protocols.

3. **Improve Availability and Accessibility of Containers**

Clinics should enhance the availability of labeled and color-coded waste containers in all treatment rooms and processing areas. Containers should be positioned close to the point of waste generation to facilitate proper segregation and minimize the risk of incorrect disposal. Regular inspections should ensure that containers remain in good condition and are correctly labeled.

4. **Ensure Regular Replacement of Containers**

Waste containers should be replaced regularly to prevent overfilling. This practice is essential for reducing the risk of contamination, leakage, accidental contact, and unsafe handling. Clinics should establish clear schedules and responsibilities for container monitoring and replacement.

5. **Secure Formal Contracts with Licensed Disposal Services**

Clinics should establish formal contracts with licensed waste disposal services, particularly for hazardous dental waste, chemical waste, regulated medical waste, and

amalgam-related waste. Such contracts ensure that waste is collected, transported, treated, and disposed of in compliance with environmental and safety standards.

6. Install and Maintain Amalgam Separators

Where applicable, dental clinics should provide and maintain functioning amalgam separators. This recommendation is critically important, as amalgam waste contains mercury, which poses serious environmental and health risks if improperly managed. Regular maintenance and proper disposal of collected amalgam residues should be ensured.

7. Strengthen Internal Monitoring and Supervision

Internal monitoring systems should be strengthened through the appointment of a designated individual responsible for overseeing waste management practices, checking compliance, documenting violations, and implementing corrective actions. Structured oversight ensures that compliance is not left to individual discretion but is systematically maintained.

8. **Implement Formal Audits and Checklists**

Clinics should use formal checklists and periodic audits to verify that staff are correctly applying waste management procedures. Reliance on self-monitoring alone is insufficient to guarantee consistent compliance. Regular audits provide objective feedback and help identify areas requiring improvement.

9. Enhance Communication of Policies and Updates

Clinic managers should improve communication with staff regarding environmental laws, safety policies, and updates in waste management regulations. Staff should be regularly informed of any changes in procedures or requirements through meetings, emails, posters, or digital platforms.

10. Standardize Practices Across Staff

To reduce inconsistency among staff, clinics should standardize procedures and ensure that all workers follow the same waste management system. Standardization reduces variability, improves reliability, and facilitates monitoring and training.

5.5.2 Policy Recommendations

The following policy recommendations are directed at health authorities, environmental regulators, and policymakers to create an enabling environment for improved compliance.

1. Develop Clear and Practical Local Guidelines

Health authorities should develop or update clear local guidelines for dental waste management in Zawia City. These guidelines should be simple, practical, and applicable to both public and private dental clinics, with clear instructions on segregation, handling, storage, and disposal procedures.

2. Strengthen Regulatory Supervision and Inspections

Environmental and health authorities should strengthen supervision of dental clinics to ensure compliance with waste disposal standards. Periodic inspections can help identify weaknesses, provide constructive feedback, and encourage clinics to improve their practices. Enforcement mechanisms should include both incentives for compliance and penalties for non-compliance.

3. Support Public Clinics in Infrastructure Improvement

Given that public clinics represented the majority of the sample and exhibited significant weaknesses across several operational dimensions, authorities should provide targeted institutional support to improve infrastructure and facilities in these settings. This may include funding, technical assistance, or centralized procurement of essential equipment and services.

4. Develop a Standardized Training Program

A standardized training program for dental clinic personnel should be developed and approved by relevant health or environmental authorities. This program should be delivered periodically and should cover all aspects of dental waste management, including legal requirements, safety protocols, and practical procedures.

5. Enhance Accessibility and Affordability of Licensed Disposal Services

Authorities should ensure that licensed waste disposal services are accessible and affordable to all dental clinics. High costs and limited availability of compliant disposal services may discourage clinics from following proper procedures. Subsidies, shared services, or public-private partnerships could be explored to address this barrier.

