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Aim

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Original Article

The Accuracy of Different Modalities in the Diagnosis of Oral Intraosseous Lesions in Comparison to Histopathological Findings

Ayat A. Kadhim[*1], *Dena N. Mohammad*[1]

Abstract

Objective: The study aimed to compare the diagnostic accuracy of different imaging modalities for detecting intraosseous jaw lesions, using histopathological diagnosis as the reference standard, and to assess interobserver agreement in response to initial radiographic reports.

Methods: A total of 108 patients diagnosed with intraosseous jaw lesions were included. Radiographic images (Cone Beam Computed Tomography, Computed Tomography, and Orthopantomography) and reports with the related histopathological diagnosis were collected. Two radiologists, blinded to the histopathological results, reviewed the images using a (semiquantitative) scoring system. Kappa coefficients were calculated to evaluate interobserver agreement.

Results: The majority of lesions were radiolucent (79.6%), with cystic lesions (50.0%) being the most common, particularly radicular cysts (24.1%). Well-defined borders were predominant (62.0%). Most lesions were related to the inferior alveolar canal (IAC) (20.4%), followed by the maxillary sinus (11.1%). Both observers showed substantial agreement in response to the extension of the lesions and relation to the tooth (0.701 and 0.660, respectively). CBCT showed the highest diagnostic accuracy between the two observers in detecting score 3 of the differential diagnosis (81.8%), which represents a correct first-ranked differential diagnosis corresponding to the histopathological findings.

Conclusions: CBCT has the best accuracy in the diagnosis of intraosseous jaw lesions, particularly for lesions' density, anatomical extension, and relation to the tooth. Still, certain radiographic interpretation parameters showed non-agreement between observers. Evidence-based diagnosis and treatment planning require standardized reporting and proper interobserver training.

Keywords: *Cone Beam Computed Tomography, Diagnostic accuracy, Histopathological findings, Intraosseous jaw lesions.*

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Introduction

Imaging is a cornerstone in the diagnosis of oral intraosseous lesions, as it provides a comprehensive view of bone architecture, lesion characteristics, and implications for adjacent osseous and non-osseous structures, facilitating early identification, characterization, and distinction of lesions[1,2].

Orthopantomography (OPG) offers a cost-effective panoramic overview of the jaws and is used for initial screening of lesion location, size, and relation to teeth, although its two-dimensional projection limits assessment of borders, cortical expansion, and internal structure, with reported diagnostic accuracy of approximately 64-70% for the first differential diagnosis[3]. Also, Computed Tomography (CT), particularly multidetector CT, provides superior cross-sectional detail of lesion extent, cortical involvement, soft tissue extension, and multiplicity, and its diagnostic performance correlates with biopsy findings in about 80-90% of mandibular cases[4]. In addition, Cone Beam Computed Tomography (CBCT) further enhances dentomaxillofacial imaging by delivering high-resolution three-dimensional visualization of lesion morphology, cortical expansion, and neurovascular relationships, and generally outperforms OPG (accuracy around 78-79% versus 64-70%), although histopathological examination remains necessary to distinguish benign and malignant entities[5]. Furthermore, Ultrasound (US) represents a non-ionizing adjunct that helps differentiate cystic from solid lesions and assess vascularity using Doppler techniques, with reported correlation with histopathology of roughly 94% in cystic lesions, while magnetic resonance imaging (MRI) contributes additional information on marrow and soft-tissue involvement without ionizing radiation. Nevertheless, all these imaging techniques provide primarily descriptive information, and histopathological evaluation continues to be the gold standard for definitive diagnosis[6].

Accurate diagnosis of intraosseous jaw lesions is of great importance in dental and maxillofacial practice; these lesions range from reactive, cystic, to neoplastic, benign[7]. The evolution of imaging techniques for their recognition, characterization, and differentiation has therefore proceeded with the goal of clinical decision-making. As alternative imaging modalities in the maxillofacial region, Cone Beam Computed Tomography (CBCT) and Orthopantomography (OPG) are the two most commonly used techniques[5]. Ultrasonography (US), Computed Tomography (CT), and Magnetic Resonance Imaging (MRI), with or without Positron Emission Tomography (PET), are other techniques utilized in the detection and classification of intraosseous lesions[8].

CBCT has already been popularized for diagnostic purposes, owing to its high-resolution three-dimensional imaging. It is valuable for assessment of lesion size, cortical expansion, and associated structures; however, it can only partially differentiate between benign and malignant lesions[9,10]. CBCT can offer descriptive information related to the morphology of a lesion, but histopathological validation is more often necessary to arrive at a definitive diagnosis[11]. Therefore, CBCT has high accuracy in the detection and diagnosis of intraosseous jaw lesions, superior to OPG[5].

Ultrasound is considered a primary imaging alternative, non-expensive, that avoids ionizing radiation exposure, enabling the assessment of intraosseous jaw lesions. The utility of ultrasound in evaluating neck lesions is well established, especially for differentiating cystic from solid lesions, with Doppler ultrasound aiding assessment of vascularity. The study by Sidhu et al (2025) found that ultrasonography correlated with the histopathological findings, especially in cystic lesions, in which a definitive diagnosis was made in 93.8% of cases[12].

Magnetic Resonance Imaging (MRI) is an important imaging technique for the detection and characterization of intraosseous lesions, especially regarding the assessment of soft tissue involvement, marrow oedema, and vascularity. MRI is increasingly gaining importance in the evaluation of head and neck disease since it offers excellent contrast resolution without ionizing radiation[13]. It has an essential role in the differentiation of benign and malignant lesions, unlike computed tomography (CT) and cone-beam computed tomography (CBCT)[13].

This study aims to evaluate the diagnostic accuracy of CBCT, CT, and OPG for intraosseous jaw lesions using histopathology as the gold standard and to assess interobserver agreement related to original radiographic reports.

Patients and Methods

Sample of the Study

The digital files and original radiograph reports were collected from several private dental clinics and hospitals in Sulaimani City, Kurdistan Region, Iraq. Ethical approval was obtained from the College of Dentistry, University of Sulaimani (Approval No: COD-EC-24-0022, Date: 16 / 12 / 2024).

Digital radiographic files (DICOM format) and original reports were retrospectively collected from private dental clinics and hospitals in Sulaimani City, Kurdistan Region, Iraq. Inclusion criteria comprised patients with intraosseous jaw lesions confirmed by both radiographic imaging (CBCT, CT, or OPG) and corresponding histopathological reports. Exclusion criteria included poor image quality that precluded accurate diagnosis and cases in which imaging was performed for non-lesional indications. From an initial pool of 200 CBCT files, 123 were excluded, yielding 77 cases. Similarly, 70 CT files were screened, with 58 excluded due to incomplete data, leaving 13 cases. Additionally, 18 OPG cases met the inclusion criteria. This resulted in a final sample of 108 cases. Demographic data (age, sex, lesion site) and imaging modality were recorded, alongside original radiographic reports and histopathological diagnoses for comprehensive evaluation.

A comprehensive case sheet was created to standardize the evaluation of all radiographs. The following parameters were recorded: lesion density, borders, extent, shape, distribution, and localization. Additional observations encompassed the relationship of the lesion to adjacent structures, its impact on teeth and vital anatomical features, as well as cortical expansion and evidence of perforation.

Evaluation and Scoring

Two oral and maxillofacial radiologists independently reviewed the radiographic images, blind to the histopathological diagnosis. Each image was analyzed by Radiant Software and assessed according to the parameters outlined in the standardized case sheet. Each radiologist proposed up to three differential diagnoses for the observed radiological features, ranked in ordinal order. Diagnostic accuracy was then calculated in relation to the histopathological diagnosis using a scoring system: 3 points for a correct first-ranked diagnosis, 2 points for a correct second-ranked diagnosis, 1 point for a correct third-ranked diagnosis, and 0 points if none were correct[5].

Statistical Analysis

Data analysis was conducted using SPSS version 27, with descriptive statistics used for demographic and radiographic characteristics. Inter-observer agreement was quantified using Kappa coefficients (κ) to compare the diagnostic evaluations of two observers with the original reports. Kappa values were interpreted as follows: 0 = no agreement, 0.01–0.20 = slight, 0.21–0.40 = fair, 0.41–0.60 = moderate, 0.61–0.80 = substantial, and 0.81–1.00 = almost perfect. Diagnostic accuracy of each imaging modality was assessed by scoring from 0 to 3[5].

Results

The study sample included 108 patients, with a mean age of 32.18 ±17.97 years. Females slightly predominated (51.9%). The majority of the lesions were found in the mandible (56.5%) and on the left side (48.1%). The imaging modality showed CBCT in 77 cases (71.3%), CT in 13 cases (12.0%), and OPG in 18 cases (16.7%). Table 1.

The majority of lesions were radiolucent in appearance (79.6%). Regarding lesion borders, well-defined margins predominated (62 %), while ill-defined borders were recorded in 21 cases (19.4%), and 16 cases (14.8%) lacked border documentation. (Table 2, Figure 1a, b).

In terms of anatomical extension, 61 cases (56.5%) involved more than one region. Isolated involvement of the anterior region was observed in 18 cases (16.7%), posterior molar in 12 cases (11.1%), and premolar region in 7 cases (6.5%). The lesion shape was undocumented in the majority of cases (68.5%). Among those identified, irregular contours were most common (13%), followed by round shapes (7.4%). Assessment of lesion distribution revealed a predominance of unilateral presentation (79.6%), with bilateral involvement in 20 cases (18.5%). Regarding locularity, unilocular lesions were present in 28 cases (25.9%) and multilocular in 17 cases (15.7%), while 63 cases (58.3%) did not report this feature, as shown in Table 2 and Figures 1(c) and 1 (d).

The most frequently reported relationship to the tooth was apical involvement (42.6%), followed by coronal (13.0%). Root resorption was evident in 27 cases (25 %), Figure 1 (e). The root resorption was absent in 41 cases (38.0%), and the status was not mentioned in 35 cases (32.4%). Tooth displacement was noted in 23 cases (21.3%). Association with impacted teeth was reported in 18 cases (16.7%), and 33 cases were not documented. Regarding vital structures, the inferior alveolar canal (IAC) was most involved (20.4%), followed by the maxillary sinus (11.1%) and nasal cavity (6.5%). Involvement of the mental foramen and lingual foramen was minimal (1.9% each). Cortical expansion was reported in 58 cases (53.7%), Figure 1 (f, g), while cortical perforation was seen in 59 cases (54.6%), Figure 1 (h), Table 3.

Table 4 summarizes the agreement levels between observer 1 and the original radiographic report, observer 2 and the original report, and between the two observers, using kappa (κ) coefficients interpreted on a scale of “no agreement" (κ = 0) to "almost perfect" (κ = 0.81).

With respect to lesion density, agreement between observers 1 (κ = 0.553) and 2 (κ = 0.566) and the original report was moderate, and inter-observer agreement was substantial (κ = 0.801). Lesion extension also showed moderate agreement with the original report for observer 1 (κ = 0.448) and observer 2 (κ = 0.543), and substantial agreement between observers (κ = 0.701).

When examining the laterality of lesions (unilateral/bilateral), there was moderate agreement for observer 1 versus the original report (κ = 0.432), substantial agreement for observer 2 versus the original report (κ = 0.713), and moderate inter-observer agreement (κ = 0.571).

Several features showed no agreement between observer 1 and the original report (κ = 0.000) and between observers (κ = 0.000), including borders, shape, locularity, root resorption, tooth displacement, impacted tooth association, cortical expansion, and cortical perforation.

The relation to the tooth showed fair agreement with the original report for both observers (observer 1: κ = 0.254, observer 2: κ = 0.324) and substantial agreement between observers (κ = 0.660).

Cystic lesions comprised the predominant diagnostic category (50%). Within this group, radicular cysts were the most frequently detected (24.1%), followed by odontogenic keratocyst (12 %). Odontogenic tumors comprised 25.9%, with ameloblastoma being the predominant neoplasm (9.3%). Developmental odontogenic lesions were the least frequent category (1.9%), Table 5.

Of the 108 case evaluations, CBCT (n = 77) showed the highest total diagnostic accuracy for score 3 of differential diagnosis (81.8%). The second observer showed higher accuracy than the first observer (87.7 versus 77.9) in identifying score 3 of the differential diagnosis in the reports in Figure 2.

Table 1: Demographic and clinical characteristics of study participants.

Demographic and Clinical Characteristics		**N (%)**
Sex	Female	56 (51.9%)
	Male	52(48.1%)
Lesion location	Mandible	61 (56.5%)
	Maxilla	44 (40.7%)
	Both	3 (2.8%)
Lesion side	Right	40 (37.0%)
	Left	52 (48.1%)
	Both sides	16 (14.8%)
Imaging modality	CBCT	77 (71.3%)
	CT	13 (12.0%)
	OPG	18 (16.7%)

Abbreviations: % = percentage; n = number; CBCT = cone-beam computed tomography; CT = computed tomography; OPG = orthopantomogram (panoramic radiograph).

Table 2: Frequency distribution of radiographic characteristics in the lesion.

Radiographic Characteristics	N (%)	Radiographic Characteristics	N (%)
Density		**Border**	
Radiolucent	86 (79.6%)	Well-defined	67 (62.0%)
Radiopaque	5 (4.6%)	Ill define	21 (19.4%)
Mixed	12 (11.1%)	Both	4 (3.7%)
Not mentioned	5 (4.6%)	Not mentioned	16 (14.8%)
Extension		**Shape**	
Anterior	18 (16.7%)	Round	8 (7.4%)
Premolar region	7 (6.5%)	Oval	4 (3.7%)
Posterior molar region	12 (11.1%)	Irregular	14 (13.0%)
Maxillary tuberosity	1 (0.9%)	Scallop	5 (4.6%)
More than one	61 (56.5%)	Toothlike structure	3 (2.8%)
Not mentioned	9 (8.3%)	Not mentioned	74 (68.5%)
Site		**Number**	
Unilateral	86 (79.65)	Unilocular	28 (25.9%)
Bilateral	20 (18.5%)	Multilocular	17 (15.7%)
Not mentioned	2 (1.9%)	Not mentioned	63 (58.3%)

Abbreviations: % = percentage; N = number.

Table 3: Radiographic interpretations in relation to teeth, vital structures, and cortical involvement.

Interpretation parameters	N (%)	Interpretation parameters	N (%)
Relation to the tooth		**Root resorption**	
Apex	46 (42.6%)	Yes	27 (25.0%)
Coronal	14 (13.0%)	No	41 (38.0%)
Lateral	2 (1.9%)	No teeth	5 (4.6%)
Not related	7 (6.5%)	Not mentioned	35 (32.4%)
Not mentioned	39 (36.1%)		
Tooth displacement		**Association with an impacted tooth**	
Yes	23 (21.3%)	Associated	18 (16.7%)
No	27 (25.0%)	Not related	57 (52.8%)
No teeth	4 (3.7%)	Not mentioned	33 (30.6%)
Not mentioned	54 (50.0%)		
Effect on the vital structure		**Cortical expansion**	
IAC	22 (20.4%)	Present	58 (53.7%)
Mental foramen	2 (1.9%)	Absent	13 (12.0%)
Lingual foramen	2 (1.9%)	Not clear	18 (16.7%)
Maxillary sinus	12 (11.1%)	Not mentioned	19 (17.6%)
Nasal cavity	7 (6.5%)		
Incisive foramen	3 (2.8%)	**Cortical perforation**	
Not affected	17 (15.7%)	Present	59 (54.6%)
Hard palate	1 (0.9%)	Absent	19 (17.6%)
More than one	23 (21.3%)	Not clear	18 (16.7%)
Not mentioned	19 (17.6%)	Not mentioned	12 (11.1%)

Abbreviations: n = number; % = percentage; IAC = inferior alveolar canal. *The differential diagnosis was documented in 58 cases, accounting for 53.7% of the total, while in 50 cases, or 46.3%, it was not mentioned.

Table 4: Comparison of observer assessments with original reports' reliability using kappa coefficients.

Interpretation of the lesion	Observer 1 vs original report		Observer 2 vs original report		Observer 1 vs Observer 2	
	κ value	Strength of agreement	κ value	Strength of agreement	κ value	Strength of agreement
Density of the lesion	0.553	Moderate	0.566	Moderate	0.801	Substantial
Borders	0.00	No agreement	0.444	Moderate	0.00	No agreement
Extension of the lesion	0.448	Moderate	0.543	Moderate	0.701	Substantial
Lesion's shape	0.00	No agreement	0.165	Slight	0.00	No agreement
Unilateral/ Bilateral lesion	0.432	Moderate	0.713	Substantial	0.571	Moderate
Unilocular/Multilocular lesion	0.00	No agreement	0.093	Slight	0.00	No agreement
Relation to the tooth	0.254	Fair	0.324	Fair	0.660	Substantial
Root resorption	0.00	No agreement	0.192	Slight	0.00	No agreement
Tooth displacement	0.00	No agreement	0.192	Slight	0.00	No agreement
Association with an impacted tooth	0.00	No agreement	0.370	Fair	0.00	No agreement
Effect on the vital structure	0.419	Moderate	0.323	Fair	0.525	Moderate
Cortical expansion	0.00	No agreement	0.487	Moderate	0.00	No agreement
Cortical perforation	0.00	No agreement	0.586	Moderate	0.00	No agreement

Abbreviations: κ = kappa coefficient. Strength of agreement is interpreted as follows: 0: No agreement, 0.01–0.20: Slight, 0.21–0.40: Fair, 0.41–0.60: Moderate, 0.61–0.80: Substantial, 0.81–1.00: Almost perfect.

Table 5: Frequency distribution of diagnosed intraosseous jaw lesions across pathological categories.

Category	**Diagnosis**	**N (%)**
Cysts of the jaw **n=54 (50.0%)**	Dentigerous cyst	11 (10.2%)
	Odontogenic keratocyst (OKC)	13 (12.0%)
	Radicular cyst	26 (24.1%)
	Residual cyst	1 (0.9%)
	Lateral periodontal cyst	1 (0.9%)
	Nasopalatine duct cyst	1 (0.9%)
	Paradental cyst	1 (0.9%)
Odontogenic Tumors **n=24 (25.9%)**	Ameloblastoma	10 (9.3%)
	Adenomatoid odontogenic tumor	2 (1.9%)
	Calcifying epithelial odontogenic tumor (pindborg tumor)	2 (1.9%)
	Odontoma	4 (3.7%)
	Odontogenic Fibromyxoma	3 (2.8%)
	Central odontogenic fibroma	3 (2.8%)
Benign Non-Odontogenic Tumors **n=10 (9.3%)**	Central giant cell granuloma (CGCG)	3 (2.8%)
	Fibrous dysplasia	2 (1.9%)
	Juvenile Ossifying Fibroma	2 (1.9%)
	Osteoma	1 (0.9%)
	Cemento-ossifying fibroma	2 (1.9%)
Malignant lesions **n=10 (9.3%)**	Primary intraosseous carcinoma	1 (0.9%)
	Metastatic tumors to the jaw	2 (1.9%)
	Osteosarcoma	2 (1.9%)
	Ewing sarcoma	1 (0.9%)
	Multiple myeloma/plasmacytoma	3 (2.8%)
	Squamous cell carcinoma	1 (0.9%)
Inflammatory jaw lesions **n=5 (4.6%)**	Osteomyelitis	1 (0.9%)
	Actinomycosis	2 (1.9%)
	Periapical granuloma	2 (1.9%)
Salivary gland tumors **n=5 (4.6%)**	Pleomorphic adenoma	1 (0.9%)
	Mucoepidermoid carcinoma	2 (1.9%)
	Adenocystic carcinoma	2 (1.9%)
Developmental odontogenic lesions **n=2 (1.9%)**	Hyperplastic dental follicle	2 (1.9%)

Abbreviations: n = number; % = percentage; OK = odontogenic keratocyst; CGCG = central giant cell granuloma; OPG = orthopantomogram.