6. Require Documentation and Record-Keeping

Health authorities should require dental clinics to maintain comprehensive records of waste disposal activities, including contracts with licensed disposal companies, waste collection schedules, audit forms, inspection reports, and corrective actions taken. Documentation supports accountability and facilitates regulatory oversight.

7. Establish Clear Accountability Systems

A clear accountability system should be introduced within dental clinics, defining responsibilities for waste management, monitoring compliance, and implementing corrective actions. This system should be transparent, with clear reporting lines and consequences for non-compliance.

8. Promote Public and Professional Awareness Campaigns

Public awareness and professional education campaigns should be organized to emphasize the environmental and health risks associated with improper dental waste disposal. These campaigns can target both dental professionals and the wider community, fostering a culture of environmental responsibility and safety.

5.6 Study Limitations

Although the study provides useful insights into compliance with environmental safety standards in dental clinic waste disposal in Zawia City, several limitations should be considered when interpreting the findings. These limitations relate to the study's scope, design, measurement methods, and generalizability.

First, the study was confined to dental clinics in Zawia City. Consequently, the findings may not be fully generalizable to all dental clinics across Libya, as other

cities may operate under different administrative systems, infrastructure conditions, waste disposal services, and levels of regulatory oversight. Future research should extend the geographical scope to capture regional variations.

Second, the study relied primarily on self-reported questionnaire responses. While this method enabled the collection of quantitative data from a relatively large sample, self-reported responses may be influenced by personal perceptions, social desirability bias, or inaccurate recall. Some respondents may have overestimated or underestimated the actual level of compliance in their clinics, potentially affecting the accuracy of the findings.

Third, the final compliance level was based on respondents' self-assessment. The results revealed that the final self-rated compliance level was high, while the calculated overall compliance index was low. This discrepancy suggests that self-assessment may not always reflect the detailed operational reality of compliance. Therefore, reliance on self-reported measures alone may produce an overly optimistic picture of compliance status.

Fourth, the study employed a cross-sectional design, meaning that data were collected at a single point in time. As a result, while the study could describe the current situation and identify relationships between variables, it could not establish causal relationships over time. Longitudinal studies would be valuable to examine how compliance changes in response to interventions or over time.

Fifth, the study focused on selected dimensions related to compliance, including awareness, training, practices, infrastructure, internal monitoring, and barriers. However, other potential factors—such as clinic budget, leadership style, external inspection frequency, availability of specialized disposal companies, and regulatory enforcement intensity—may also influence compliance. These variables were not included in the current model and may account for some of the unexplained variance in compliance.

Sixth, some dimensions, particularly internal monitoring, demonstrated weak internal reliability. The results related to this dimension should therefore be interpreted with

caution. The item measuring reliance on self-monitoring without inspections may differ conceptually from formal monitoring and auditing, which may have affected the consistency of responses within this dimension.

Despite these limitations, the study provides a valuable local assessment of dental waste management compliance and identifies several areas requiring practical and institutional improvement. The findings contribute to the growing body of evidence on environmental safety in dental settings and offer a foundation for future research and intervention.

5.7 Suggestions for Future Research

Based on the findings and limitations of the current study, several suggestions are proposed for future research to further advance understanding of compliance with environmental safety standards in dental waste management.

First, future studies should extend the geographical scope to include dental clinics from different Libyan cities. Comparative analyses across regions would help determine whether the weaknesses identified in Zawia City are localized or reflect a broader national pattern. Such research would provide valuable evidence for the development of regionally tailored or nationally standardized interventions.

Second, future research should combine questionnaire data with direct observation of waste management practices within dental clinics. Observational methods can provide more objective and reliable evidence regarding actual segregation, storage, labeling, container use, and disposal procedures, thereby reducing the potential biases associated with self-reported data.

Third, further studies should examine the role of external regulatory inspection in improving compliance. This is particularly important because internal monitoring alone may be insufficient to ensure consistent application of environmental safety standards. Investigating the frequency, quality, and impact of external inspections would provide insights into the effectiveness of regulatory oversight mechanisms.

Fourth, future researchers should investigate the relationship between clinic management style and waste disposal compliance. Leadership, accountability structures, and decision-making processes may play a significant role in determining whether clinics implement and sustain proper waste management systems. Understanding these organizational dynamics would inform the development of targeted management interventions.

Fifth, qualitative studies involving dentists, dental assistants, clinic managers, and waste disposal service providers are recommended. In-depth interviews or focus group discussions could provide richer, more nuanced understanding of the practical barriers that prevent full compliance, including contextual, cultural, and operational challenges that quantitative surveys may not fully capture.

Sixth, future studies should examine the effectiveness of training programs using pre- and post-intervention designs. Such longitudinal evaluations would help determine whether structured training can produce measurable improvements in awareness, practices, and compliance over time, providing evidence for the scalability and sustainability of training initiatives.

Finally, future research should focus specifically on hazardous dental waste streams, including amalgam waste, chemical waste, sharps, and contaminated liquids. These categories require specialized handling and pose higher environmental and occupational risks. Investigating their management practices, disposal pathways, and associated challenges would contribute to the development of targeted safety protocols and regulatory frameworks.

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7 APPENDICES

7.1 Appendix 1: The Questionnaire

Evaluating Compliance with Environmental Safety Standards in Dental Clinic Waste Disposal

Quantitative Analysis of Challenges and Level of Compliance

Introduction

You are invited to participate in a research questionnaire about waste management practices in dental clinics, This questionnaire aims to understand current practices, challenges, and factors influencing compliance with environmental safety standards, Your participation is voluntary and anonymous, and your responses will be kept strictly confidential, Completing the questionnaire takes approximately 15 minutes, Thank you for your valuable contribution.

Part 1: Participant and Clinic Profile

Question	Response Options
1, Gender	☐ Male ☐ Female
2, Type of clinic	☐ Public ☐ Private
3, Practice pattern in the clinic	○ Solo practice ○ Group practice (2 to 5 dentists) ○ Large group or institutional practice (6 dentists or more) ○ Public health clinic or university clinic
4, Number of clinical staff (dentists, oral health specialists, assistants)	○ 1 to 5 ○ 6 to 10 ○ 11 to 20 ○ 21 or more
5, Your role in the clinic	○ Dentist or owner ○ Clinic or office manager ○ Oral health specialist ○ Dental assistant ○ Other, please specify: _____

Rating Scale for Parts 2 to 6

For each statement, please select one answer: Strongly Disagree, Disagree, Neutral, Agree, or Strongly Agree.

Part 2: Awareness and Knowledge

Statement	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
I am aware of specific Environmental Protection Agency regulations related to dental amalgam waste.	☐	☐	☐	☐	☐
I am aware of the Occupational Safety and Health Administration bloodborne pathogens standard related to sharps and regulated medical waste.	☐	☐	☐	☐	☐
I am aware of World Health Organization or national standards for dental clinic waste management.	☐	☐	☐	☐	☐
I regularly follow updates and changes in environmental health regulations.	☐	☐	☐	☐	☐
The clinic regularly informs staff about environmental laws and safety policies.	☐	☐	☐	☐	☐

What is your main source of information about waste disposal regulations? (You may select more than one option)

○ Local dental association ○ Continuing education courses ○ Waste disposal company
○ Colleagues and peers ○ Internet search ○ Other: _____

Part 3: Training and Protocols

Statement	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
I received formal training on waste management during the past months.	☐	☐	☐	☐	☐
The training content was practical and applicable to my work.	☐	☐	☐	☐	☐
Regular workshops or awareness sessions are held about waste safety.	☐	☐	☐	☐	☐
Guidelines or manuals for waste management are available in the clinic.	☐	☐	☐	☐	☐
The clinic has a written waste management plan or protocol that is easily accessible to all staff.	☐	☐	☐	☐	☐

1, Who receives formal training on waste segregation and disposal? (You may select more than one option)