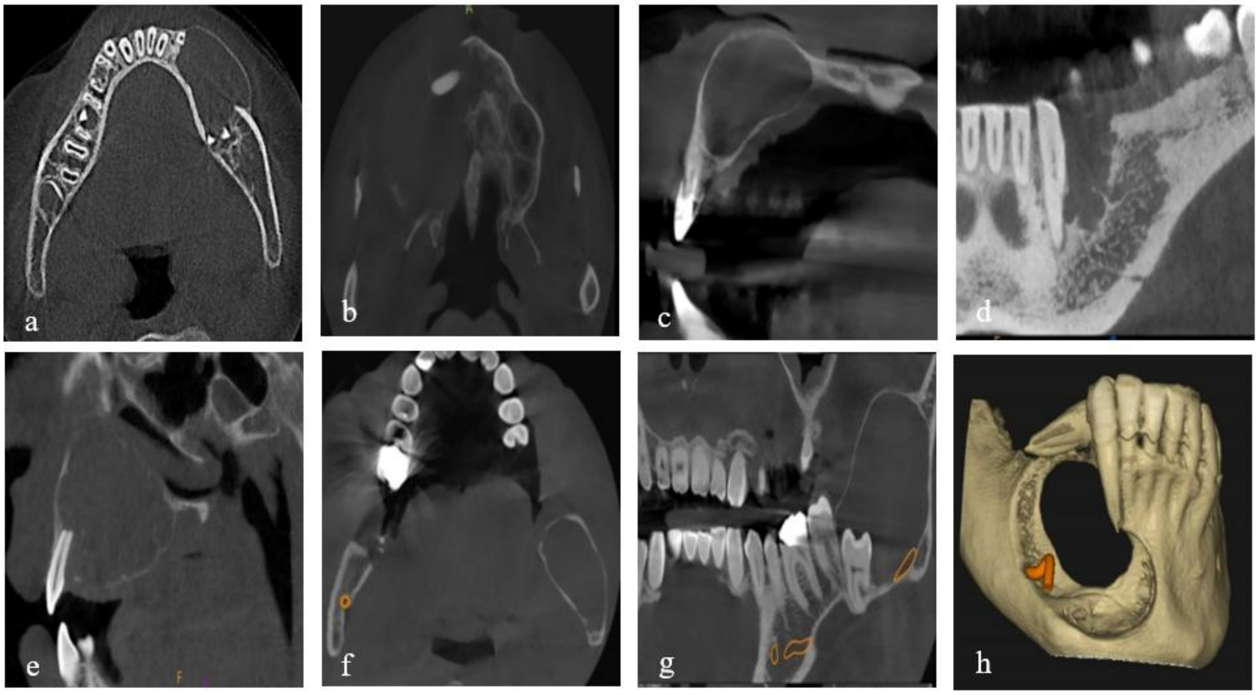

Figure 1: CBCT images depicting distinct jaw lesions with different characterization: (a) axial sections of a dentigerous cyst with well-defined borders, and (b) axial section of adenoid cystic carcinoma showing ill-defined margins. (c) sagittal views of a radicular cyst presenting a unilocular radiographic pattern; (d) coronal views of ameloblastoma exhibiting a characteristic multilocular appearance. (e) Demonstrates a sagittal view revealing apical root resorption associated with a radicular cyst. (f) axial and (g) coronal views with buccolingual expansion in a dentigerous cyst. Furthermore, image (h) shows a three-dimensional view of cortical perforation in fibromyxoma.

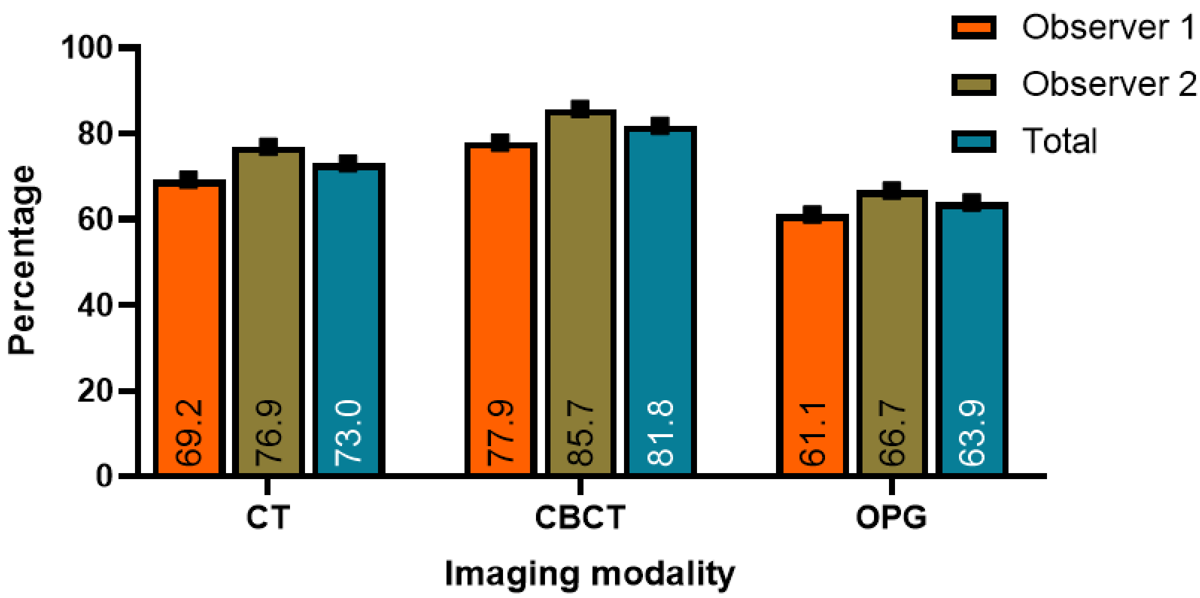

Figure 2. The accuracy of differential diagnosis (score 3) in response to the two radiologists.

Discussion

The evaluation of intraosseous jaw lesions requires an appropriate radiographic image modality to obtain comprehensive diagnostic information, which aids in planning an effective treatment strategy[5].

In the present study, mandibular lesions were more prevalent, accounting for 56.5% of the cases. This observation is consistent with the regional and international studies. A retrospective clinicopathological study conducted in Baghdad, Iraq, similarly reported a predominance of lesions in the mandible, particularly in the posterior regions[14]. Likewise, a recent cross-sectional study from Hail, Saudi Arabia, demonstrated greater involvement of the posterior mandibular region compared to the maxilla[15]. Furthermore, a large retrospective analysis of 1,121 intraosseous jaw lesions identified the mandible as the most frequently affected site[16].

Interestingly, lesions are more common in the mandible, but specific types of lesions, such as radicular cysts, occur more frequently in the maxilla. In this study, a total of 26 cases of radicular cysts were identified, of which 16 (61.5%) were detected in the maxilla. A study of Deshmukh et al (2014) supports this finding, reporting that the prevalence of radicular cysts in the maxilla is about 60% compared to the mandible[17], as also documented in prior CT-based studies[18].

A well-structured radiographic report not only distinguishes between benign, aggressive, and malignant lesions but also guides clinicians in making an accurate diagnosis and determining effective treatment plans. To achieve this, the radiologist should carefully describe the key features of the lesion including its location, size, borders, locularity, density, and the impact on surrounding structures[19,20].

The characterization of lesion borders remains a pivotal element in the radiologic assessment of intraosseous jaw pathologies, as it provides essential information regarding biological behavior and potential aggressiveness. The systematic review by Singh et al. demonstrated that lesions with well-defined, corticated margins are generally indicative of benign, slow-growing entities such as radicular or dentigerous cysts, whereas poorly defined or non-corticated borders suggest aggressive or malignant behavior[21].

In the present study, the borders were described in (85.1%) of reports, with a predominance of well-defined margins (62%), consistent with features typically associated with benign and less aggressive entities. By contrast, a CBCT-based investigation by Begum et al. (2025) reported that the majority of mandibular radiolucent lesions exhibited scalloped borders, indicating aggressive lesions (64%), while only 36% demonstrated smooth margins, referring to non-aggressive lesions[22].

Furthermore, the lack of documentation of border characterization in 16 cases (14.8%) in this study highlights a limitation of routine radiographic reporting in predicting lesion aggressiveness, which potentially influences the subsequent treatment planning.

The locularity of lesions is another fundamental radiographic criterion that should be documented in the radiographic report[20].

Multilocular patterns are frequently associated with aggressive lesions, whereas unilocular lesions are more often indicative of odontogenic cysts[23]. However, as emphasized by the systematic review by Zaghden et al., the locularity alone is not pathognomonic, as they highlighted that unilocular lesions, although commonly cystic in origin, can also represent neoplastic processes, thus creating diagnostic overlap and uncertainty when locularity is interpreted in isolation. Therefore, while locularity remains a key radiographic parameter, it must always be assessed in conjunction with other imaging features and clinical findings[24].

In the present study, unilocular lesions were more predominant (28 cases, 25.9%), of which cystic lesions were more prominent (17/28, 60.7 %), specifically showing radicular and keratocyst. Notably, in 63 cases (58.3%), locularity was not documented in the radiographic reports, representing a significant reporting gap given its diagnostic relevance, reinforcing the importance of interpreting locularity alongside other imaging and clinical features.

Evaluating root resorption offers valuable insight into the aggressiveness of a lesion and its potential impact on adjacent teeth. Although root resorption is not a consistent feature of all intraosseous jaw lesions, it is more frequently associated with ameloblastoma and central giant cell granulomas, whereas it is less commonly observed in dentigerous and radicular cysts[20].

Sueyoshi et al. demonstrated that ameloblastoma had significantly higher rates of root resorption compared to OKCs, dentigerous cysts, and simple bone cysts using the CT imaging modality[25]. Whereas Nair et al. reported root resorption in only 1 of 28 OKC cases on CBCT and panoramic imaging[26].

Moreover, a study involving 132 cases of unicystic ameloblastoma revealed that root resorption along with cortical and soft tissue invasion was significantly correlated with an increased risk of disease recurrence[27].

In this study, root resorption was documented in 27 cases (25.0%), including cystic lesions such as radicular cysts and tumors like ameloblastoma, though exact per-lesion rates were not stratified due to sample size. Initial reports omitted it in 35 cases (32.4%), but re-evaluation identified it in 9 cases (Observer 1) and 3 cases (Observer 2), highlighting interobserver variability that may stem from subjective interpretation influenced by experience and training. This pattern aligns with Sueyoshi et al. (2025), who demonstrated significantly higher root resorption rates in ameloblastomas compared to odontogenic keratocysts, dentigerous cysts, and simple bone cysts on CT imaging[25].

Vital anatomical landmarks are essential not only for maintaining sensory integrity but also for preserving a patient's overall quality of life. Their involvement may significantly affect both the patient’s clinical presentation and the complexity of the required treatment. For instance, displacement or compression of the inferior alveolar canal (IAC) can result in paresthesia or anesthesia of the affected area. Invasion of the maxillary sinus or nasal cavity may give rise to oroantral communication, chronic sinusitis, and surgical complications[1].

In this study, most reported cases involved the IAC, followed by the maxillary sinus. Lu Ru et al. described a rare dentigerous cyst encircling the inferior alveolar nerve, underscoring the frequent displacement of the IAC in mandibular odontogenic lesions[28]. Similarly, Shahad A. Waheed et al. conducted a clinicopathological analysis of maxillary odontogenic cysts and tumors, confirming that extension into the maxillary sinus is a common finding[29].

Cortical expansion and cortical perforation reflect the aggressive biological behavior of many intraosseous jaw lesions. In this study, the interpretation of radiographic reports in relation to histological findings revealed that (53.7%) of cases with cortical expansion and (54.6%) with cortical perforations were consistent with odontogenic cysts. These findings are consistent with the study by Meng et al., who reported a high prevalence of cortical expansion in radicular cysts assessed using CBCT and CT imaging[30].

In the present study, the substantial inter-observer agreement regarding lesion density indicates that this parameter is highly reproducible, thereby reinforcing its reliability in diagnostic assessment. Still, both lesion extensions and tooth relations showed substantial agreement; another study by Mao et al. reported substantial agreement in shape, border, cortical thickness, internal density, and tooth displacement. Notably, they found moderate agreement for the extension of the lesions and their relation to the teeth. This difference might be due to differences in sample size, multicenter-based study, imaging modalities, interpretation of the same case with two modalities simultaneously, and the diagnostic expertise of the investigators[5].

In the current study, cystic lesions were the most common diagnosis category, with radicular cysts accounting for nearly a quarter of all cases. This finding was consistent with the work of Nainani and Sidhu, who reported radicular cysts represent 52-68% of jaw cysts[31].

In the current study, odontogenic OKCs accounted for 12% and showed unilocular, well-defined borders, as they are the most prevalent diagnostic category. This is in accordance with the findings of Borghesi et al., who described OKCs (10%) as radiolucent lesions, most commonly unilocular and well-defined[32].

Furthermore, most imaging modalities utilized in this study were CBCT (71.3%), which can serve as an alternative to CT in dental practice, by providing detailed diagnostic information through high-resolution, three-dimensional imaging, while maintaining relatively low radiation exposure and cost for patients[33].

In the current study, CBCT demonstrated superior diagnostic accuracy (81.8% score 3 differential diagnosis), with Observer 2 (87.7%) outperforming Observer 1 (77.9%; interobserver variability noted), likely attributable to differences in observer experience and subjective judgment during image analysis. These findings align with Mao et al., who reported CBCT first-diagnosis accuracy of 78.7% (both observers) compared with (64.4-70.2%) for panoramic radiograph in 225 lesions, attributing superiority to better visualization of borders, density, and structures, consistent with the kappa agreements observed in the present study[5]. Likewise, Kadhim's study emphasized CBCT's precise lesion boundary and anatomical relation in comparison with two-dimensional imaging, which is in agreement with the findings of the present study, despite their focus on radiopaque/mixed lesions versus our predominantly radiolucent (79.6%) sample; minor differences may stem from our larger cohort (108 cases versus 20) and the histopathological gold standard[34].

Conclusion

The highest diagnostic performance was achieved by CBCT, especially in identifying the correct differential diagnosis. Interestingly, benign cystic lesions were predominant. Still, reporting of radiographic features using qualitative categories varied between observers, reflecting the need for standardized reporting, technical, and training improvements for the radiologists.

Declarations

Ethics Approval and Informed Consent (Institutional Review Board) Statement: This research was approved by the Ethics Committee of the College of Dentistry, University of Sulaimani, Iraq, under application No. (COD-EC-24-0022), Issued on 16/12/2024. Informed consent statement: Written informed consent was obtained from all participants prior to their inclusion in the study.

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References

1. Choi, WJ, Lee P, Thomas PC, Rath TJ, Mogensen MA, Dalley RW, et al. Imaging approach for jaw and maxillofacial bone tumors with updates from the 2022 world health organization classification. World J Radiol. 2024;16(8):294.
2. Fuoad, SaA, Mohammad DN, Hamied MA, Garib BT. Oro-facial malignancy in north of iraq: A retrospective study of biopsied cases. BMC Oral Health. 2021;21(1):147.
3. Stera, G, Giusti M, Magnini A, Calistri L, Izzetti R, Nardi C. Diagnostic accuracy of periapical radiography and panoramic radiography in the detection of apical periodontitis: A systematic review and meta-analysis. La radiologia medica. 2024;129(11):1682-95.
4. Gill, N, Meena V, Shivkumar. Diagnostic accuracy of CT and MRI for mandibular invasion in oral cavity carcinoma: A histopathology-correlated study using brown's and mcgregor's criteria. Eur Arch Otorhinolaryngol. 2026;283(1):425-32.
5. Mao, W-Y, Lei J, Lim LZ, Gao Y, Tyndall DA, Fu K. Comparison of radiographical characteristics and diagnostic accuracy of intraosseous jaw lesions on panoramic radiographs and CBCT. Dentomaxillofacial Radiol. 2021;50(2):20200165.
6. Dedeoğlu, N, Duman Ş B, Altun O, Arıkan B. In vitro comparison of cone beam computed tomography and ultrasonography imaging methods in the evaluation of artificial mandible intraosseous lesions. J Dent (Shiraz). 2021;22(3):198-205. doi:10.30476/dentjods.2021.87481.1264/
7. Salim, G, Mohammed D, Garib B. Prevalence of oral maxillofacial lesions in major histopathological centers in Sulaimani city. Sulaimani Dent J. 2021;8:1-9.
8. Shetty, SR, Al Bayatti SW, Marei H, Shetty R, Abdelmagyd HA, Luke AM. Cone-beam computed tomography characterization of the intraosseous vascular canal in the lateral wall of the maxillary antrum. J Korean Assoc Oral Maxillofac Surg. 2021;47(1):34-39.
9. De Lima Dias-Junior, LC, De Souza DL, Bezerra AP, Correa M, Da Silveira Teixeira C, Bortoluzzi EA, et al. Exploring diagnostic reliability of CBCT for vertical root fractures: A systematic review and meta-analytical approach. Int J Dent. 2025;2025(1):8824867.
10. Al Amin, N, Farook TH, Oscandar F, Abdullah MF, Ibrahim NB, Eusufzai SZ, et al. The diagnostic accuracy of cone-beam computed tomography for assessing in vitro osseous alterations of the mandibular condyle: A systematic review and meta-analysis. Oral Radiol. 2025:1-11.
11. Bayrakdar, IS, Yilmaz AB, Caglayan F, Ertas U, Gundogdu C, Gumussoy I. Cone beam computed tomography and ultrasonography imaging of benign intraosseous jaw lesion: A

prospective radiopathological study. Clin Oral Investig. 2018;22:1531-39.
12. Sidhu, VK, Nath S, Debbarma H, Lahiri B, Amin R, Chakraborty S. Evaluation of the efficiency of ultrasonography and color doppler in diagnosis of intraosseous jaw lesions: An in vivo study. J Contemp Dent Pract. 2025;25(10):963-67.
13. Soluk-Tekkesin, M, Sinanoglu A, Selvi F, Karabas HC, Aksakalli N. The importance of clinical and radiological findings for the definitive histopathologic diagnosis of benign fibro-osseous lesions of the jaws: Study of 276 cases. J Stomatol Oral Maxillofac Surg. 2022;123(3):364-71.
14. Al-Qazzaz, HH, Abdulllah BH, Museedi OS. Clinicopathological analysis of odontogenic cysts in iraqi population. J Med Chem Sci. 2023;6(4):891-7.
15. Elnaem, IS, Alanazi Y, Alghris AM, Alenzi LH, Aldkhayel GD. Prevalence of radiolucent and radiopaque jawbone lesions using panoramic radiographic analysis in hail, Saudi Arabia: A retrospective, cross-sectional, observational study. Cureus. 2024;16(9):e69533.
16. Jaafari-Ashkavandi, Z, Akbari B. Clinicopathologic study of intra- osseous lesions of the jaws in southern iranian population. J Dent. 2017;18(4):259-64.
17. Deshmukh J, Shrivastava R, Bharath KP, Mallikarjuna R. Giant radicular cyst of the maxilla. BMJ Case Rep. 2014;2014:bcr2014203678.
18. Sukegawa, S, Matsuzaki H, Katase N, Kawai H, Kanno T, Asaumi JI, et al. Morphological characteristics of radicular cysts using computed tomography. Odontology. 2020;108(1):74-83.
19. Taylor, HH, Huffman HS, Parker KG, Morris RW. Top 10 facts to know about bone lesions identified on radiographs. J Miss State Med Assoc. 2024;65(9/10).
20. White, SC, Pharoah MJ. Oral radiology: Principles and interpretation. 8 ed: Elsevier 2019.
21. Singh, HP, Chahal GK, Sharma G, Gandhi P. A systematic review on odontogenic cysts and tumours. J Oral Maxillofac Pathol. 2024;28(2):268-74.
22. Begum, R, Malik R, Gupta K, Kaur P, Bhat M, Garg I, et al. Quantitative assessment of bone density at the borders of radiolucent mandibular lesions using cone-beam computed tomography: Correlations with lesion aggressiveness. Cureus. 2025;17(6):e86111.
23. Kumar, J, Vanagundi R, Manchanda A, Mohanty S, Meher R. Radiolucent jaw lesions: Imaging approach. Indian J Radiol Imaging. 2021;31(01):224-36.
24. Zaghden, O, Debré T, Nguyen TH, Duong L, Ferré F. The use of magnetic resonance imaging in the diagnosis of unilocular radiolucent images of the jawbone: A systematic review of the literature. J Oral Med Oral Surg. 2024;30(3):37.
25. Sueyoshi, T, Sameshima J, Kaneko N, Chikui T, Chen H, Yokomizo S, et al. Comparison of computed tomographic findings for radiolucent lesions of the mandibular ameloblastoma, odontogenic keratocyst, dentigerous cyst, and simple bone cyst. J Dent Sci. 2025;20(1):605-12.
26. Nair, AK, Lamees F, Sreela L. Imaging characteristics of odontogenic keratocysts: A retrospective radiographic study. J Indian Acad Oral Med Radiol. 2024;36(3):269-73.
27. Yang, R, Lin X, Zhang W, Gokavarapu S, Lin C, Ren Z, et al. Unicystic ameloblastoma: A retrospective study on recurrent factors from a single institute database. Oral Dis. 2024;30(3):1475-82.
28. Ru, L, Ding S, Zou B. Impacted mandibular first molar with root encircling the inferior alveolar nerve and an odontogenic cyst formation. BMC Oral Health. 2025;25(1):1022.
29. Waheed, SA, Zaidan TF, Abdullah BH. Odontogenic cysts and tumors of maxilla and maxillary sinus (a clinicopathological analysis). J Baghdad Coll Dent. 2021;33(4):38-43.
30. Meng, Y, Zhang LQ, Zhao YN, Liu DG, Zhang ZY, Gao Y. [three-dimentional radiographic features of 67 maxillary radicular cysts]. Beijing Da Xue Xue Bao Yi Xue Ban. 2021;53(2):396-401. doi:10.19723/j.issn.1671-167X.2021.02.027/
31. Nainani, P, Sidhu GK. Radicular cyst–an update with emphasis on pathogenesis. J Adv Med Dent Scie Res. 2014;2(3):97-101.
32. Borghesi, A, Nardi C, Giannitto C, Tironi A, Maroldi R, Di Bartolomeo F, et al. Odontogenic keratocyst: Imaging features of a benign lesion with an aggressive behaviour. Insights Imaging. 2018;9(5):883-97.
33. Zaman, MU. Comparing radiation doses in cbct and medical CT imaging for dental

applications. J Pharm Bioallied Sci. 2024;16(Suppl 1):S883-5.
34. Kadhim, SS. Cbct in imaging radiopaque and mixed lesions of the jaw. Osol J Med Sci. 2023;1(1):36-42.