○ Dentists ○ Oral health specialists ○ Dental assistants ○ Reception and administrative staff ○ Cleaning and service workers ○ No one

2, Frequency of waste management training:

○ Annually (according to requirements) ○ Only when new staff join ○ More than once a year ○ Only when problems occur or never

Part 4: Practices and Segregation Procedures

Statement	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
Hazardous and non-hazardous waste are properly separated inside the clinic.	☐	☐	☐	☐	☐
Color-coded containers are used for waste segregation.	☐	☐	☐	☐	☐
Chemical waste, such as mercury and disinfectants, is disposed of safely.	☐	☐	☐	☐	☐
Amalgam waste is collected, stored, and recycled through a licensed body.	☐	☐	☐	☐	☐
Contaminated fluids, such as blood and saliva, are handled safely.	☐	☐	☐	☐	☐
Regulated medical waste is disposed of in properly labeled biohazard bags or containers.	☐	☐	☐	☐	☐
Radiographic chemical waste is recycled or transferred by a licensed hazardous waste body.	☐	☐	☐	☐	☐

Part 5: Infrastructure and Facilities

Statement	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
Labeled and sufficient waste containers are available in every treatment room and processing area.	☐	☐	☐	☐	☐
Waste containers are replaced regularly to avoid overfilling.	☐	☐	☐	☐	☐
The clinic has a formal contract with a licensed waste disposal service.	☐	☐	☐	☐	☐
The clinic has a functioning amalgam separator.	☐	☐	☐	☐	☐

Part 6: Internal Monitoring Systems

Statement	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
Compliance with waste protocols is	☐	☐	☐	☐	☐

Statement	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
usually monitored internally.					
Violations are documented and corrective actions are taken.	☐	☐	☐	☐	☐
Formal audits or checklists are conducted by an assigned person.	☐	☐	☐	☐	☐
Self-monitoring is relied upon without inspections.	☐	☐	☐	☐	☐

Part 7: Challenges and Barriers

Please rate the extent to which the following factors are barriers to full compliance: 1 = Not a barrier, 2 = Minor barrier, 3 = Moderate barrier, 4 = Major barrier.

Factor	1	2	3	4
High cost of compliant waste disposal services.	☐	☐	☐	☐
Time pressure or shortage of staff.	☐	☐	☐	☐
Complexity of regulations.	☐	☐	☐	☐
Lack or obsolescence of equipment.	☐	☐	☐	☐
Lack of staff training or knowledge.	☐	☐	☐	☐
Inconsistency of practices among staff.	☐	☐	☐	☐
Absence of clear leadership or accountability.	☐	☐	☐	☐

What is the single biggest barrier to achieving full compliance?

Final Assessment

How do you rate your clinic's compliance with all safety and environmental regulations related to waste disposal?

○ Fully compliant

○ Mostly compliant (minor and infrequent issues)

○ Partially compliant (noticeable gaps in some aspects)

○ Non-compliant (major gaps in most aspects)

Thank you for taking the time to complete this questionnaire, Your valuable contribution is highly appreciated.

7.2 Appendix 2: Ethical Approval letter

المركز الليبي للبحوث الطبية
(Libyan Medical Research Center)

دولة ليبيا
الهيئة الليبية للبحث العلمي

اللجنة الفرعية للسلامة الحيوية والأخلاقيات البيولوجية
Biosafety and Bioethics committee

Ethical Approval Letter

NBC:018.H.24. 90

Project Title: Evaluating Of Compliance With Environmental Safety Standards In Dental Clinic Waste Disposal .

Dear : Osama Hasan Alkhadrawi .

According to the Libyan Medical Research Center Bioethics Committee meeting held on 4/ 2 /2026 to review ethical approval applications

We hereby inform you the following.

Application Approved without any modifications ☒

Application Rejected ☐

***If the application rejected, please indicate the reason and recommendation in the table bellow**

Reasons for rejection	
Recommendation	

Signed by Chairman of the Committee

Dr. Salah Bahroon .....

Date ...../...../2026