Original Article

The Pulpal Response to Posterior Bite Raisers: A Prospective Study of Material and Height Effect

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Abstract

Objective: Posterior bite raisers (PBRs) induce temporary posterior disocclusion during fixed orthodontic treatment but may affect pulp vitality under prolonged occlusal load. Objective: To compare pulpal responses to injectable nanohybrid composite PBRs and resin-modified glass ionomer cement (RMGIC) PBRs at two heights (1–2 mm; >2–4 mm) in relation to gender and age.

Methods: Eighty patients (16- 40 years old, with a mean age of 22.9 ± 5.7 years and an equal male-to-female ratio were assigned to four groups according to the material and height of PBRs, with twenty patients in each group. Cold testing and electric pulp testing (EPT) were documented at baseline, 1 week, 1 month, 2 months, and 3 months. The outcomes were divided into two groups: sensibility (positive or negative), and the differences among the four groups were compared in relation to gender and age.

Results: At 3 months, negative pulpal responses were observed only in the composite groups: >2–4 mm (15%) and 1–2 mm (5%). Material choice was the strongest independent predictor of EPT threshold change (P=0.008), with the composite associated with significantly decreased responsiveness. The interaction between material and height was highly significant (p=0.012), indicating a fivefold higher risk of negative sensibility responses with high-volume composite than with RMGIC. Younger patients showed greater susceptibility to pulpal changes (p=0.03).

Conclusions: Composite PBRs, particularly at heights exceeding 2 mm, are associated with increased pulpal stress, whereas RMGIC demonstrates superior pulpal stability and is recommended for initial orthodontic phases to minimize adverse biological effects.

Keywords: *Nanohybrid Composite, Posterior Bite Raisers, Pulp Sensibility, Resin-Modified Glass Ionomer Cement.*

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Introduction

Posterior bite raisers (PBRs) are widely used during fixed orthodontic therapy to achieve posterior disocclusion, reduce occlusal interferences, and facilitate tooth movement. However, concentrating occlusal forces on a limited number of teeth may affect pulpal microcirculation, vascular integrity, and neural response[1]. Previous studies have demonstrated that orthodontic forces alone can alter pulpal blood flow, provoke reversible inflammatory responses, and modify sensitivity thresholds[2,3].

Furthermore, pulpal hemodynamics may become more vulnerable when orthodontic loading is combined with direct occlusal forces applied through bite-raising appliances[4]. The biological response of the pulp to functional or orthodontic stress is influenced not only by the magnitude and duration of force but also by the properties of the material through which the force is transmitted. Composite resin, commonly used for PBR fabrication, exhibits a relatively high elastic modulus, enabling occlusal loads to be transmitted more directly to underlying tooth structures[5].

Rigid materials such as composites have been associated with increased pulpal strain under functional or orthodontic loading[6,7]. In contrast, resin-modified glass ionomer cement (RMGIC) demonstrates a lower modulus of elasticity and superior stress-absorbing characteristics due to its polyalkenoate matrix reinforced with light-activated resin components. This hybrid composition has been shown to reduce load concentration and attenuate stress transmitted to dentin–pulp tissues when used in clinical settings[8].

Riser height also represents a critical mechanical and biological variable. Increasing the vertical dimension concentrates occlusal force distribution and can lead to greater pulpal strain. Higher bite blocks have been associated with altered sensitivity, discomfort, and temporary pulpal changes in orthodontic patients[9]. In addition, patient-related factors, particularly age and gender, may influence pulpal reactivity. Younger individuals generally exhibit larger pulp chambers, greater vascularity, and heightened metabolic activity, making their pulpal tissues more responsive to mechanical stimuli[10-14].

Previous research using laser Doppler flowmetry has confirmed that younger pulps exhibit greater reductions in pulpal blood flow following orthodontic force application than in adults[15]. Although gender-related differences in pain perception and neural threshold have been reported, their clinical relevance in orthodontic bite-raising procedures remains unclear[15,16]. Diagnostic tools such as cold testing and electric pulp testing (EPT) remain essential for evaluating pulpal status during orthodontic treatment.

These methods have demonstrated high reliability and diagnostic validity in assessing pulpal vitality and differentiating transient pulpal alterations from irreversible changes[1,17]. Using a combination of sensibility tests is recommended, particularly when occlusal loading may influence pulpal responsiveness[18-20].

While the impact of orthodontic forces on pulpal blood flow is documented, there is limited clinical data comparing the biological response of the pulp to different PBR materials under varying vertical dimensions. Specifically, the interaction between the high elastic modulus of composite resins and the stress-dampening properties of RMGIC at different clinical heights remains poorly understood. Furthermore, the influence of patient-related factors such as age and gender on these specific mechanical challenges has not been fully elucidated. The aim of this prospective clinical study was to compare pulpal responses to posterior bite risers (PBRs) made from composite resin and resin-modified glass ionomer cement (RMGIC) at two different vertical heights (1–2 mm and >2–4 mm) using cold testing and electric pulp testing (EPT). A secondary aim was to evaluate the influence of age and gender on vitality outcomes following the application of PBRs during fixed orthodontic treatment.

The null hypothesis stated that there is no significant difference in pulpal vitality outcomes between teeth treated with composite PBRs and those treated with RMGIC PBRs. Vertical height of the PBR (1–2 mm vs. >2–4 mm) has no effect on pulpal vitality or EPT threshold changes. Furthermore, age and gender have no influence on pulpal response following the application of PBRs.

Patients and Methods

This prospective stratified randomized clinical study included 80 participants (16-40) years old with a mean age of 22.9 ± 5.7 years and an equal male-to-female ratio from 126 screened patients (IOTN 2 and 3) requiring posterior bite risers (PBRs) as part of fixed orthodontic treatment as shown in the Consort flow diagram (Figure 1). The study was conducted in a private dental center in Sulaimani, between July 2025 and December 2025." Universal injectable nanohybrid composite (GC G-ænial (GC, Japan)) and RMGIC (GC Fuji Ortho Band, Japan) were used for the fabrication of PBRs on mandibular 1st molars (Fig. 2). Patients were divided into four equal groups (n = 20 each): 1. Composite PBR, 1–2 mm 2. Composite PBR, >2–4 mm 3. RMGIC PBR, 1–2 mm 4. RMGIC PBR, >2–4 mm. Randomization was carried out using a computer-generated sequence, and allocation was concealed in sealed envelopes to minimize selection bias. All PBRs were placed on the mandibular first molars following standard bonding protocols. A periodontal probe was used to verify riser height, and adjustments were made to achieve the desired disocclusion.

Randomization

Following the screening process, participants were enrolled and assigned to groups via stratified randomization to balance groups by gender and riser height. This approach resulted in equal numbers of males and females in each group (1:1 ratio), minimizing potential confounding effects of gender on pulpal response outcomes. Participants were assigned to raiser height groups based on their pre-existing clinical needs to (1-2 mm) or (>2-4 mm) subgroups, and only the material was randomized. The material (Composite vs RMGIC) was assigned using a computer-generated sequence, and allocation was concealed in sealed envelopes to minimize selection bias. The envelopes were opened only by a dental assistant during the procedure to assign participants to their respective groups. While the operators were not blinded due to material characteristics, the primary outcome was assessed using objective instrumental measurements (Electric Pulp Test). The data analyst was successfully blinded to the group allocation. The primary data were coded (e.g., Group 1, 2, 3, 4) by the principal investigator before being transferred to the statistician for analysis. The group identities were revealed only after the statistical modelling was completed.

Pulp Sensibility Testing

Two diagnostic tests were used to evaluate pulpal response: first, the cold test, performed with ethyl chloride spray. An absence of response after repeated stimuli suggested loss of sensibility. Second test: Electric Pulp Testing (EPT) with a digital electric pulp tester (Digitest II, Parkell Inc., USA) used to measure sensibility thresholds. The lowest numerical reading at which the patient responded was recorded as the EPT value (10-13). The diagnostic value of combining cold test and EPT has been well established, improving accuracy in distinguishing vital from non-vital pulps[21,22]. Testing intervals included: Baseline, 1 week, 1 month, 2 months, and 3 months.

Pulpal status was assessed using standardized and validated sensibility tests, consisting of cold testing with ethyl chloride and electric pulp testing (EPT). For the cold test, a cotton pellet saturated with refrigerant spray (Hygenic Endo-Ice) was applied to the mid-buccal surface for up to 5 seconds. A positive response was recorded when the patient reported a sharp, transient sensation that was resolved immediately upon removal. A negative response was defined as the absence of sensation after two consecutive applications separated by 1 minute. For the EPT assessment, the electrode was placed on the mid-buccal surface, gingival to the buccal tube, with toothpaste as a conducting medium. The numerical value at which the patient first perceived a tingling sensation was recorded as the EPT threshold. All readings were documented duplicate to ensure reliability, and the lower value was used for analysis.

Diagnosis of non-vital pulp required both no response to the cold test, confirmed by repeating the test twice; and no response at maximum output on EPT (80 reading), repeated twice to exclude false-negative results due to anxiety, thick enamel, or temporary neural suppression. To avoid misdiagnosis, teeth that initially showed no response were retested after 1 week, as orthodontic forces and occlusal loading may cause temporary sensory suppression. Only teeth that showed a consistent lack of response in both tests and at two separate appointments were classified as non-vital.

Bite raiser height measurement

Patients were first categorized into two strata (1–2 mm or >2–4 mm) based on the vertical clearance required to unlock the malocclusion or prevent bracket interference. Then, the incremental application of the chosen material (Nanohybrid Composite or RMGIC) was applied to the mid-occlusal surface of the mandibular first molars. The material was built up incrementally to reach the target height. A calibrated periodontal probe was used to measure the vertical height of the material from the deepest part of the central fossa to the highest point of the riser.

To ensure the height was functionally accurate, articulating paper and calibrated shim stock were used to confirm bilateral simultaneous contact. This ensured that the vertical dimension was uniform and that the patient did not have an unstable or deflected path of closure.

Inclusion and Exclusion Criteria

To minimize confounding variables, the following criteria were applied:

Inclusion criteria

- Patients with orthodontic treatment need (IOTN 2 and 3)
- Permanent mandibular first molars
- Healthy teeth with no restorations or ongoing pulpal pathology

Exclusion criteria

- Age below 16 years
- Extensive restorations
- Systemic diseases affecting pulpal physiology
- Trauma history
- Pre-existing non-vital teeth
- Patients with 'short-face' morphology (brachyfacial) and those with existing deep bites were excluded to prevent molar intrusion.

Ethical Approval

Ethical approval was obtained from the College of Dentistry, University of Sulaimani on 11/08/2025 (no. 320/25). The study was conducted in strict accordance with the Declaration of Helsinki and local ethical guidelines. Informed consent was collected from all participants.

Statistical Analysis

All analyses were performed using SPSS version 26.0, with significance set at $P < 0.05$. Descriptive statistics summarized the data. Fisher's Exact test was used to evaluate differences in positive and negative outcomes among groups. To evaluate changes in pulpal sensibility thresholds over the five-time intervals (Baseline, 1 week, 1 month, 2 months, and 3 months), a Repeated Measures ANOVA, Multivariable Linear Regression for factors influencing 3-month EPT change, and a Generalized Linear Mixed Model for factors influencing pulpal sensibility were conducted.

Sample size calculation

Sample size was determined by power analysis using G*Power version 3.1.9.7 (α = 0.05, power = 80%), based on Abtahi et al. (2016), we targeted a large effect size (f=0.40), assuming a 10-unit difference in EPT Digitest II scores and a standard deviation of 12[23]. This yielded 18 participants per subgroup; increased to 20 to account for 10% attrition, giving a total of 80 participants (n=80, 20 per group).

Examiner Calibration and Reliability Testing

To ensure consistency and repeatability of measurements, the examiner performing all pulp sensibility tests underwent a calibration process prior to data collection. Calibration consisted of performing cold and EPT tests on 10 orthodontic patients not included in the study sample, followed by comparison of repeated readings taken 1 week apart. Intra-examiner reliability was assessed using the intra-class correlation coefficient (ICC) for EPT threshold values and Cohen's Kappa for categorical cold-test outcomes (vital vs. non-vital). The ICC for EPT readings was 0.91, indicating excellent reliability, while the Kappa coefficient for cold-test responses was 0.88, demonstrating strong agreement. During the study period, 10% of randomly selected participants were re-examined at the same appointment to verify consistency, and no significant differences were noted between the first and second recordings. Regarding PBR height measurements, to ensure intra-operator reliability, the primary investigator performed duplicate measurements for the first 10 participants, achieving an Intraclass Correlation Coefficient (ICC) of 0.92, indicating excellent consistency.

Results

Intra-examiner reliability was assessed using the intra-class correlation coefficient (ICC) for EPT threshold values and Cohen's Kappa for categorical cold-test outcomes (vital vs. non-vital). The ICCs for EPT readings and PBR measurements were 0.91 and 0.92, respectively, indicating excellent reliability, while the Kappa coefficient for cold-test responses was 0.88, demonstrating strong agreement.

Demographic characteristics of the study groups are summarized in Table 1. At the 3-month evaluation, negative responses to cold tests were observed in the composite PBR groups: composite 1–2 mm, 1/20 (5%); composite >2–4 mm, 3/20 (15%), as illustrated in Table 2. In contrast, no cases of negative responses were recorded in either RMGIC group. The Fisher's exact test showed no statistical differences between groups ($P>0.05$).

The repeated measures ANOVA revealed significant changes in pulpal sensibility thresholds over the 3-month study period (Table 3). The composite PBR (1–2 mm) showed a statistically significant change over time ($P=0.012$). A significant drop occurred at 2 months, followed by a slight recovery by the third month.

The composite PBR (>2–4 mm) group showed a significant longitudinal change ($p < 0.00$). EPT values decreased progressively from the baseline to their lowest point in 2 months. Although a minor increase was noted in 3 months, the overall decline from baseline remained substantial.

RMGIC PBR (1–2 mm) group demonstrated the highest level of pulpal stability ($p = 0.584$) with no statistically significant deviation.

RMGIC PBR >2–4 mm group showed a minor but statistically significant change over time ($P=0.042$). The thresholds remained relatively stable compared to the composite groups, though a gradual decline was noted from baseline to 3 months.

A multivariable linear regression analysis was performed to identify independent predictors of change in the 3-month EPT threshold while controlling for clinical and demographic covariates (Table 4). Material choice was identified as the strongest independent predictor, with the use of composite associated with a significant decrease in pulpal responsiveness compared to RMGIC (P=0.008). Furthermore, riser height significantly influenced the outcome (P = 0.012), confirming that vertical disarticulation exceeding 2 mm independently contributes to reduced pulpal responses. Among the demographic factors, Age was a significant covariate (P=0.03), indicating that older participants exhibited slightly higher baseline resistance to electrical stimulation, whereas gender did not significantly influence the sensory outcome (P=0.16).

Based on the Generalized Linear Mixed Model in Table 5, the results demonstrate that pulpal sensibility is significantly influenced by the PBR material (P=0.032). While the independent effect of riser height was not statistically significant on its own (P = 0.108), the material-by-height interaction was highly significant (P = 0.012), indicating that the risk of a negative sensibility response is over five times higher when high-volume composite is used compared to RMGIC. Furthermore, the significant interaction between material and time (P=0.015) confirms that this divergent response between materials becomes progressively more pronounced as orthodontic treatment continues.

Table 1: Demographic characteristics by groups.

Group	N(%)	Age (mean ± SD)
Composite 1-2 mm	20 (25%)	21.4 ± 4.1
Composite >2–4 mm	20 (25%)	23.1± 6.2
RMGIC 1-2 mm	20 (25%)	22.8 ± 3.9
RMGIC >2–4 mm	20 (25%)	24.2 ± 7.5
Total	80 (100%)	22.9 ± 5.7

Table 2: Cold test response at 3 months by group (Positive / Negative; n, %) using Fisher's Exact test.

Group	Positive n (%)	Negative n (%)	Total n (%)	P-value
Composite 1-2 mm	19 (95%)	1 (5%)	20 (100%)	P=0.115
Composite >2–4 mm	17 (85%)	3 (15%)	20 (100%)	
RMGIC 1-2 mm	20 (100%)	0 (0%)	20 (100%)	
RMGIC >2–4 mm	20 (100%)	0 (0%)	20 (100%)	
Total	76 (95%)	4 (5%)	80 (100%)	

Table 3: Electric pulp test (EPT) thresholds (mean ± SD) with Repeated Measure ANOVA.

Group	Baseline	1 week	1 month	2 months	3 months	P-value
Composite1-2 mm	44.1 ± 3.1	44.7 ± 2.8	42.8± 6.3	36.0 ± 15.4	39.4 ± 14.7	0.012
Composite >2–4 mm	43.8 ± 2.9	44.1 ± 3.2	41.6± 7.3	31.2 ± 17.9	34.2 ± 16.3	<0.001
RMGIC 1-2 mm	44.5 ± 2.7	44.6 ± 2.4	43.9 ± 4.3	43.9± 4.8	43.1 ± 3.1	0.584
RMGIC >2–4 mm	45.1± 2.1	44.7 ± 1.9	44.4 ± 2.6	43.3 ± 5.1	40.6 ± 5.7	0.042

Table 4: Multivariable Linear Regression for factors influencing 3-month EPT change (n=80).

Variable	β coefficient	95% CI Lower	95% CI Upper	p-value
Material (Composite, RMGIC)	-6.2	-10.1	-2.3	0.008
Height (1–2 mm, 2–4 mm)	-4.8	-8.5	-1.1	0.012
Age (Year)	0.3	0.03	0.57	0.03
Gender (Male, Female)	-0.25	-6.1	1.1	0.16

Table 5: Generalized Linear Mixed Model for factors influencing pulpal sensibility.

Variable	Odds Ratio	95% CI Lower	95% CI Upper	p-value
Material (Composite, RMGIC)	4.35	1.14	16.38	0.032
Height (1–2 mm, 2–4 mm)	2.95	0.81	10.72	0.108
Time (month)	1.9	0.9	3.95	0.09
Material × Height	5.16	1.44	18.5	0.012
Material × Time	3.2	1.2	8.2	0.015
Height × Time	2.12	0.85	5.3	0.11

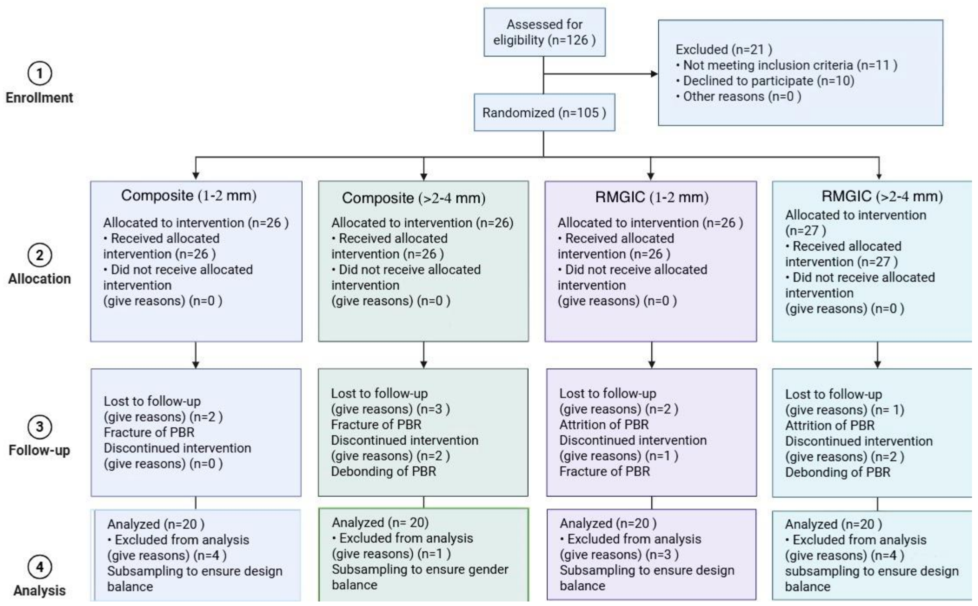

Figure 1: CONSORT Flow Diagram of the study

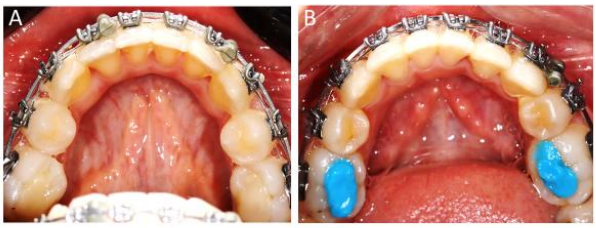

Figure 2: Posterior bite risers (PBRs) A: Composite, B: Resin modified glass ionomer cement.

Discussion

Orthodontic forces naturally influence pulpal blood flow and neural activity, and adding posterior bite risers further concentrates biomechanical loading on individual teeth. In orthodontics, shifts in pulpal sensibility are considered biotracers that reflect tissue adaptation to mechanical stress. Material differences also play a role: composite resin, with its higher stiffness, transmits occlusal forces more directly to enamel and dentin, whereas RMGIC forms a chemical bond with enamel and dissipates stress more effectively. These combined biomechanical and material factors help explain the differing pulpal responses observed in this study[24-26].

The findings of this study demonstrate that composite posterior bite risers (PBRs) were associated with a higher incidence of negative pulpal responses compared with resin-modified glass ionomer cement (RMGIC). Similar patterns have been reported in studies evaluating occlusal load concentration and pulpal outcomes in orthodontic patients[27]. This difference was especially pronounced when riser height exceeded 2 mm. These results underscore the importance of material rigidity and vertical elevation in determining the magnitude of occlusal load transmitted to the pulp[28]. The results of this study support the use of RMGIC over composite resin when designing PBRs, particularly in cases requiring higher elevations.

Composite resin, owing to its relatively high elastic modulus, tends to transmit occlusal forces more directly to the underlying dentin–pulp complex. Under conditions of continuous orthodontic loading, this may increase pulpal strain, leading to reversible or even irreversible changes in pulpal physiology[29]. In contrast, RMGIC demonstrates a lower elastic modulus and superior capacity for stress absorption. Its hybrid structure, combining polyalkenoate chemistry with resin reinforcement, allows it to dissipate forces more effectively and reduce pulpal stress, which may account for the absence of non-vital responses in the RMGIC groups[30-32].

The EPT findings further support these biomechanical differences. Composite groups exhibited progressive reductions in EPT thresholds at 2 and 3 months, reflecting altered neural responsiveness under increased load transmission. Conversely, RMGIC groups maintained stable EPT readings, suggesting minimal irritation of pulpal tissues. These results correlate with earlier reports describing reduced pulpal inflammation and neural disruption when stress-dampening materials are used during orthodontic therapy[33].

A significant association between age and pulpal outcomes was observed, with younger patients demonstrating greater susceptibility to negative pulpal responses. This pattern conforms with previous studies showing that younger pulps, with larger vascular networks, exhibit greater reactivity to mechanical and orthodontic stimuli[19]. RMGIC appears to provide a more favorable biomechanical environment by reducing pulpal stress and minimizing unintended biological consequences. Clinicians should also carefully evaluate patient age and selectively monitor pulpal responses using validated diagnostic tools.

This is consistent with histological evidence indicating that young pulps possess larger vascular networks and heightened metabolic activity, making them more reactive to mechanical stresses[34]. Such findings highlight the need for conservative design choices such as using RMGIC or minimizing riser height when treating younger orthodontic patients. Although gender differences were not statistically significant, all negative pulpal responses occurred in females. Gender-related differences in pain perception, neural threshold, and vascular responsiveness have been documented in the literature[24]. While the present findings may partly reflect sampling distribution, they suggest that clinicians should remain aware of potential sex-related variability in pulpal reactivity.

The recovery of vitality in some teeth between the 2-month and 3-month assessments suggests that many pulpal changes induced by PBRs and orthodontic forces are transient rather than permanent, consistent with the stress-dampening properties of the material[35]. This highlights the importance of serial pulp testing with cold and EPT tests throughout orthodontic treatment.

To maximize experimental control and standardize occlusal loading, this study isolated the intervention to the mandibular first molars. While distributing posterior bite risers (PBR) to the second molars could theoretically dissipate localized stress, our focused design eliminated the confounding anatomical and mechanical variables associated with multi-tooth loading. Furthermore, limiting the PBR to the first molars served as a preventative measure against the risk of second molar super-eruption, which could occur if these units are left out of active occlusion for extended periods. Although these findings provide high-precision baseline data for the first molar, future research is warranted to determine if these pulpal response patterns remain consistent across different dental units or more complex occlusal configurations where forces are distributed more broadly.

Another limitation of this clinical trial was the inability to achieve true double-blinding. Due to the distinct handling characteristics, curing protocols, and optical properties of Composite versus RMGIC, both the operator and the participants could potentially identify the material used. However, the reliance on objective instrumental data (Electric Pulp Testing) provides an additional layer of protection against the influence of unblinded observations.

Another limitation involves the inherent nature of Electric Pulp Testing (EPT). Although the EPT is an objective instrumental measure of sensory nerve response, it assesses pulpal sensibility (innervation) rather than vitality (blood flow). Consequently, transient changes in EPT thresholds may reflect neurophysiological adaptations to pressure rather than true pathological changes in pulpal health. Future studies incorporating Laser Doppler Flowmetry could provide a more comprehensive assessment by monitoring real-time pulpal microcirculation alongside sensory thresholds.

While the 3-month longitudinal follow-up provided sufficient data to observe the acute and subacute pulpal responses to bite-riser application, it may not capture long-term reparative dentin formation or chronic pulpal changes. Extended observation periods could provide additional insight into the pulp status following the removal of occlusal interference.

Conclusion

The study confirms that both the type of material and the vertical height of posterior bite raisers play a significant role in influencing pulpal sensibility. Composite materials, particularly at greater thicknesses, tend to have a more pronounced effect on pulpal response compared to RMGIC. Additionally, pulpal stress appears to increase progressively over the course of orthodontic treatment. Therefore, the use of RMGIC at a conservative height is advisable during the initial leveling and aligning phase to help minimize potential adverse pulpal effects.

Declarations

Ethics Approval and Informed Consent (Institutional Review Board) Statement: Ethical approval was obtained from the Ethics Committee, College of Dentistry-University of Sulaimani, on August 11, 2025 (no. 320/25). Informed consent was collected from all participants.

Author Contributions: AJA: methodology; DSA: software; AJA: validation; Formal analysis: DSA; investigation: AJA; resources: AJA; data curation: DSA; writing—original draft preparation: AJA; writing review and editing: LB; visualization: LB; supervision: AJA; project administration: AJA; funding acquisition: DSA. All authors have read and approved the published version of the manuscript.

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References

1. Alattas MH. Pulp changes secondary to orthodontic forces: a comprehensive review. Cureus. 2023;15(6):e40176.
2. Scherer I, Tzanetakis GN, Eliades T, Koletsi D. Changes in the pulp tissue complex induced by orthodontic force: a clinical study. Int J Environ Res Public Health. 2022;19:14079.
3. Wang CW, Wang KL, Ho KH, Hsieh SC, Chang HM. Dental Pulp Response to Orthodontic Tooth Movement. Taiwan J Orthod.2017; 29(4):204-12.
4. Moga RA, Olteanu CD, Delean AG. The effect of larger orthodontic forces and movement types over a dental pulp and neurovascular bundle of lower premolars in intact periodontium-A numerical analysis. Dent J (Basel). 2024 14;12(10):328.
5. Beatty MW, Pidaparti RM. Elastic and fracture properties of dental direct filling materials. Biomaterials. 1993; 14(13):999-02.
6. Silvestrini-Biavati F, Abate A, Kola E, Grecolini ME, Lanteri V, Ugolini A. Anterior vs. posterior bite raisers: assessment of quality of life and pain experience. Children. 2025;12(8):1040.
7. Vitali FC, Cardoso IV, Mello FW, Flores-Mir C, Andrada AC, Dutra-Horstmann KL, et.al. Effect of orthodontic force on dental pulp histomorphology and tissue factor expression. Angle Orthod. 2021;91(6):830-42.
8. Rabelo K, Ellakwa A. Mechanical properties of a resin-modified glass-ionomer cement reinforced with short-glass fiber flowable resin composites. Am J Dent. 2023;36(4):177-82.
9. Raisan NQ. Bite Raisers in Orthodontics: A review. Mustansiriya Dent J. 2022;18(2),318-36.
10. Petersson K, Söderström C, Kiani-Anaraki M, Lévy G. Evaluation of the ability of thermal and electrical tests to register pulp vitality. Endod Dent Traumatol. 1999;15(3):127-31.
11. Jespersen JJ, Hellstein J, Williamson A, Johnson WT, Qian F. Evaluation of dental pulp sensibility tests in a clinical setting. J Endod. 2014;40(3):351-4.
12. Weisleder R, Yamauchi S, Caplan DJ, Trope M, Teixeira FB. The validity of pulp testing: a clinical study. J Am Dent Assoc. 2009;140(8):1013-7.
13. Pigg M, Nixdorf DR, Nguyen RH, Law AS; National dental practice-based research network collaborative group. validity of preoperative clinical findings to identify dental pulp status: a national dental practice-based research network study. J Endod. 2016;42(6):935-42.
14. Huokuna J, Loimaranta V, Laine MA, Svedström-Oristo AL. Adverse effects of orthodontic forces on dental pulp. Appearance and character. A systematic review. Acta Odontol Scand. 2023;81(4):267-77.
15. Parashos P. The orthodontic-endodontic interface: trauma and pulpal considerations. Br Dent J. 2024;237(5):389-97.
16. Caviedes-Bucheli J, Azuero-Holguin MM, Correa-Ortiz JA, Aguilar-Mora MV, Pedroza-Flores JD, Ulate E, et.al. Effect of experimentally induced occlusal trauma on substance p expression in human dental pulp and periodontal ligament. J Endod. 2011;37(5):627-30.
17. Uppalapati V, Onteru P, Mathew T, Sandhu NS, Dutta SD, Nanda J, et al. The impact of the gender on the pulp vitality testing for the various types of the conducting media: An original research. J Pharm Bioallied Sci. 2024 ;16(Suppl 1):S168-S170.
18. Salles AW, Salles AM, Nogueira GE. Laser doppler blood-flow signals from human teeth during an alignment and leveling movement using a superelastic archwire. ISRN Dent. 2013 ;19;2013:102816.
19. Han G, Hu M, Zhang Y, Jiang H. Pulp vitality and histologic changes in human dental pulp after the application of moderate and severe intrusive

orthodontic forces. Am J Orthod Dentofacial Orthop. 2013;144(4):518-22.

20. Sidhu SK, Nicholson JW. A Review of glass-ionomer cements for clinical dentistry. J Funct Biomater. 2016;7(3):16.
21. Al-Manei KK, Alzaidi S, Almalki G, Al-Manei K, Almotairy N. Incidence and influential factors in pulp necrosis and periapical pathosis following indirect restorations: a systematic review and meta-analysis. BMC Oral Health. 2023;23(1):195.
22. Verma RK, Verma S, Singh SP, Kumar V, Rajagopalan A, Subbaiah NK, et.al. Volumetric pulpal changes in permanent first molars following AdvanSyncTM and Twin Block functional appliance: A CBCT study. J Orthod Sci. 2025;25;14:1.
23. Abtahi M, Eslami N, Abadi RZ, Rezaei SP. The effect of intrusive orthodontic force on dental pulp of adults versus adolescents. Dent Res J (Isfahan). 2016;13(4):367-72.
24. Abu Alhaija ESJ, Al-Abdallah SY, Taha NA. A comparative study of initial changes in pulpal blood flow between clear aligners and fixed orthodontic appliances. Am J Orthod Dentofacial Orthop. 2019;156(5):603-10.
25. Golež A, Ovsenik M, Cankar K. Evaluation of pulpal blood flow during orthodontic space closure: Prospective clinical trial. Am J Orthod Dentofacial Orthop. 2024;166(6):549-60.
26. Xie D, Brantley WA, Culbertson BM, Wang G. Mechanical properties and microstructures of glass-ionomer cements. Dent Mater. 2000;16(2):129-38.
27. Ganeshapooban D, Shahid S, Stefanova V, Todorova V. Comparison of the compressive strength of conventional and resin-modified glass ionomer cements. J IMAB. 2024;30(4):5840-44.
28. Malhotra S, Bhullar KK, Kaur S, Malhotra M, Kaur R, Handa A. Comparative evaluation of compressive strength and flexural strength of gc gold hybrid, gic conventional and resin-modified glass-ionomer cement. J Pharm Bioallied Sci. 2022;14:S214-16.
29. Pfeifer CS, Ferracane JL, Sakaguchi RL. *Craig's restorative dental materials*. 15th ed. St Louis: Elsevier; 2025. p.74.
30. Noori AJ. Kreem FA. Setting time, mechanical and adhesive properties of magnesium oxide nanoparticles modified glass-ionomer cement; J Mater Res Technol. 2020;9(2):1809-18.
31. Mhammed GA, Faraj BM, Abdalrahim RH, Mahmood MA. Effect of different bonded base materials on the fracture resistance and failure mode of complex cavity of endodontically treated premolars: An in vitro study. Sulaimani Dent J. 2016;3(1):45-51.
32. Fields HW, Larson B, Sarver DM, Proffit WR. Contemporary Orthodontics. 7th ed. St Louis: Elsevier; 2025. 388 p.
33. Jafarzadeh H, Abbott PV. Review of pulp sensibility tests. Part II: electric pulp tests and test cavities. Int Endod J. 2010;43(11):945-58.
34. Proulx C, Dumais Y, Beauchamp G, Steagall P. Reliability of electric pulp test, cold pulp test or tooth transillumination to assess pulpal health in permanent dog teeth. J Vet Dent. 2022;39(2):133-41.
35. Von Böhl M, Ren Y, Fudalej PS, Kuijpers-Jagtman AM. Pulpal reactions to orthodontic force application in humans: a systematic review. J Endod. 2012;38(11):1463-9.

Original Article

Prevalence of Carious and Non-Carious Cervical Lesions in Teeth with Gingival Recession

Milan K. Fatah [*1], *Harem J. Hamarasheed*[1]

Abstract

Objective: The essential objective of this research was to explore the association between gingival recession (GR) and both carious (CCL) and non-carious cervical lesions (NCCLs), encompassing abrasion, erosion, and abfraction, and to evaluate their association with selected mechanical and demographic factors.

Methods: A total of 69 males and females between the ages of 18 and 80 participated in this cross-sectional observational study. From October 2023 to March 2024, these individuals were enrolled in the University of Sulaimani's College of Dentistry. They frequently visited the periodontics department to receive periodontal treatments. The presence of CCLs and NCCLs was clinically assessed in 410 teeth with GR. Negative binomial regression, Spearman's correlation, and non-parametric tests were used to analyze the data.

Results: Of the 69 patients with gingival recession (GR), 81.2% were aged 30–60 years, with a median of 4 affected teeth per patient. Incorrect brushing was reported by 94.2%. GR severity was not significantly associated with age, gender, brush stiffness, or brushing method. GR was significantly associated with non-carious lesions ($p = 0.022$) and abrasion ($p = 0.001$), but not erosion ($p = 0.063$). Hard toothbrush use showed a non-significant increase in GR count (IRR = 1.30, $p = 0.489$).

Conclusions: In this study the gingival recession was commonly associated with cervical lesions. Age and gender were not significantly related to GR, while hard toothbrush users were expected to have a 30% higher GR count, though not significant. GR was significantly linked to non-carious lesions, particularly abrasion.

Keywords: *Gingival recession, Carious cervical lesions, Non-carious cervical lesions, Prevalence, Cross-sectional study.*

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Introduction

Gingival recession (GR) has been defined by the apical displacement of the marginal gingiva in relation to the cementoenamel junction (CEJ), which results in root surface exposure and a loss of the periodontal attachment apparatus[1]. GR is associated with clinical attachment loss and may present as either localized or generalized. Its development and progression are influenced by a wide range of factors that can be broadly categorized into anatomical, physiological, and pathological groups[2,3].

Anatomical factors include alveolar bone dehiscence and abnormal tooth positioning. Physiological contributors include orthodontic treatment, the use of partial dentures, abrasive or traumatic toothbrushing, intra- or perioral piercings, and sub-gingivally placed dental restorations. Pathological factors include tooth mobility, plaque and calculus accumulation, periodontal disease, pathogenic damage, tobacco use, particularly smoking, and occlusal trauma. Socio-demographic factors, gingival phenotype, and mechanical trauma are also significant risk factors for GR[4-9]. The prevalence, severity, and extent of GR can vary significantly among individuals and populations[10].

Noncarious cervical lesions (NCCLs), characterized by loss of tooth structure at the CEJ, often on the buccal surfaces, are commonly associated with GR[11]. The exact etiology of NCCLs has not been precisely defined; however, there is broad agreement among researchers that the cause of this kind of defect may be multifactorial and thus difficult to identify[12].

Senna et al.[13] reported a prevalence of NCCLs ranging from 0.8% to 85.7%, with the mandibular first premolars appearing to be the most highly impacted teeth[14]. Risk factors associated with NCCLs included thin gingival phenotype, inadequate keratinized tissue width, poor oral hygiene (as reflected by higher Plaque Index and Gingival Index scores), and increased occlusal wear[15-18]. Other risk factors, such as age, gender, gastric reflux, soft drinks, alcohol consumption, and citrus fruits, were also observed in different studies to be correlated with NCCLs[19-22].

Cervical carious lesions (CCLs) present similarly but are primarily of infectious origin, typically affecting dentin below the CEJ and diagnosed through visual and tactile examination[23-25].

Although GR, NCCLs, and CCLs have been extensively studied, most research has examined these conditions in isolation, and there is limited information on their co-occurrence and associated risk factors in specific populations. Furthermore, prevalence and lesion patterns may vary with socio-demographic characteristics, oral hygiene practices, dietary habits, and access to dental care.

To date, no cross-sectional epidemiological studies have investigated the prevalence of CCLs and NCCLs in patients with GR among the Kurdish population attending the College of Dentistry. This knowledge gap limits clinicians' ability to develop targeted preventive and management strategies for this group.

Therefore, this study aims to determine the relationship between gingival recession, CCLs, and NCCLs (including abrasion, erosion, and abfraction), and to identify associated risk factors and lesion distribution patterns. Findings from this study are expected to inform early diagnosis, prevention, and clinical management of cervical lesions in patients with GR.

Patients and Methods

Sample description

This study included a sample of 69 participants (both males and females) aged 18- 80 years. They were attending the College of Dentistry from October 2023 to March 2024. The volunteers were usually regular attendees visiting the periodontics department for periodontal treatments. Ethical approval No. 55 for the study was granted by the relevant institutional committee, and informed consent was obtained from each participant before data collection began.

For the purposes of analysis, the subjects were categorized into three groups based on the presence and type of cervical lesions in teeth with GR: Group 1 (GR only): Participants with GR without any cervical or root surface lesions. Group 2 (GR with NCCLs): Participants with GR in teeth exhibiting non-carious cervical lesions (NCCLs), such as abrasion, abfraction, and erosion. Group 3 (GR with CCLs): Participants with GR in teeth showing carious cervical lesions (CCLs) affecting the cervical or root surfaces.

Participants presenting with both NCCLs and CCLs in teeth with GR were classified in Group 3, due to the greater clinical significance of carious lesions. The severity of gingival recession in each tooth was measured in millimeters from the cementoenamel junction to the free gingival margin using a periodontal probe and recorded for all affected teeth. This allowed for quantitative assessment of the depth of recession across the dentition.

The frequency of GR in specific teeth was also recorded to identify which teeth were most affected, enabling analysis of tooth-specific patterns and lesion distribution.

The limited recruitment period and strict eligibility criteria resulted in a relatively small sample size, which may affect the generalizability of the findings. Future multicenter studies with longer recruitment periods and larger samples are recommended.

Clinical parameters

CCL and NCCLs/root lesions were identified through clinical examination under adequate lighting. CCLs were diagnosed based on: The presence of softened dentin or enamel at the cervical or root surface; discoloration (brown or black), often with cavitation; a tactile stick with a sharp probe indicating demineralization or loss of structure[26]; lesions consistent with bacterial decay, confirmed by probing and visual assessment.

NCCLs were diagnosed based on hard tissue loss at the cervical region not associated with caries, smooth hard surfaces with no softness or stickiness, V-shaped notches (abrasion/abfraction), shallow concavities (erosion), and absence of discoloration or carious softness. Correlation with brushing habits, occlusal stress, or dietary acids as per patient history[27-29].

Photographic documentation was not included in the study protocol. Therefore, lesion identification and classification were based exclusively on standardized visual and tactile clinical criteria performed by trained examiners to ensure diagnostic consistency and reliability.

The inclusion criteria focused on patients with GR, while the exclusion criteria included: third molar teeth, periodontal health status, History of orthodontic treatment, Systemic diseases, Medications affecting the Gingiva, and Smoking. The materials used were a dental mirror, a dental explorer, and a questionnaire form.

Examiner Calibration

To guarantee uniformity and standardization in clinical evaluation and data recording, the study supervisor led a calibration training session for all examiners prior to the start of the study. Reviewing the diagnostic standards for GR, CCLs, and NCCLs was part of the calibration procedure. Standardized training on the evaluation and scoring of the gingival index (Mühllemann & Son, 1971) and plaque index (Silness and Löe, 1964) was conducted. To align clinical scoring and interpretation, volunteer patients participated in practice sessions[42,43].

During the calibration phase, a subset of 10 patients was evaluated independently by each examiner to assess inter-examiner reliability. Two statistical techniques were used to determine examiner agreement: the intraclass correlation coefficient (ICC) for continuous outcome scores and Cohen's kappa statistics for categorical data. Before data collection began, all examiners met or exceeded the acceptable reliability thresholds, with kappa>0.80 and ICC >0.85.

Statistical Analysis

To ensure confidentiality, each participant's case sheet was given an identity number for statistical analysis. All variables were properly coded prior to data entry. For analysis, the data were first entered into IBM SPSS Statistics for Windows, Version 25.0 (IBM Corp., Armonk, NY, USA). The Chi-square test and the Negative Binomial Regression were employed. When the p-value was less than 0.05, the results were deemed statistically significant.

Results

Demographic Characteristics

A total of 69 patients were included in this analysis. The study population was nearly evenly distributed between genders, with 34 females (49.3%) and 35 males (50.7%). Most participants (n = 56, 81.2%) were in the 30–60-year age group. Regarding oral hygiene habits, 94.2% (n = 65) reported using an incorrect brushing method (Table 1). The overall median number of teeth with GR per patient was 4.0 (IQR: 2.0–7.0).

Association Between GR Severity and Risk Factors

There was no significant association between gender and GR severity ($\chi^2 = 12.795$, $p = 0.618$), although males showed a slightly higher median GR count (Median = 5.0) compared to females (Median = 4.0).

Similarly, while the >60 years group demonstrated a higher median GR count (Median = 6.0) than the younger age groups (Median = 4.0), the difference across age categories was not statistically significant ($\chi^2 = 25.729$, $p = 0.689$).

Brush stiffness was not significantly associated with GR severity ($\chi^2 = 29.527$, $p = 0.964$), despite a higher median among hard brush users (Median = 5.5). Likewise, brushing method showed no significant association with GR severity ($\chi^2 = 12.016$, $p = 0.999$) (Table 2).

Association Between GR and Other Dental Lesions

Chi-square analysis demonstrated a significant association between GR and non-carious lesions (χ^2 =

7.604, df = 2, p = 0.022; Cramer's V = 0.330), indicating a moderate association. A stronger significant association was observed between GR and abrasion (χ^2 = 13.113, df = 2, p = 0.001; Cramer's V = 0.433).

However, the association between GR and erosion was not statistically significant (χ^2 = 5.537, df = 2, p = 0.063) (Table 3).

Regression Analysis of Risk Factors

A Negative Binomial regression model was constructed to assess predictors of GR count.

Using the 30–60 years age group, female gender, soft brush stiffness, and correct brushing method as reference categories, none of the predictors showed a statistically significant association with GR count. Hard toothbrush use was associated with an IRR of 1.30 (95% CI: 0.62–2.74, p = 0.489), indicating a 30% higher expected GR count compared with soft-brush users; however, this was not statistically significant. Similarly, age group, gender, and brushing method were not significant predictors in the adjusted model (Table 4).

Table 1: Demographic distribution of the sample.

Variable	Category	Frequency (n)	Percentage (%)
Total Sample		69	100.00%
Gender	Female	34	49.30%
	Male	35	50.70%
Age Group	< 30 years	6	8.70%
	30–60 years	56	81.20%
	> 60 years	7	10.10%
Brush Stiffness	Soft	29	42.00%
	Medium	28	40.60%
	Hard	12	17.40%
Brushing technique	Wrong	65	94.20%
	Correct	4	5.80%
Main Habit	Bruxism	29	42.00%
	Mouth breathing	15	21.70%
	Smoking	8	11.60%
	Trauma	5	7.20%
	Other*	12	17.40%

*Lip piercing, Pencil biting, Biting.

Table 2: Assessment of GR severity according to risk factors.

Variable	Category	N	Median Number of Teeth with GR	Interquartile Range (25th–75th)	Chi-Square test	P-value
Gender	Female	34	4	2.0 – 6.0	12.795	0.618
	Male	35	5	3.0 – 9.0		
Age Group	< 30 years	6	4	1.8 – 4.0	25.729	0.689
	30–60 years	56	4	2.0 – 8.3		
	> 60 years	7	6	4.5 – 9.5		
Brush Stiffness	Soft	29	4	2.0 – 7.0	29.527	0.964
	Medium	28	4	2.8 – 6.0		
	Hard	12	5.5	2.8 – 10.0		
Brushing Method	Correct	4	4	3.3 – 6.0	12.016	0.999
	Wrong	65	4	2.0 – 7.0		

Table 3: Chi-square test showing the relationship between GR and Other Dental Lesions.

Outcome Variable	Chi-Square Value	df	p-value	Cramer's V	Interpretation
Non-caries Lesion Positive	7.604	2	**.022**	.330	**Significant** (Moderate association)
Abrasion Positive	13.113	2	**.001**	.433	**Significant** (Moderate-strong association)
Erosion Positive	5.537	2	.063	.281	Not Significant

* Correlation is significant at the 0.05 level.

Table 4: Negative Binomial Regression Model for Predictors of Gingival Recession.

Predictor	Category	Incidence Rate Ratio (IRR)	95% Confidence Interval	P-value
Age Group	30–60 Years	Reference*	—	—
	< 30 Years	0.56	0.20 – 1.57	0.27
	> 60 Years	1.4	0.60 – 3.25	0.436
Gender	Female	Reference	—	—
	Male	1.28	0.76 – 2.16	0.35
Brush Stiffness	Soft	Reference	—	—
	Medium	1.03	0.58 – 1.84	0.915
	Hard	1.3	0.62 – 2.74	0.489
Brushing Method	Correct	Reference	—	—
	Wrong	0.86	0.25 – 2.89	0.803

*Used as a reference for prediction.

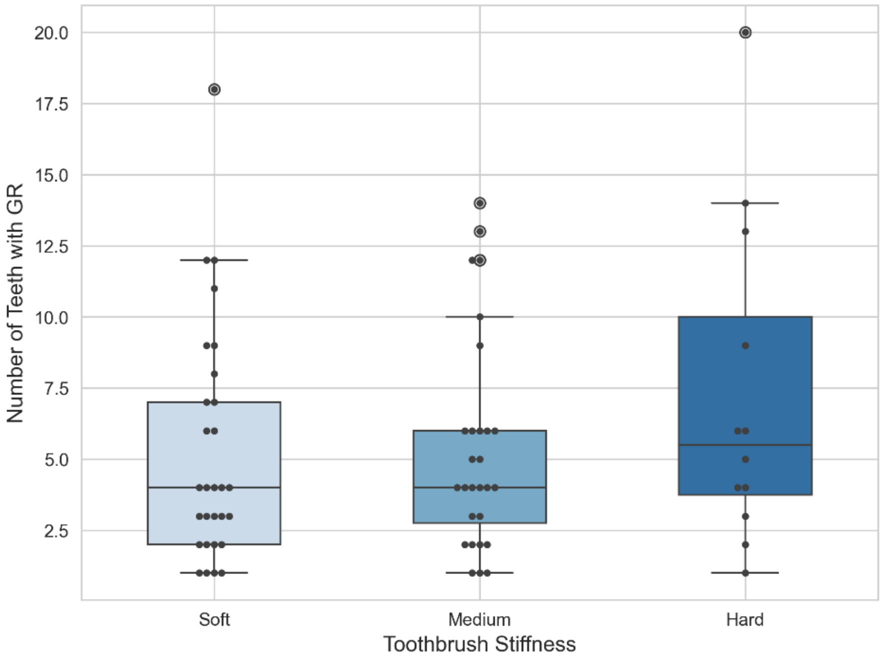

Figure 1: Distribution of GR by Toothbrush type.

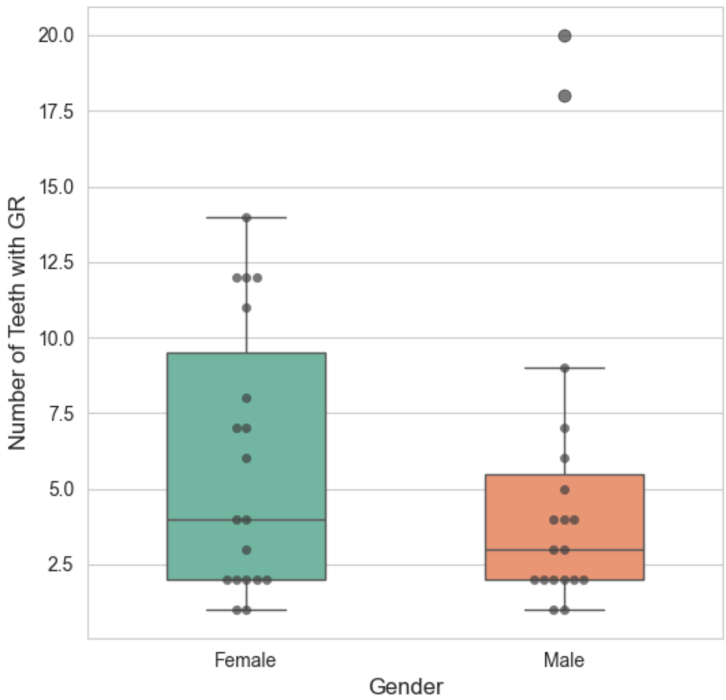

Figure 2: Severity of GR by gender.

Discussion

The research aimed to investigate the prevalence of CCL and NCCLs and their correlation with GR in patients visiting the College of Dentistry. The study examined this specific group of people to determine how GR and related cervical lesions were affecting them in their area.

The results showed that GR was very common, consistent with findings from other studies: isolated recession is more common than CCLs or NCCLs[30].

Our results showed that teeth with gingival recession were most often associated with CCLs, followed by NCCLs such as abrasion, erosion, and other stress-related cervical defects (previously referred to as abfraction). The observed correlations among caries and abrasion suggest that these lesions frequently coexist with gingival recession, whereas erosion demonstrated a weaker association. These patterns may indicate the cumulative effect of physical and biological factors on the cervical tooth surfaces in individuals with GR.

The study identified that aggressive and frequent toothbrushing, particularly employing a horizontal scrub technique, constitutes the primary etiological factor in gingival recession (GR). Such brushing habits were associated with 93.8% of documented recession cases. This statistically significant correlation underscores the critical importance of individualized oral hygiene guidance provided by dental professionals. It highlights that neither toothbrush design nor brushing method is universally superior; rather, selection should be tailored to each patient's specific needs and based on evidence-based professional recommendations.[31,32]. The lack of a statistically significant association between brushing technique and gingival recession may be partly explained by the small number of participants using the correct brushing technique ($n = 4$), which may have limited the statistical power to detect a significant difference.

The chi-square test showed a strong association between GR and the three defined clinical categories: recession without other conditions, recession with CCLs, and recession with NCCLs. The substantial standardized residuals in the recession-only group, relative to the expected frequencies, indicate that factors such as brushing habits, occlusal stress, inflammation, or anatomical variations are influencing the distribution beyond chance alone. This underscores the necessity for a multifactorial strategy in both prevention and treatment[34,35].

In this study, abrasions were the most common type of NCCL, followed by erosions. This pattern was consistent with earlier findings that identified mechanical factors, such as harsh brushing techniques, as significant causes of abrasion development[35].

On the other hand, erosion was less common, suggesting that chemical factors such as dietary acids do not play a major role in this group. These results endorse the formulation of targeted preventive strategies. Teaching people to brush their teeth gently, such as avoiding horizontal strokes and using toothbrushes with medium bristles, could reduce the number of mechanical lesions[36].

These results show how important it is to use preventive methods that address physical factors contributing to non-carious cervical lesions and gingival recession. One example is an educational program that teaches people how to clean their teeth gently and use the right dental tools. Oral hygiene aids may help reduce the frequency of abrasion-induced mechanical lesions. There is still no clear answer on how toothbrush design and bristle hardness affect plaque control and hard-tissue damage, and no single toothbrush has been found to be the best for everyone[37].

Even though erosion didn't seem to have a big effect on gingival recession in this study, other studies have shown that counseling people on their diets to limit acidic foods and drinks may lower the risk of dental erosion[38-41]. Moreover, age, gender, and a history of scaling and polishing did not exhibit a significant correlation with gingival recession in this study.

This study has several limitations. First, it was cross-sectional, making it hard to draw cause-and-effect conclusions. Second, the brushing method was reported by the participants themselves, which could introduce recall bias. Third, the sample was confined to a single dental institution and may not represent wider population trends. Future longitudinal studies involving heterogeneous populations are essential to validate these findings and investigate causal relationships.

Conclusion

This study highlights the prevalence of gingival recession (GR) and its association with cervical lesions. gingival recession was commonly associated with cervical lesions. Age and gender were not significantly related to GR or cervical lesions. Hard toothbrush users were expected to have a 30% higher GR count than soft brush users, though this was not statistically significant. GR was significantly linked to non-carious lesions, particularly abrasion. Findings reflect associations, not causation.

Declarations

Ethics Approval and Informed Consent (Institutional Review Board) Statement: This study was conducted in accordance with the principles of the Declaration of Helsinki. Ethical approval was obtained from the Ethics Committee of the College of Dentistry, University of Sulaimani, with approval number [210\23] dated [05\11\2023]. Written informed consent was obtained from all participants prior to inclusion in the study.

Author Contributions: MKF: Conceptualization, methodology, investigation, data curation, formal analysis, validation, visualization, writing—original draft preparation, writing—review and editing, project administration, manuscript submission, correspondence with the journal, response to editors' and reviewers' comments, and supervision. HJH: Writing—review and editing (contribution to the manuscript introduction). All authors have read and agreed to the published version of the manuscript.

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References

1. Wennström JL. Mucogingival therapy. Ann Periodontol. 1996;1(1):671-701.
2. Marschner F, Pfister W, Lechte C, Kanzow P, Hraský V. Systematic review and meta-analysis on prevalence and risk factors for gingival recession. J Clin Periodontol. 2021;48(9):1123-33.
3. Dias D, Flores PCS, Hilgenberg SP, Pinto EPS, Kozlowski Jr VA, et al. Risks and complications

in the use of oral piercing - clinical cases report. J Pathol Res Rev Rep. 2024;6(2):4-15.
4. Carranza F, Klokkevold P, Takei H, Newman M. Carranza's Clinical Periodontology. 13th ed. Philadelphia: Elsevier Saunders; 2019.
5. Fan J, Caton JG. Occlusal trauma and excessive occlusal forces: narrative review, case definitions, and diagnostic considerations. J Clin Periodontol. 2018;45(Suppl 20):S199-S206.
6. Steffens J, Marcantonio R. Classificação das doenças e condições periodontais e peri-implantares 2018: guia prático e pontos-chave. Rev Odontol UNESP. 2018;47(4):189-97.
7. Ustun K, Sari Z, Orucoglu H, Duran I, Hakki SS. Severe gingival recession caused by traumatic occlusion and mucogingival stress: a case report. Eur J Dent. 2008;2(2):127-33.
8. Merijohn GK. Management and prevention of gingival recession. Periodontol 2000. 2016;71(1):228-42.
9. Kundapur PP, Bhat KM, Bhat GS. Association of trauma from occlusion with localized gingival recession in mandibular anterior teeth. Dent Res J (Isfahan). 2009;6(2):71-4.
10. Hamed AM, Zardawi FM, Karim SA. Prevalence, extension, and severity of the gingival recession in an adult population sample of Sulaimani city–Iraq. Sulaimani Dent J. 2015;2(1):31-7.
11. Cortellini P, Bissada NF. Mucogingival conditions in the natural dentition: Narrative review, case definitions, and diagnostic considerations. J Periodontol. 2018;89(Suppl 1):S204-S213.
12. Nemcovsky CE, Artzi Z. Erosion-abrasion lesions revisited. Compend Contin Educ Dent. 1996;17(4),:416-20.
13. Senna P, Del Bel Cury A, Rösing C. Non-carious cervical lesions and occlusion: a systematic review of clinical studies. J Oral Rehabil. 2012;39(6):450-62.
14. Kolak V, Pešić D, Melih I, Lalović M, Nikitović A, Jakovljević A. Epidemiological investigation of non-carious cervical lesions and possible etiological factors. J Clin Exp Dent. 2018;10(7):e648-e656.
15. Bernhardt O, Gesch D, Schwahn C, Mack F, Meyer G, John U, et al. Epidemiological evaluation of the multifactorial aetiology of abfractions. J Oral Rehabil. 2006;33(1):17-25.
16. Bergström J, Eliasson S. Cervical abrasion in relation to toothbrushing and periodontal health. Scand J Dent Res. 1988;96(5):405-11.
17. West NX, Lussi A, Seong J, Hellwig E. Dentin hypersensitivity: pain mechanisms and aetiology of exposed cervical dentin. Clin Oral Investig. 2013;17(S1):9-19.
18. Kim DM, Neiva R. Periodontal Soft Tissue Non–Root Coverage Procedures: A Systematic review from the AAP regeneration workshop. J Periodontol. 2015;86(2-s):S56-72.
19. Smith WA, Marchan S, Rafeek RN. The prevalence and severity of non-carious cervical lesions in a group of patients attending a university hospital in Trinidad. J Oral Rehabil. 2008;35(2):128-34.
20. Teixeira DNR, Zeola LF, Machado AC, Gomes RR, Souza PG, Mendes DC, et al. Relationship between noncarious cervical lesions, cervical dentin hypersensitivity, gingival recession, and associated risk factors: A cross-sectional study. J Dent. 2018;76:93-7.
21. Larsen MJ, Nyvad B. Enamel erosion by some soft drinks and orange juices relative to their ph, buffering effect and contents of calcium phosphate. Caries Res. 1999;33(1):81-7.
22. Yoshizaki KT, Francisconi-Dos-Rios LF, Sobral MAP, Aranha ACC, Mendes FM, Scaramucci T. Clinical features and factors associated with noncarious cervical lesions and dentin hypersensitivity. J Oral Rehabil. 2017;44(2):112-8.
23. Ellefsen B, Holm-Pedersen P, Morse DE, et al. Assessing caries increments in elderly patients with and without dementia: a one-year follow-up study. J Am Dent Assoc. 2009;140(10):1233-40.
24. Powell LV, et al. Factors associated with caries incidence in an elderly population. Community Dent Oral Epidemiol. 1998;26(3):123-30.
25. Fure S. Ten-year cross-sectional and incidence study of coronal and root caries and some related factors in elderly Swedish individuals. Gerodontology. 2004;21(3):123-9.
26. Kidd EAM, Fejerskov O. Dental Caries: The Disease and Its Clinical Management. 3rd ed. Oxford: Wiley-Blackwell; 2015.
27. Grippo JO, Simring M, Coleman TA. Abfraction, abrasion, biocorrosion, and the enigma of noncarious cervical lesions: A 20-year perspective. J Esthet Restor Dent. 2012;24(1):10-23.
28. Bartlett DW, Shah P. A critical review of non-carious cervical (wear) lesions and the role of abfraction, erosion, and abrasion. J Dent Res. 2006;85(4):306-12.
29. Litonjua LA, Andreana S, Bush PJ, Cohen RE. Noncarious cervical lesions and abfractions: A re-evaluation. J Am Dent Assoc. 2003;134(7):845-50.
30. Susin C, Oppermann RV. Gingival recession: epidemiology and risk indicators in a representative urban Brazilian population. J Clin Periodontol. 2006;33(1):21-9.

31. Lee W, Kim SJ. The relationship between tooth brushing and gingival recession. J Periodontol. 2003;74(5):673-8.
32. Tenenbaum H. A clinical study comparing the effectiveness of plaque removal by brushing and flossing techniques. J Clin Periodontol. 1982;9(1):58-64.
33. Kassab MM, Cohen RE. The etiology and prevalence of gingival recession. J Am Dent Assoc. 2003;134(2):220-6.
34. Albandar JM, Kingman A. Gingival recession, gingival bleeding, and dental calculus in adults 30 years of age and older in the United States, 1988-1994. J Periodontol. 1999;70(1):30-43.
35. Rees JS. The biomechanics of abfraction. Proc Inst Mech Eng H. 2002;216(3):207-12.
36. Litonjua LA, Andreana S, Bush PJ. Noncarious cervical lesions and abfractions: a re-evaluation. J Am Dent Assoc. 2003;134(7):845-50.
37. Khursheed DA, Zardawi FM, Karim SA, Abdulrahman AA, Gul SS, Salih RO. Validity of CPITN Index Applied by Undergraduate Dental Students. Sulaimani Dent J. 2019;6(2):69-75.
38. Van der Weijden GA, Slot DE. Oral hygiene in the prevention of periodontal diseases: the evidence. Periodontol 2000. 2015;67(1):130-41.
39. Addy M, Hunter ML. Can tooth brushing damage your health? Effects on oral and dental tissues. Int Dent J. 2003;53(S3):177-86.
40. Eccles JD, Jenkins WG. Dental erosion and diet. J Dent. 1974;2(4):153-9.
41. West NX, Lussi A. Dental erosion: an increasing clinical problem? J Dent. 2013;41(11):889-904.
42. Silness J, Löe H. Periodontal disease in pregnancy. II. Correlation between oral hygiene and periodontal condition. Acta Odontol Scand. 1964;22(1):121-35.
43. Mühlemann HR, Son S. Gingival sulcus bleeding: a leading symptom in initial gingivitis. Helv Odontol Acta. 1971;15(2):107-13.

Original Article

Patient Preference and Perceptions Regarding Amalgam and Tooth-Colored Restoration in an Iraqi Subpopulation

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Abstract

Objective: Patient perception increasingly influences the selection of restorative dental materials, especially as aesthetic expectations grow within modern dental practice. This study aimed to evaluate patient awareness, attitudes, and preferences regarding amalgam and tooth-coloured restorative materials in the Iraqi subpopulation.

Methods: A descriptive cross-sectional survey was conducted using a structured questionnaire distributed to patients attending various dental clinics. The questionnaire obtained demographic information, previous restorative experiences, aesthetic expectations, and perceptions of the functional, aesthetic, and biological characteristics of amalgam and composite resin materials.

Results: The results showed that most participants preferred tooth-coloured restorations due to their natural appearance and higher aesthetic compatibility. Amalgam was favoured by a smaller proportion of respondents who emphasized its durability, strength, and relative affordability. Younger patients and those with higher educational levels demonstrated stronger preference for aesthetic materials, while awareness of possible health concerns associated with amalgam varied considerably among participants.

Conclusions: Overall, the findings reflect a noticeable shift toward aesthetic-driven choices in restorative dentistry within the region. The study concludes that dental practitioners should acknowledge patient preferences during treatment planning and provide balanced, evidence-based information about the advantages and limitations of available restorative materials to support informed decision-making and enhance patient satisfaction.

Keywords: *Amalgam, Tooth-colored restoration, Patients' attitude, Restorative dentistry outcomes, Patient satisfaction, Regional dental health research.*

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Introduction

Dental caries, also known as tooth decay or tooth cavity, is the most common chronic disease among people around the world. It is an infectious disease that causes the calcified tissue of the teeth to dissolve and be destroyed locally[1,2].

Removing the carious lesions and restoring them with biocompatible materials in a timely manner is of great importance to protecting oral health and the overall well-being of the patient. Dentists and oral health givers have been in continuous efforts to develop the optimum materials for this purpose[3]. Dentistry has evolved to become a well-established and highly respected profession. It is built on a foundation of solid scientific knowledge, a genuine dedication to serving the public, and an ethical responsibility to prioritize the health and well-being of patients seeking dental care. When dentists restore a tooth with a direct restoration, they must account for numerous factors influencing the restoration's durability and longevity. These factors can be based on scientific evidence or the personal preferences of the patient or dentist[4]. Clinical decision-making is at the core of dental practice, influencing treatment choices that impact long-term patient outcomes. In restorative dentistry, these decisions require a balance between scientific evidence, clinical expertise, and patient preferences[5].

The most popular materials for repairing and restoring teeth are amalgam and tooth-colored restorations. Dental amalgam is a metal alloy composed primarily of mercury, silver, and tin. It has been widely utilized in dental treatment for over 170 years. Amalgam is regarded as the optimal dental restorative material, particularly for posterior teeth that endure significant occlusal forces[6]. It is cost-effective, long-lasting, and durable, making it easy to place in prepared teeth. Amalgam exhibits high compressive strength, excellent wear resistance, and minimal dimensional change over time. Notably, amalgams are recognized for their superior marginal sealing capacity, attributed to the formation of corrosion products at the interface between the amalgam and tooth structure. However, its use is limited due to aesthetic concerns and the need for extensive tooth structure removal during placement. Additionally, the potential toxicity of mercury in amalgam has raised concerns[4,7].

Resin composites offer a high level of aesthetic value. These materials develop a micro-mechanical bond with the tooth structure and require minimal cavity preparation. However, these materials are highly technique-sensitive. It is crucial to ensure proper isolation during their application and setting, as these materials need a dry field. Saliva or blood contamination could interfere with the bond between the composite and the tooth, potentially leading to the debonding of the resin composite later on[8]. Resin composite undergoes polymerization shrinkage during light curing, leading to gap formation at the composite-tooth interface, compromising the quality of the restoration and exposing the tooth to the potential development of secondary caries[4] .

Longitudinal clinical trials show that amalgam restorations last about as long as, or slightly longer than, composite resin restorations. In contrast, cross-sectional retrospective studies of restorations done in general practice reveal that amalgam restorations last more than twice as long as composite resin restoration[9] .

According to a previous study, “Pathway to mercury-free dentistry: an insight into past, present, and future”,[10] awareness of the toxicity of mercury in dental amalgam was somewhat low among the patients seeking dental treatment. Most patients still accept amalgam, but the majority prefer tooth-colored fillings for a more natural appearance. Overall, the acceptance of amalgam seems to be influenced by economic factors, dental education, and the aesthetic preferences of the community[11].

This study aimed to determine patients' perceptions of amalgam and tooth-colored restoration materials and to fill the gap in our understanding of people’s preferences regarding different kinds of restorative materials. Estimate patients’ knowledge and attitudes towards amalgam and composite restorations, and correlate the findings with participants’ age, sex, and education level in Iraqi subpopulation.

Patients and methods

After obtaining ethical approval from the College of Dentistry, University of Sulaimani, a questionnaire survey (Appendix A) was conducted with 476 participants in Sulaimani City from November 2023 to February 2024. Close-ended questions were included in the study.

Inclusion:

Individuals aged 18 and above and Patients who possessed knowledge about different dental filling materials[12,13].

Exclusion criteria:

1. Patients below 18 years old.
2. Patients who didn’t have any information regarding dental filling materials.

3. Patients who failed to answer the opening question were omitted from participating in the survey[14].

The participants were asked five knowledge- and opinion-based questions, starting with (1) "Which restoration material do you know?" to assess their level of understanding of basic dental information. If one of the presented choices was selected, they were elicited to move on to the following two questions which are "Yes and No" questions concerned with the respondents' opinions on the two types of tooth filling materials presented. The questions are as follows: (2) "Do you think amalgam can be used to restore the carious tooth?" and (3) "Do you think tooth-colored material can be used to restore carious tooth?". The fourth question is a preference-based question to inquire about the participants' desired choice of restorative material: (4) "Which material will you prefer for tooth filling?" Lastly, the final question in this category is: (5) "Have you taken any knowledge regarding the restorative material for tooth filling from the internet", which serves the purpose of authenticating the status of the respondents' answers as either purely anecdotal and/or experience-based or fact-based[13].

The second group of questions serves to assess the patients' decision-making or approach process for selection between amalgam and tooth-colored restoration. The first of these questions is: (1) "To whom will you give the choice of selection of restorative material for tooth filling?", with the answers being either "choose by yourself" or "according to doctor" to determine the principal basis of their decision-making. This is followed by a series of basic inquiry questions:

(2) "According to you, which material is cheaper?" (3) "According to you, which material has more strength?" (4) "According to you, which material will you choose for restoring anterior teeth?" and (5) "According to you, which material will you choose for restoring posterior teeth?" These aim to find out whether the choice of material selected by the participant is related to financial factors, physical property of the material, or location of the tooth to be filled, respectively[15].

Another common misconception among the general population concerns the adverse effects of mercury toxicity associated with amalgam fillings, so the second-to-last question addresses this concern: (1) "Have you heard of mercury toxicity due to amalgam restoration?" Lastly, the final question is (2) "What do you think your preference should be based on?", to find out the patients' most preferred qualities in a dental filling in terms of "Cost", "Appearance", "Life of filling material," and "post-operative pain", with participants allowed to select more than one option[16].

Statistical Analysis

Pearson's Chi-Square Test was performed to examine the association between variables in the questionnaire and gender, age, socioeconomic status, and education among 476 individuals using IBM SPSS (version 25), with $P \leq 0.05$ considered statistically significant.

Results

A total of 476 participants, comprising 232 males (48.7%) and 244 females (51.3%), were included in the study. The age ranged from 18 to 67 years, with a mean age of 32.6 years.

As shown in Table 1, participants' responses to the questionnaire questions show no significant differences across any questions ($p>0.05$), except for selection and cost of materials ($p<0.05$). Regarding material selection, there were more responses to amalgam and tooth-colored restoration among females than males, whereas more males than females responded to amalgam, tooth-colored, and other. Regarding the question asking which restoration is cheaper, more females than males responded to amalgam,

According to the responses of participants to the questionnaire, there are no statistically significant differences across age groups for any of the questions ($p>0.05$).

Table 3 demonstrates significant differences among different socioeconomic statuses in response to these questions: (material knowledge, amalgam for posterior teeth, choice of material, anterior tooth restoration material choice, and toxicity) with a p-value< 0.05

Table 4: The responses of the participants to the questions above show significant differences ($p<0.05$) in relation to all the categories except their knowledge source, their opinion on the strength of the material, and the toxicity of amalgam restoration ($p> 0.05$), based on their education level.

Discussion

Two primary materials are important in restorative procedures: dental amalgam and composite resin. Both materials are widely used to fill cavities and restore the structural integrity of teeth affected by decay or damage. Despite serving similar purposes, they possess distinct characteristics, applications, and considerations that dentists and patients must understand[18,19].

According to the current study, 66% of total participants preferred tooth-colored material over amalgam (14.4%), contrary to other studies[20,21] which found that amalgam is more popular than composite. Among female participants, 67.6% chose tooth-colored restoration, while 12.2% preferred amalgam; among male participants, 65’9% also chose tooth-colored, while 16.8% preferred amalgam. This finding is similar to that recorded by Mahmood et al.[22] Most people preferred tooth-colored restorations, commonly referred to as white fillings, over traditional silver-colored ones.

In contemporary culture, individuals prioritize their appearance, recognizing its significant impact on self-esteem and success. This emphasis on aesthetics extends to oral health, with many seeking cosmetic interventions to enhance their smiles. Seeking beauty through dental professionals has thus become synonymous with improving one’s overall appearance and self-confidence[23] More females than males preferred tooth-colored restorations, and fewer females preferred amalgam, because females tend to be more sensitive to aesthetics.

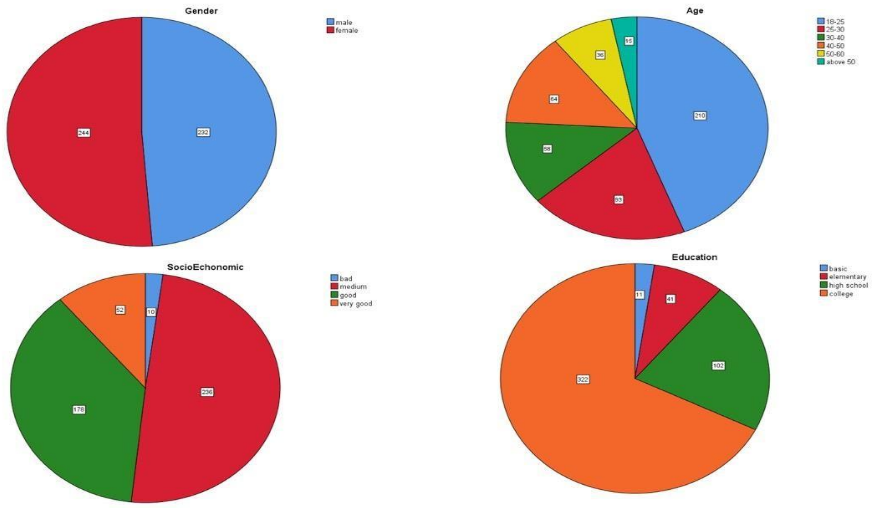

Figure 1: Pie Charts representing the distribution of data according to gender, age, socioeconomic status, and education.

Table 1: Participants' responses to the questionnaires in relation to gender.

Questionnaire		Gender Male	Female	Total	Chi-square *P*-value
Material	Amalgam	32	25	57	X^2=14.053 P=0.003
	Tooth-colored	109	85	194	
	Other	16	14	30	
	Amalgam & tooth-colored	75	120	195	
Amalgam	Yes	63	71	134	X^2=.253 P=0.881
	No	101	105	206	
	Not sure	68	68	136	
Tooth-colored	Yes	159	182	341	X^2=2.674 P=0.263
	No	23	16	39	
	Not sure	50	46	96	
Choice of material	Amalgam	39	30	69	X^2=3.234 P=0.357
	Tooth-colored	153	165	318	
	Other	13	12	25	
	Both	26	37	63	
Knowledge	Yes	61	71	132	X^2=1.453 P=0.484
	No	145	153	298	
	Not sure	26	20	46	
Choice	Patient	39	43	82	X^2=.055 P=0.814
	Doctor	193	201	394	
Cheaper	Amalgam	94	126	220	X^2=6.372 P=0.041
	Tooth-colored	62	58	120	
	Not sure	76	60	138	
Strength	Amalgam	77	97	174	X^2=2.929 P=0.231
	Tooth-colored	96	84	180	
	Not sure	59	63	122	
Anterior	Amalgam	11	3	14	X^2=5.539 P=0.063
	Tooth-colored	191	213	404	
	Not sure	30	28	58	
Posterior	Amalgam	66	66	132	X^2=1.939 P=0.379
	Tooth-colored	115	111	226	
	Not sure	51	67	118	
Toxicity	Yes	48	56	104	X^2=1.281 P=0.527
	No	153	149	302	
	Not sure	31	39	70	
	Total				

Table 2: Participants' responses to the questionnaires in relation to age group.

Questionnaire		Age groups							Chi-square *P*-value
		18-25	**25-30**	**30-40**	**40-50**	**50-60**	**Above 60**	**Total**	
Material	Amalgam	21	10	5	10	8	3	57	X^2=20.583 P=0.151
	Tooth-colored	79	36	26	25	20	8	194	
	Other	13	7	4	4	0	2	30	
	Amalgam & tooth-colored	97	40	23	25	8	2	195	
Amalgam	Yes	52	29	12	23	12	6	134	X^2=8.957 P=0.536
	No	90	39	27	28	16	6	206	
	Not sure	68	25	19	13	8	3	136	
Tooth-colored	Yes	147	69	47	42	25	11	341	X^2=7.140 P=0.712
	No	20	6	2	7	4	0	39	
	Not sure	43	18	9	15	7	4	96	
Choice of material	Amalgam	25	11	7	13	9	4	69	X^2=12.773 P=0.620
	Tooth-colored	142	66	39	39	23	9	318	
	Other	11	6	2	3	2	1	25	
	Both	32	10	10	8	2	1	63	
Knowledge	Yes	66	29	13	12	8	4	132	X^2=9.627 P=0.474
	No	123	54	41	46	23	11	298	
	Not sure	21	10	4	6	5	0	46	
Choice	Patient	40	15	8	11	5	3	82	
	Doctor	170	78	50	53	31	12	394	
Cheaper	Amalgam	103	41	26	30	15	5	220	X^2=7.369 P=0.690
	Tooth-colored	52	29	14	15	7	3	120	
	Not sure	55	23	18	19	14	7	136	
Strength	Amalgam	85	27	20	25	11	6	174	X^2=3.833
	Tooth-colored	72	41	20	25	17	5	180	
	Not sure	53	25	18	14	8	4	122	
Anterior	Amalgam	5	2	2	2	2	1	14	P=0.955
	Tooth-colored	180	78	47					
	Not sure	25	13	9	6	4	1	58	
Posterior	Amalgam	53	25	11	24	10	9	132	X^2=16.112 P=0.096
	Tooth-colored	101	43	30	27	20	5	226	
	Not sure	56	25	17	13	6	1	118	
Toxicity	Yes	54	21	9	9	9	2	104	X^2=12.612 P=0.246
	No	126	57	43	47	21	8	302	
	Not sure	30	15	6	8	6	5	70	
	Total	210	93	58	64	36	15	476	

Table 3: Participants' responses to the questionnaires in relation to socioeconomic status.

Questionnaire		Bad	Medium	Good	Very good	Total	Chi-square *P*-value
Material	Amalgam	5	34	14	4	57	X^2=28.318 *P*=0.001
	Tooth-colored	2	85	89	18	194	
	Other	0	19	7	4	30	
	Amalgam & tooth-colored	3	98	68	26	195	
Amalgam	Yes	7	69	44	14	134	X^2=13.039 *P*=0.042
	No	2	98	87	19	206	
	Not sure	1	69	47	19	136	
Tooth-colored	Yes	8	163	130	40	341	X^2=8.463 *P*=0.206
	No	2	24	9	4	39	
	Not sure	0	49	39	8	96	
Choice of material	Amalgam	5	44	19	1	69	X^2=33.716 *P*=0.000
	Tooth-colored	2	143	132	41	318	
	Other	0	11	9	5	25	
	Both	3	37	18	5	63	
Knowledge	Yes	3	56	56	17	132	X^2=6.812 *P*=0.339
	No	6	161	103	28	298	
	Not sure	1	19	19	7	46	
Choice	Patient	2	45	29	6	82	X^2=1.904 *P*=0.593
	Doctor	8	191	149	46	394	
Cheaper	Amalgam	5	108	80	27	220	X^2=2.698 *P*=0.846
	Tooth-colored	2	59	44	15	120	
	Not sure	3	69	54	10	136	
Strength	Amalgam	4	97	56	17	174	X^2=8.906 *P*=0.179
	Tooth-colored	2	79	80	19	180	
	Not sure	4	60	42	16	122	
Anterior	Amalgam	2	7	3	2	14	X^2=16.273 *P*=0.012
	Tooth-colored	5	205	151	33	404	
	Not sure	3	24	24	7	58	
Posterior	Amalgam	3	74	44	11	132	X^2=10.585 *P*=0.102
	Tooth-colored	2	103	96	25	226	
	Not sure	5	59	38	16	118	
Toxicity	Yes	1	43	51	9	104	X^2=13.309 *P*=0.038
	No	5	156	104	37	302	
	Not sure	4	37	23	6	70	
	Total						

Table 4: Participants' responses to the questionnaires in relation to education.

Questionnaire		Education					
		Basic	Elementary	High school	College	Total	Chi-square *P*-value
Material	Amalgam	5	8	19	25	57	X^2=26.645 P=0.002
	Tooth-colored	1	15	42	136	194	
	Other	1	3	7	19	30	
	Amalgam & tooth-colored	4	15	34	142	195	
Amalgam	Yes	7	17	36	74	134	X^2=20.273 P=0.002
	No	2	11	37	156	206	
	Not sure	2	13	29	92	136	
Tooth-colored	Yes	8	23	69	241	341	X^2=18.825 P=0.004
	No	2	9	5	23	39	
	Not sure	1	9	28	58	96	
Choice of material	Amalgam	4	11	23	31	69	X^2=32.156 P=0.000
	Tooth-colored	4	18	62	234	318	
	Other	0	5	6	14	25	
	Both	3	7	11	42	63	
Knowledge	Yes	2	8	18	104	132	X^2=10.809 P=0.094
	No	8	29	74	187	298	
	Not sure	1	4	10	31	46	
Choice	Patient	4	4	9	65	82	X^2=11.459 P=0.009
	Doctor	7	37	93	257	394	
Cheaper	Amalgam	4	22	31	163	220	X^2=15.414 P=0.017
	Tooth-colored	4	9	30	77	120	
	Not sure	3	10	41	82	136	
Strength	Amalgam	4	16	40	114	174	X^2=8.205 P=0.223
	Tooth-colored	1	18	36	125	180	
	Not sure	6	7	26	83	122	
Anterior	Amalgam	3	1	3	7	14	X^2=23.552 P=0.001
	Tooth-colored	7	35	86	276	404	
	Not sure	1	5	13	39	58	
Posterior	Amalgam	6	17	32	77	132	X^2=15.22 P=0.019
	Tooth-colored	2	15	40	169	226	
	Not sure	3	9	30	76	118	
Toxicity	Yes	1	5	15	83	104	X^2=11.635 P=0.071
	No	8	26	72	196	302	
	Not sure	2	10	15	43	70	
	Total						

The present study also shows that among the participants aged between 18 and 25 years, 67.6% preferred tooth-colored restorations over amalgam restoration, while only 11.9% chose amalgam as their preferred material. Among the other age groups, the 25-30 group also preferred tooth-colored restorations (70.9%), while only 11.8% chose amalgam. Among the age group 50-60 years tooth-colored restorations were still the majority choice, but a significant portion chose amalgam restoration (25%), which is a significant increase compared to the previous age group. Moreover, there was an even higher percentage among participants aged above 60 (26.6%), as was also recorded by another study[24].

As is obvious from the aforementioned results, the older the age of participants, the higher the percentage preferring amalgam restoration, (this could be linked to tradition and culture and even more to older patients' familiarity with amalgam and their good impressions of it). However, the present study had a lot more participants in the 18-25 age group, which will have skewed the results[11].

Another factor that influenced the choice of material was the participants' education level. It can be seen from the results that 22% of high school students chose amalgam as their preferred material, while only 0.96% of participants with college-level education chose amalgam. It is obvious that college students will have more knowledge and information about amalgam, and maybe its toxicity, which would explain why such a small percentage chose it as their preferred material.

The results of this study show that only 21.8% of participants had knowledge of the toxicity of amalgam, while 63.4% of participants had no knowledge of its toxicity and 14.7% of participants were not sure whether they had knowledge about it or not, and these findings are similar to those recorded in some studies[11,20,25,26], while they are significantly different from other studies[25,27,28] which reported a much higher percentage of patients knowing the harmful effects of amalgam. The concern about amalgam restoration arises from the fact that this material contains about 50% mercury by weight[19] and during chewing, dental amalgam restorations can emit elemental mercury vapor in amounts that are lower than half of what is typically encountered in natural daily exposure[19]. This result reflects the lack of dental education among the people in Sulaymaniyah city regarding their knowledge about the materials used for tooth restoration, whereas the dental profession is one of the largest end-users of mercury[29]. The Kurdistan Dental Association should take a leading role in awareness raising and promoting clinical and epidemiological research, to support the cause of getting economical alternatives to amalgam imported into the country. Amalgam is a material of choice due to its low cost, and dental professionals need to be trained to adopt the best practices for amalgam waste management in the dental setting[27] and to find alternatives to amalgam containing mercury[30].

Since the current study showed no statistically significant difference by gender, the choice of restoration material is more likely related to the population's age and education level. Regarding the toxicity of amalgam, among the participants aged between 18 and 25 years, 25.7% knew about the toxicity of amalgam, while among participants aged 25-30, 30-40, and 40-50, only 22.5%, 15.5%, and 14.0%, respectively, knew about this hazard. These findings can be explained by the fact that younger generations in the city are more educated than the older ones because of having a better education environment and more education resources than were available for the older generations.

As for the education level, we can see from the results that 25.7% of participants with a college-level education knew of the toxicity, while only 14.7% of participants with a high school education and 12.1% of participants with elementary school level education knew of it, and these findings coincide with what was recorded by other studies[24,31]. This further shows that having a good, higher-level education makes people more aware of this information, as is reinforced by the age results. However, the educational results are more skewed towards college-level education, with 67.6% of all participants having this level, which might have affected the current results.

Among the limitations of the current study is the need for inclusion of a larger population. Moreover, all age groups should be included.

Conclusion

Within the constraints of this cross-sectional study, the results indicate a clear preference for tooth-colored restorative materials over dental amalgam among participants, with aesthetics as the primary influencing factor. While some individuals still appreciate amalgam for its durability and affordability, current trends reflect a shift toward appearance-based choices. Differences in material preference were also associated with age and educational background, especially among those with dental training, underscoring the impact of knowledge on attitudes.

Awareness regarding potential mercury-related concerns was relatively limited, emphasizing the need for improved patient education and communication. Overall, the results support the importance of integrating patient preferences with clinical evidence to ensure informed, patient-centered decision-making in restorative dentistry.

Declarations

Ethics Approval and Informed Consent (Institutional Review Board) Statement: This study was conducted in accordance with the principles of the Declaration of Helsinki. Ethical approval was obtained from the Ethics Committee of the College of Dentistry, University of Sulaimani, with approval number [211\23] dated [05\11\2023]. Written informed consent was obtained from all participants prior to inclusion in the study.

Author Contributions: KMS: Study design, and results. KOA: Discussion section, patient recruitment, and questionnaire development. DSA: Conceptualization, and drafting the initial manuscript. RPK: Literature review and supervision. HMS: Data entry and the result section. SMA: Writing conclusion section and supervision.

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References

1. Selwitz RH, Ismail AI, Pitts NB. Dental caries. The Lancet. 2007;369(9555):51-9.
2. Correa MB, Peres MA, Peres KG, Horta BL, Barros AD, Demarco FF. Amalgam or composite resin? Factors influencing the choice of restorative material. J Dent. 2012;40(9):703-10.
3. Shah RJ, Malek FG, Agarwal P. A study of patient satisfaction with maxillary anterior teeth restorations and desirable esthetic treatment options. J Dent Med Sci. 2014;13(10):79-86.
4. Kusumawardani A, Sukmasari S, Ab Halim N, Nhari RHBR ,Habi SABA. Patient satisfaction towards composite and amalgam restorations in IIUM dental polyclinic. Scientific Dental Journal. 2020;4(3):93-6.
5. Saeed HM, Kazzaz S, Babarasul D, Gharib DH, Abdulateef D. Decisions in Restorative Dentistry Based on Gender, Knowledge, and Experience. Sulaimani Dent J. 2025;12(3):42-50.
6. Alreshaid L, El-Badrawy W, Kulkarni G, Santos MJ, Prakki A. Resin composite versus amalgam restorations placed in United States dental schools. Oper Dent. 2023;48(1):21-32.
7. Taut C. Dental amalgam: is this the end? J Ir Dent Assoc. 2014;59(6):311-7.
8. Riley JL 3rd, Gordan VV, Rindal DB, Fellows JL, Qvist V, Patel S, et al. Components of patient satisfaction with a dental restorative visit: results from the Dental Practice-Based Research Network. J Am Dent Assoc. 2012;143(9):1002-10.
9. Opdam NJ, Bronkhorst EM, Roeters JM, Loomans BA. A retrospective clinical study on longevity of posterior composite and amalgam restorations. Dent Mater. 2007;23(1):2-8.
10. Dudeja P, Dudeja KK, Grover S, Singh H, Jabin Z. Pathway to mercury-free dentistry: an insight into past, present, and future. Eur Oral Res. 2023;57(2):60-7.
11. Faraj BM, Mohammad HM, Mohammad KM. The changes in dentists' perception and patient's acceptance on amalgam restoration in kurdistan-iraq: a questionnaire-based cross-sectional study. J Clin Diagn Res. 2015;9(4):ZC22-5.
12. Al-Hassiny A, Végh D, Bányai D, Végh Á, Géczi Z, Borbély J, et al. User experience of intraoral scanners in dentistry: Transnational questionnaire study. Int Dent J. 2023;73(5):754-9.
13. Parkin Kullmann JA, Pamphlett R. A Comparison of Mercury Exposure from Seafood Consumption and Dental Amalgam Fillings in People with and without Amyotrophic Lateral Sclerosis (ALS): An International Online Case-Control Study. Int J Environ Res Public Health. 2018;15(12):2874.

14. Bansal R, Jain A. An insight into patient's perceptions regarding root canal treatment: A questionnaire-based survey. J Family Med Prim Care. 2020 Feb 28;9(2):1020-1027.
15. Estrich CG, Lipman RD, Araujo MWB. Dental amalgam restorations in nationally representative sample of US population aged ≥15 years: NHANES 2011-2016. J Public Health Dent. 2021;81(4):327-30.
16. Yang LC, Liu FH, Su NY, Wang YH, Yang PY, Chang YC. Decreased trends of using dental amalgam filling for decayed teeth in Taiwan from 1997 to 2013. J Dent Sci. 2023;18(1):400-06.
17. Agrawal MG, Cirigiri S, Burande A, Goenka S, Aslam BM, Soni P. Evaluation of knowledge, approach & perception of the rural population regarding amalgam and tooth-colored composite material: A questionnaire-based study. Int J Appl Dent Sci. 2022;8(2):254-58.
18. Hervás García A, Lozano M, Cabanes Vila J, Barjau Escribano A, Fos Galve P. Composite resins: a review of the materials and clinical indications. Med Oral Patol Oral Cir Bucal. 2006;11(2):E215-E220.
19. Magkert Jr JR. Dental amalgam and mercury. The Journal of the American Dental Association. 1991;122(8):54-61.
20. Bamise C, Oginni AO, Adedigba MA, Olagundoye O. Perception of patients with amalgam fillings about toxicity of mercury in dental amalgam. J Contemp Dent Pract. 2012;13(3):289-93.
21. Jebur N, Vinall-Collier K, Umair AA, Aggarwal VR. Dental amalgam teaching phase-out - a step too soon? Foundation trainees' experience of amalgam use in dental school compared to practice: a mixed-methods survey. Br Dent J. 2023;235(5):329-34.
22. Mahmood H, Abd-alqader AM, jasm Al-Naimi R. Choice between composite and amalgam restorations according to dentists and patients perception. Al-Rafidain Dent J. 2020;20(1):1-17.
23. Tin-Oo MM, Saddki N, Hassan N. Factors influencing patient satisfaction with dental appearance and treatments they desire to improve aesthetics. BMC Oral Health. 2011;11:6.
24. Beltrán-Aguilar ED, Thornton-Evans G, Wei L, Bernal J. Prevalence and mean number of teeth with amalgam and nonamalgam restorations, United States, 2015 through 2018. J Am Dent Assoc. 2023;154(5):417-26.
25. Doumani M, Habib A, Hatshan AR, Alnofiai SR, Alqahtani FM, Sadeka MA, et al. Saudi patients' knowledge and awareness about mercury in dental amalgam. IOSR J Dental Medical Sci. 2017;16(8):68-70.
26. Al-Nahedh HN, El-Hejazi AA, Habib SR. Knowledge and attitude of dentists and patients toward use and health safety of dental amalgam in Saudi Arabia. Eur J Dent. 2020;14(2):233-38.
27. Adedigba MA, Nwhator SO, Afon A, Abegunde AA, Bamise CT. Assessment of dental waste management in a Nigerian tertiary hospital. Waste Manag Res. 2010;28(9):769-77.
28. Pooja S, Antony SD. Dentists attitude towards amalgam restoration and its safety measures-KAP survey. Drug Invent Today. 2019;12:9-12.
29. Hörsted-Bindslev P. Amalgam toxicity—environmental and occupational hazards. J Dent. 2004;32(5):359-65.
30. Brian HC, Lam OL, Jagannathan N, Botelho MG. A systematic review of amalgam bonded restorations: in vitro and clinical findings. J Contemp Dent Pract. 2018;19(8):1013-24.
31. Erçin Ö, Berkmen B, Durukan E, Arhun N. Awareness about dental amalgam among Turkish dentists and patients: a questionnaire and search engine based cross-sectional study. Int Den J. 2021;71(2):113-21.

Appendix A

Questionnaire[17]

1) Which restoration material do you know?

a. Amalgam
b. Tooth-colored restoration
c. Any other

2) Do you think amalgam can be used to restore the carious tooth?

a. Yes
b. No
c. Not sure

3) Do you think tooth-colored material can be used to restore the carious tooth?

a. Yes
b. No
c. Not sure

4) Which material would you prefer for tooth filling?

a. Amalgam
b. Tooth-colored restoration
c. Any other

5) Have you gained any knowledge regarding the restorative materials for tooth filling from the internet?

a. Yes
b. No
c. Not sure

6) To whom will you give the choice of selection of restorative material for tooth filling?

a. Choose by yourself
b. According to the doctor

7) According to you, which material is cheaper?

a. Amalgam
b. Tooth-colored restoration
c. Not sure

8) According to you, which material has more strength?

a. Amalgam
b. Tooth-colored restoration
c. Not sure

9) According to you, which material will you choose for restoring anterior teeth?

a. Amalgam
b. Tooth-colored restoration
c. Not sure

10) According to you, which material will you choose for restoring posterior teeth?

a. Amalgam
b. Tooth-colored restoration
c. Not sure

11) Have you ever heard about mercury toxicity due to amalgam restoration?

a. Yes
b. No
c. Not sure

12) What do you think your preference should be based on?

a. Cost
b. Appearance
c. Life of filling material
d. Post-operative pain

Original Article

Association of Salivary Janus Kinase 1 and Secretory Leukocyte Protease Inhibitor with Dental Caries and Periodontal Status in Different Stages of Type II Diabetes Mellitus: A comparative cross-sectional study

Roza A. Saeed[*1], *Fadil A. Kareem*[1]

Abstract

Objective: This research was formulated to investigate the relationship between salivary biomarkers which include Janus Kinase 1 (JAK1) and Secretory Leukocyte Protease Inhibitor (SLPI), and glycemic status in individuals with normal, prediabetic, controlled diabetic and uncontrolled diabetic conditions, and to assess their potential role in oral health.

Methods: Unstimulated saliva was obtained from 80 individuals aged 30-60 years who participated in this study: 20 healthy individuals and 60 with type II diabetes mellitus. Participants were assigned into four groups (20 in each group) according to their HbA1c level: normal, prediabetic, controlled diabetic and uncontrolled diabetic. Salivary pH was measured using Merck pH paper. All saliva samples were stored at -80 ℃, and salivary JAK1 and SLPI levels were measured using ELISA. Each participant was examined at the time of sample collection for dental caries and periodontal health using the decayed, missing, and filled teeth (DMFT) index and clinical attachment loss (CAL), respectively.

Results: Salivary JAK1 and SLPI showed no significant differences among the groups ($p = 0.423$ and $p = 0.940$, respectively). In contrast, DMFT scores ($p = 0.031$) and CAL ($p = 0.006$) were significantly higher in the diabetic groups than in controls. HbA1c was positively correlated with CAL ($r = 0.420$, $p < 0.001$) and DMFT ($r = 0.248$, $p = 0.027$). Regression analysis revealed that age and HbA1c were significant predictors of periodontal status, while salivary biomarkers were not associated with clinical outcomes.

Conclusions: Poor glycemic control was associated with increased periodontal attachment loss and higher caries experience, while salivary JAK1 and SLPI showed no significant diagnostic value. Age and HbA1c emerged as key predictors of oral health outcomes in diabetic patients.

Keywords: *Diabetes mellitus, Dental caries, Periodontitis, Saliva, Biomarkers, ELISA.*

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Introduction

The global prevalence of diabetes is estimated to be around 285 million, with a projected 50% increase by 2030[1]. Diabetes mellitus is a general term that refers to a group of metabolic disorders characterized by long-term hyperglycemia, which results in damage to and failure of various organs, including the heart, blood vessels, kidneys, eyes, and nerves[2,3]. An evidence-based correlation has developed between oral health and systemic conditions such as diabetes in the last few decades[4]. Diabetes has been identified as a significant risk factor for periodontitis in epidemiological studies, with a risk that is approximately three times higher than that of an individual without diabetes[5]. The most notable modifications in uncontrolled diabetes are the heightened susceptibility to infection and the reduction in defense mechanisms, which ultimately result in destructive periodontal disease. Periodontal abscesses, accelerated bone loss, deep periodontal pockets, and severe gingival inflammation are frequently observed in diabetic patients who have poor oral hygiene[6]. The transition from periodontally healthy states to disease conditions is promoted by dysbiosis between oral bacteria and host immune response[7].

Salivary composition and functions are altered in diabetes mellitus. Pathogenic bacteria are initiated by changes in the oral environment. Saliva normally has a protective effect; however, when salivary function is significantly reduced, dental caries may develop. An acidogenic environment is created by the low pH of the saliva that promotes the development of aciduric bacteria, causing dental caries[8].

The pathway through which numerous cytokines that are implicated in inflammatory pathologies communicate is called the Janus kinase-signal transducer and activator of transcription pathway. Janus Kinase 1 is involved in signaling by pro-inflammatory cytokines, such as IL-6 and IFN, which are soluble factors produced and secreted by both immune and non-immune cells. Several immune-mediated inflammatory diseases are characterized by the loss of immune homeostasis, which is the result of abnormal cytokine production or responsiveness[9].

Secretory leukocyte protease inhibitor (SLPI) is an anti-protease that protects mucosal tissue integrity through its antimicrobial and immunomodulatory properties. It has the capacity to allow scarless wound healing and keep epithelial integrity of junctional epithelium[10].

SLPI has several important biological functions. It protects tissues against inflammatory products by downregulating the macrophage response to bacterial lipopolysaccharide (LPS). In addition, SLPI safeguards local tissues from the harmful effects of inflammation by inhibiting the activity of various proteases, including cathepsin G, elastase, trypsin, polymorphonuclear neutrophil (PMN) chymotrypsin, acinar cell trypsin, and mast cell chymase. It reduces C5a-related chemotactic activity, promotes cutaneous wound healing, and exhibits antimicrobial activity against bacteria, fungi, and viruses[11].

Periodontitis and diabetes adversely affect each other in a chronic, vicious cycle. Diabetes can also lead to dry mouth and an increased risk of dental caries. On the other hand, HbA1c is increased by periodontitis, causing or worsening diabetes and its complications[12]. Therefore, this study aims to evaluate salivary biomarkers (JAK1 and SLPI) alongside clinical oral examination in patients with different stages of type II diabetes mellitus, compared to people without diabetes, and to assess the association between biochemical and clinical parameters. However, the diagnostic value of salivary JAK1 and SLPI across different glycemic stages remains unclear.

Patients and Methods

Study Design

The eighty individuals who participated in the study were divided into four groups: 20 healthy individuals and 60 with type II diabetes mellitus diagnosed for at least two years. The diabetic patients were divided into three groups (20 in each group) according to their HbA1c levels into prediabetic, controlled, and uncontrolled diabetes according to the American Diabetes Association (ADA)[13]. G Power software version 3.1.9.7 was utilized to determine the sample size depending on data from a previous study using DMFT as primary outcome[14]. An effect size of 0.4 was assumed, with the significance level (α) set at 0.05 and statistical power of 80%. Group 1: healthy individuals with HbA1c (less than 5.7%; 39 mmol/mol). Group 2: prediabetes with HbA1c (between 5.7% and 6.4%; between 39 mmol/mol and 48 mmol/mol). Group 3: controlled type 2 diabetes with HbA1c (between 6.5% and 7.0%; between 48 mmol/mol and 53 mmol/mol). Group 4: uncontrolled type 2 diabetes with HbA1c (More than 7.0%; 53 mmol/mol). Inclusion criteria were male and female patients aged 30-60 years diagnosed with type II diabetes for at least 2 years. Exclusion criteria included those with systemic disease other than diabetes, smokers, pregnant women, and edentulous individuals.

Sample collection

Unstimulated whole saliva was collected from 80 participants aged 30-60 years in the morning, between 9 a.m. and 11 a.m. The individuals were requested to refrain from eating, drinking, and brushing for at least 90 minutes prior to saliva collection. The participants were asked to sit upright in a chair in a cool environment, with their heads slightly bent forward, while collecting saliva. The participants expectorated all secreted saliva directly into sterilized plastic cups every minute for 5 minutes[15]. Salivary pH was measured directly using Merck pH paper (Merck, Germany); the paper strips were dipped into the saliva samples for 1-3 seconds, and the color was compared to the reference chart[8]. The samples were transferred into sterile Eppendorf tubes, placed in a cold box at 4°C, and then stored at -80°C for long-term storage. The saliva samples were placed at room temperature and centrifuged for 20 minutes at 2000 revolutions per minute to get clear supernatant ready for the ELISA test[16]. Salivary concentrations of JAK1 and SLPI were measured by ELISA according to the manufacturer's instructions. The JAK1 ELISA kit had a sensitivity of 0.14 ng/mL with a standard curve range of 0.25-16 ng/mL. The SLPI ELISA kit demonstrated a sensitivity of 10.23 ng/L, and a standard curve range of 20-4500 ng/L. Ethical approval was obtained before conducting the experiment.

Salivary JAK1 and SLPI measurement

ELISA (sandwich technique) was used to measure JAK1 and SLPI levels in saliva samples, using JAK1 and SLPI ELISA kits from (BT LAB/China). The saliva samples were transferred into sterile Eppendorf tubes, placed in a cold box at 4°C, and then stored at -80°C for long-term storage. The saliva samples were placed at room temperature and centrifuged for 20 minutes at 2000 revolutions per minute according to the manufacturer's instructions to get clear supernatant ready for the ELISA test, as shown in Figure 3.

Intra-oral examination

This included examining all 80 participants in the study and recording their clinical attachment loss and DMFT index. To determine if a tooth was decayed, missing, or filled (DMFT /dmft), the WHO modification (World Health Organization, 2013) [17] was followed, in which D/d represents the number of decayed teeth, M/m represents the number of missing teeth due to caries, and F/f represents the number of filled teeth. A systematic approach to examination of tooth condition was conducted, beginning from the upper right side to the upper left side in an orderly manner, followed by the lower teeth in the same manner. Full mouth CAL examination was performed for all participants using William's periodontal probe, and the measurements were recorded, as shown in Figure 3-A. CAL was determined by adding the extent of gingival recession to the probing depth measurement. However, when the recession was not visible, the height of the marginal gingiva coronal to the cementoenamel junction (CEJ) was assessed, and that measurement was subtracted from the probing depth to determine the level of clinical attachment loss[18].

The severity of periodontitis based on the CAL is classified according to the new classification of periodontal diseases by the American Academy of Periodontology into 4 stages[19]: Stage I periodontitis: Interdental CAL of 1-2 mm at ≥ 2 non-adjacent teeth.

- Stage II periodontitis: Interdental CAL of 3-4 mm at ≥ 2 non-adjacent teeth.
- Stage III and IV periodontitis: Interdental CAL of ≥ 5 mm at ≥ 2 non-adjacent teeth.

Reliability was assessed to assess the consistency of the clinical measurements. A strong positive correlation was observed between repeated measurements, with an inter-item correlation coefficient r = 0.931. The interclass correlation coefficient (ICC) was calculated using a two-way mixed effects model with a consistency definition. The analysis demonstrated an ICC value of 0.952 (95% CI: 0.536–0.995; p = 0.006), indicating excellent reliability of the DMFT index measurement. Calibration between examiners for CAL measurements was performed following the same standardized protocol used for DMFT scoring.

Statistical Analysis

To test the normality of data, the Shapiro-Wilk test was used. For data analysis, IBM SPSS version 22 was used. The mean with standard deviation and the median with interquartile range were used for quantitative variables, with the latter used for non-normally distributed data, while for qualitative data, frequencies and percentages were used. ANOVA and the Kruskal-Wallis tests were used to compare the means and medians of normally distributed and non-normally distributed data, respectively. Chi-square test was used for qualitative variables. Spearman's Correlation was used to determine the correlation between quantitative variables, and Multiple linear regression analysis was performed to identify independent predictors of the dental health outcome, DMFT, which was considered the dependent variable, while age, HbA1c, CAL, JAK1, and SLPI were included as independent variables.

Results

Descriptive statistics

A total of 80 participants were included in the study, comprising 35 males (43.8%) and 45 females (56.3%). The median age of the participants was 48.0 years with an interquartile range (IQR) of 41.5 to 54.0 years. The median HbA1c level was 6.5% (IQR: 5.6–8.1), indicating a range of glycemic control among the participants. Salivary JAK1 levels had a median of 0.51 ng/mL (IQR: 0.43–0.60), and SLPI had a median of 0.76 ng/mL (IQR: 0.61–0.91). The mean DMFT score was 10.83 ± 4.89, reflecting the participants' dental caries experience. The median clinical attachment loss (CAL) was 2.83 mm (IQR: 0.0–4.0), and the median salivary pH was 6.0 (IQR: 6.0–7.0), indicating slightly acidic to neutral salivary conditions, as shown in Table 1.

Demographic and Clinical Characteristics

Gender distribution was relatively balanced across all groups, with no significant difference observed ($p = 0.681$). The percentage of males ranged from 55% in the controlled-diabetic group to 35% in the uncontrolled-diabetic group. Age appeared higher in the diabetic groups than in the normal group, but the difference was not statistically significant ($p = 0.073$). As expected, HbA1c levels differed significantly among the groups ($p < 0.001$), with median values increasing progressively from 5.05% in the normal group to 10.7% in the uncontrolled diabetic group. Salivary pH showed a median value of 6.0 across all diabetic groups and 6.5 in the normal group. However, this difference was not statistically significant ($p = 0.614$), as shown in Table 2.

Comparison of Biomarker Levels, Dental Caries, and Periodontal Status Across Glycemic Groups.

There was no statistically significant difference in the levels of salivary JAK1 among the groups ($p = 0.423$). The median JAK1 concentration was 0.58 ng/mL in the controlled diabetic group and it was 0.48 ng/mL in the prediabetic group. Similarly, SLPI levels did not differ significantly between groups ($p = 0.940$), with median value was 0.77 ng/mL in both the prediabetic and controlled diabetic groups and 0.70 ng/mL in the normal group. In contrast, the DMFT scores differed significantly across the groups ($p = 0.031$). The highest scores were observed in the diabetic groups, particularly the controlled diabetic group (12.0 ± 5.9), while the normal group had the lowest mean DMFT score (8.1 ± 4.3). In clinical attachment loss (CAL) between the groups, the normal group had a median CAL of 0.0 mm, which progressively increased with the severity of diabetes, reaching 4.0 mm (IQR: 2.0-5.8) in the uncontrolled diabetic group, which is a statistically significant result ($p = 0.006$), as shown in Table 3.

Spearman's correlation was used to evaluate the relationship between salivary biomarkers (JAK1, SLPI), glycemic control (HbA1c) and clinical dental parameters (CAL, DMFT). A statistically significant positive correlation was observed between HbA1c and CAL ($\rho = 0.420$, $p < 0.001$), indicating that greater periodontal attachment loss was associated with higher HbA1c levels. Additionally, HbA1c was also positively correlated with DMFT ($\rho = 0.248$, $p = 0.027$), suggesting a link between increased dental caries experience and poor glycemic control. JAK1 showed a moderate positive correlation with SLPI ($\rho = 0.532$, $p < 0.001$), whereas no significant correlations were observed between the other clinical parameters and JAK1. SLPI was not significantly correlated with HbA1c, DMFT, or CAL. No significant correlations were detected between CAL and either salivary biomarker (JAK1 or SLPI), nor between DMFT and the salivary biomarkers, as shown in Table 4.

Multiple Linear Regression

To recognize factors associated with DMFT scores, Multiple linear regression analysis was used. The model included age, salivary JAK1, SLPI, HbA1c and clinical attachment loss (CAL) as independent variables. None of the predictors showed a statistically significant association with DMFT scores. Age demonstrated a marginal positive association with DMFT ($B = 0.136$, $p = 0.092$), but this did not reach statistical significance. HbA1c ($B = 0.225$, $p = 0.353$), JAK1 ($B = 3.311$, $p = 0.260$), SLPI ($B = -1.128$, $p = 0.559$), and CAL ($B = 0.069$, $p = 0.795$) were also not significantly associated with DMFT scores. These findings suggest that within the studied sample, none of the included variables were significant predictors of dental caries experience as measured by DMFT, as shown in Figure 1.

Multiple linear regression analysis was utilized to assess the association between age, salivary JAK1, SLPI, HbA1c, and DMFT scores with the dependent variable (CAL). The model revealed that both HbA1c and age were statistically significant predictors. Specifically, age demonstrated a significant positive association ($B = 0.152$, $SE = 0.031$, standardized $\beta = 0.486$, 95% CI: 0.090–0.214, $p < 0.001$), indicating that the dependent variable increased with increasing age. Similarly, HbA1c showed a significant positive effect ($B = 0.331$, $SE = 0.099$, standardized $\beta = 0.315$, 95% CI: 0.134–0.529, $p = 0.001$), indicating that higher glycemic levels were associated with higher outcome measure values. In contrast, DMFT as well as the salivary biomarkers JAK1 and SLPI scores were not significantly associated with the outcome. Salivary JAK1 ($B = 0.597$, $SE = 1.291$, standardized $\beta = 0.050$, 95% CI: –1.975 to 3.168, $p = 0.645$). Similarly, SLPI was not significantly associated with the outcome ($B = –0.639$, $SE = 0.844$, standardized $\beta = –0.081$, 95% CI: –2.321 to 1.043, $p = 0.452$). DMFT also did not exhibit a statistically significant effect within the regression model ($B = 0.013$, $SE = 0.051$, standardized $\beta = 0.025$, 95% CI: –0.088 to 0.115, $p = 0.795$). These findings suggest that among the studied variables, only age and glycemic control (HbA1c) had a meaningful influence on the dependent outcome, whereas salivary biomarkers and dental caries index (DMFT) did not show significant associations in this analysis, as shown in Figure 2.

Table 1: Descriptive statistics for the number or percentage of the demographic characteristics, clinical parameters, and salivary biomarkers.

	Variables	Frequency (%)
Gender		
Male		35 (43.8%)
Female		45 (56.3%)
Age (Year)	Median (IQR)	48.0 (41.5-54.0)
HbA1c (%)	Median (IQR)	6.5 (5.6-8.1)
JAK1 (ng/mL)	Median (IQR)	0.51 (0.43-0.60)
SLPI (ng/mL)	Median (IQR)	0.76 (0.61-0.91)
DMFT	Mean ± SD	10.83 ± 4.89
CAL (mm)	Median (IQR)	2.83 (0.0-4.0)
Salivary pH	Median (IQR)	6.0 (6.0-7.0)

Table 2: Demographic and Clinical Characteristics Across Glycemic Status Groups.

Variable		Normal (n=20)	Prediabetic (n=20)	Controlled DM (n=20)	Uncontrolled DM (n=20)
Age	Median (IQR)	39.5 (34.0-49.5)	50.0 (46.0-54.5)	50.5 (45.0-54.0)	45.5 (44.5-51.5)
Sex					
Male	n (%)	9 (45.0%)	8 (40.0%)	11 (55.0%)	7 (35.0%)
Female		11 (55.0%)	12 (40.0%)	9 (45.0%)	133 (65.0%)
HbA1c (%)	Median (IQR)	5.05 (4.9-5.3)	6.25 (6.0-6.4)	6.95 (6.8-7.0)	10.7 (9.8-12.4)
Salivary pH	Median (IQR)	6.5 (6.0-7.0)	6.0 (6.0-7.0)	6.0 (6.0-7.0)	6.0 (6.0-7.0)

*Determined by Kruskal-Wallis Test, **Determined by Chi-square Test

Table 3: Comparison of Biomarker Levels, Dental Caries, and Periodontal Status Across Glycemic Groups.

Variable		Normal (n=20)	Prediabetic (n=20)	Controlled DM (n=20)	Uncontrolled DM (n=20)	*p-value*
JAK1(ng/mL)	Median (IQR)	0.51 (0.41-0.60)	0.48 (0.41-0.58)	0.58 (0.45-0.63)	0.52 (0.42-0.59)	0.423**
SLPI (ng/mL)	Median (IQR)	0.70 (0.52-0.83)	0.77 (0.62-0.97)	0.77 (0.66-0.91)	0.76 (0.60-0.96)	0.940**
DMFT	Mean± SD	8.1 ± 4.3	11.95 ± 4.2	12.0 ± 5.9	11.3 ± 4.2	0.031*
CAL (mm)	Median (IQR)	0.0 (0.0-1.6)	2.0 (1.0-3.9)	3.7 (1.8-4.6)	4.0 (2.0-5.8)	0.006**

*Determined by one-way ANOVA Test, **Determined by Kruskal-Wallis Test

Table 4: Spearman's Correlation Coefficients between HbA1c, salivary biomarkers (JAK1, SLPI) and clinical parameters (CAL, DMFT).

Parameters	HbA1c (ρ)	*P-value*	JAK1 (ρ)	*P-value*	SLPI (ρ)	*P-value*	CAL (ρ)	*P-value*	DMFT (ρ)	*P-value*
HbA1c	1.0	-	0.071	0.533	0.144	0.204	0.420	<0.001	0.248	0.027
JAK1	0.071	0.533	1	-	0.532	<0.001	-0.113	0.319	0.103	0.364
SLPI	0.144	0.204	0.532	<0.001	1	-	0.038	0.736	0.150	0.183
CAL	0.420	<0.001	-0.113	0.319	0.038	0.736	1	-	0.137	0.226
DMFT	0.248	0.027	0.103	0.364	0.150	0.183	0.137	0.226	1	-

Spearman's Correlation (ρ)

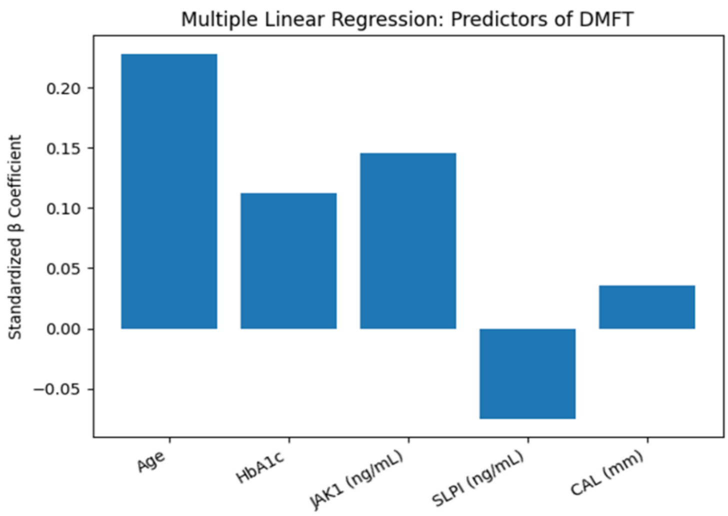

Figure 1: Multiple Linear Regression Analysis of the Association Between Age, HbA1c, Salivary Biomarkers (JAK1 and SLPI), Clinical Attachment Loss (CAL), and DMFT Scores.

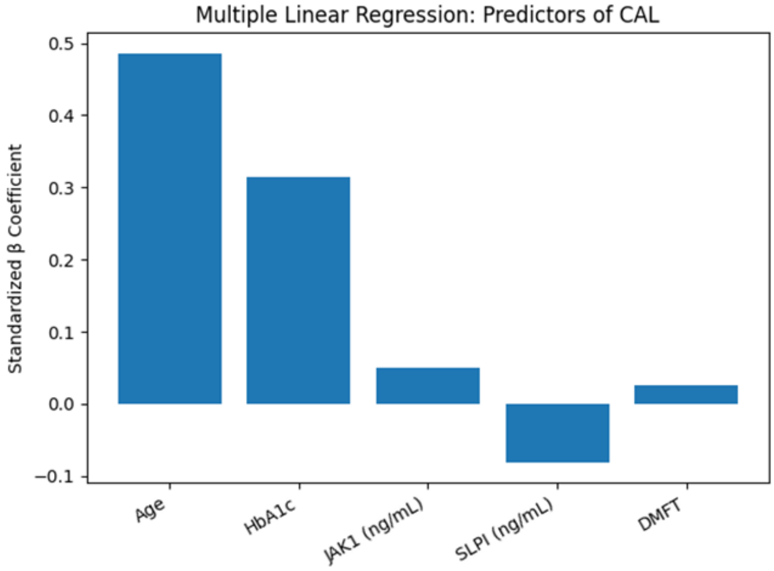

Figure 2: Multiple Linear Regression Analysis of the Association Between Age, HbA1c, Salivary Biomarkers (JAK1 and SLPI), DMFT scores, and Clinical Attachment Loss (CAL).

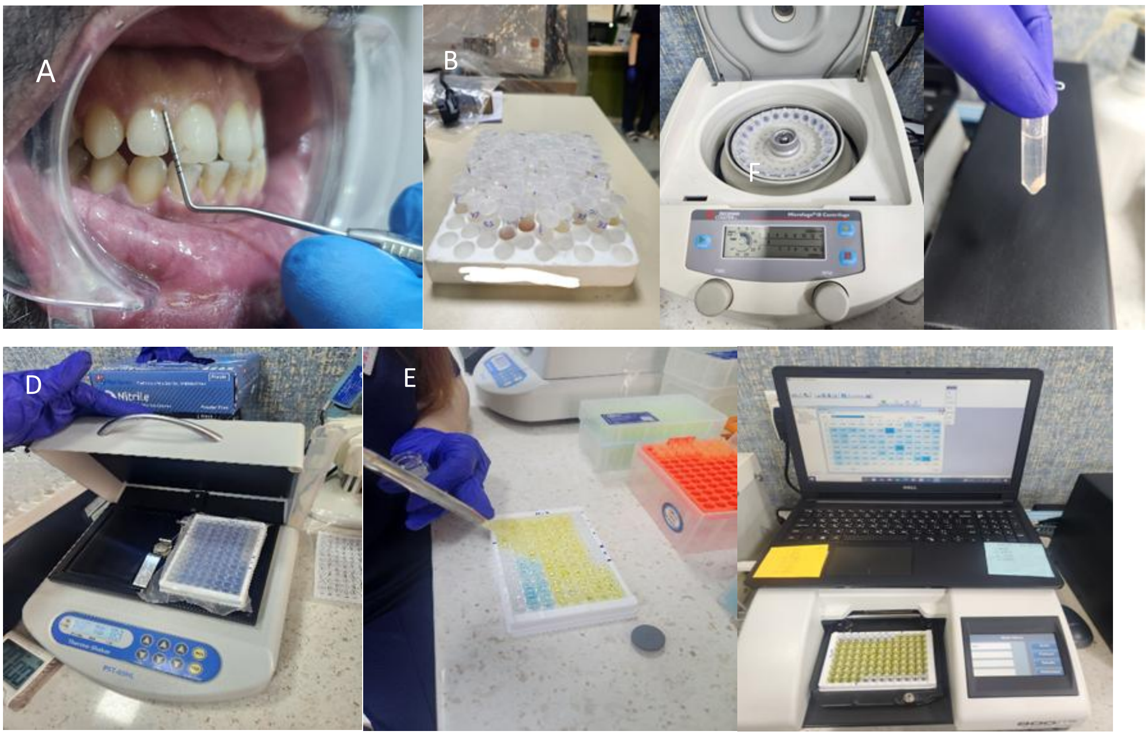

Figure 3: **A:** Full mouth clinical data collection. **B:** Saliva collection from participants. **C:** Saliva samples centrifugation. **D:** Obtaining supernatant. **E:** Saliva samples in incubator. **F:** Color changing of saliva samples after adding Stop Solution to each well. **G:** Determining the optical density of each well using a microplate reader.

Discussion

Type II diabetes mellitus is a substantial worldwide health issue. At present, the diagnosis of diabetes mellitus is determined through the invasive assessment of serological parameters, which may be discomforting for the patient. It is intriguing that novel diagnostic methods, such as the use of non-invasive methods to obtain specimens such as saliva, are currently being implemented[20].

New and recurrent dental lesions are more likely to develop in diabetic patients, and a decrease in the salivary purifying and buffering capacity can increase the incidence of tooth decay. Inadequate glycemic control can be linked to the outbreak and progression of gingivitis, periodontitis, and alveolar bone loss. The prevalence of severe periodontitis in nondiabetic patients is 39%, while in diabetic patients it is 59.6%[21].

Saliva is an appropriate biomaterial that offers a modern and readily accessible physiological fluid that can be obtained in a non-invasive manner and evaluated using a variety of analytical methods[22]. The Enzyme-Linked Immunosorbent Assay (ELISA) is a widely used method for the detection and quantification of specific proteins, such as salivary biomarkers, in biological samples[23].

The mean age of participants demonstrated a progressive increase from the normal to uncontrolled diabetic group, which is consistent with the well-established trend that impaired glucose tolerance and type 2 diabetes become more prevalent as age increases. This finding is consistent with the findings of Ahmed et al. (2017) and Al-Maweri et al. (2021), who attributed this pattern to the accumulation of metabolic risk factors over time [16,24]. The sex distribution in our sample was relatively balanced, with no statistically significant differences between the categories. This parity minimizes the likelihood of sex-related confounding effects in biomarker and oral health outcomes, as hormonal and behavioral factors have been demonstrated to affect salivary composition and periodontal status[25].

Although previous research has established a correlation between systemic inflammation in diabetes and JAK-STAT signaling pathways, the salivary levels observed in this study did not adequately reflect these associations[26]. The glycemic groups did not show any statistically significant differences in the salivary concentrations of JAK1 and SLPI. Similarly, SLPI displayed constant levels across all groups, suggesting that its expression may be controlled by processes other than glucose management, such as systemic immunological responses or local oral inflammation[10]. The salivary levels found in this investigation would reflect localized rather than systemic inflammatory activity.

Our results differ from a study conducted by Sun et al, 2024 in which blood SLPI levels were observed to fluctuate greatly across healthy controls, individuals with diabetes, and patients with varied stages of diabetic kidney disease (DKD). The concentrations were progressively higher at more advanced stages of illness. The different regulation mechanisms and compartmentalization of these biomarkers in systemic circulation vs oral fluids may be indicative of the considerable disparities in serum—but not salivary—SLPI levels[27].

Although there were no significant differences in salivary JAK1 levels across glycemic groups or clinical parameters in the current investigation, there was a positive association between JAK1 and SLPI ($r = 0.532$, $p < 0.001$), suggesting a potential role in regulating the oral immune system. In contrast, Yang et al. (2023) demonstrated that Inhibiting JAK1 in human periodontal ligament stem cells reduced inflammatory damage and enhanced osteogenic differentiation. The current study investigated total salivary JAK1, which may not reflect its intracellular activity, while Yang et al. focused on activated JAK1 (phosphorylated form) under inflammatory conditions. The discrepancy in observed outcomes is likely related to differences in study models—in vitro cellular stress versus in vivo salivary biomarker analysis[28].

Our findings did not show a statistically significant association between the presence or severity of dental caries and JAK1 concentrations. The study suggests that salivary JAK1 may not be a sensitive or specific biomarker for caries-related processes in the oral environment, despite its well-known role in inflammatory signaling through the JAK-STAT pathway, consistent with the results of a study by Paqué et al. (2023). Although participants with poor oral health exhibited a decline in SLPI, the glycemic groups did not show significant differences in salivary SLPI levels, and these levels were not strongly associated with caries or periodontal status. This is consistent with the findings of a study by Ahmed and Al-Jubouri (2017). The combined findings of both studies indicate that SLPI levels may not be a dependable diagnostic indicator for periodontal disease or caries, even if it may have a protective effect on oral health[16,29].

The results of the current study indicate that clinical oral health parameters, including periodontal status (CAL) and dental caries experience (DMFT), varied significantly among various glycemic control groups. In comparison to the healthy participants, members of the diabetic groups, particularly those with controlled and uncontrolled diabetes, exhibited significantly greater clinical attachment loss and higher DMFT, which is similar to several other studies[30-33]. Although diabetes mellitus has been associated with an elevated risk of dental caries due to changes in pH, salivary composition, and the host immune response, this association is not inevitable. There is evidence to suggest that individuals who adhere to well-regulated oral hygiene practices, including interdental cleansing, regular toothbrushing and routine professional dental care, can keep caries rates that are comparable to those of non-diabetic individuals[34,35].

In this study, the uncontrolled diabetic group exhibited a substantially higher level of Clinical Attachment Loss (CAL) than the controlled diabetics and healthy individuals. This result is consistent with other studies, who reported that higher CAL values were found in patients with inadequately controlled type 2 diabetes than both well-controlled diabetics and non-diabetic controls[36-38]. Compared with the study by Luong et al. (2021), notable differences in methodology are evident. Although our research was based on clinical measurements of CAL and periodontal status in diabetic patients, Luong et al. conducted a thorough examination of the molecular mechanisms linking periodontitis and diabetes. Their analysis underscores common inflammatory pathways, including elevated pro-inflammatory cytokines (e.g., TNF-α, IL-6), oxidative stress, and altered immune responses. These pathways contribute to both periodontal tissue disintegration and impaired glycemic regulation. Although the two studies differ in their methodologies, they both acknowledge that diabetes has a substantial impact on periodontal health[39].

The uncontrolled diabetic participants in the current study exhibited a lower salivary pH, with the lowest values compared to the normal healthy group. This acidic shift in the salivary environment may increase susceptibility to dental caries and periodontal destruction, emphasizing the adverse effects of poor glycemic control on oral homeostasis. Prathibha et al. also reported a reduction in salivary pH among type 2 diabetes mellitus (T2DM) patients when compared to non-diabetics[40].

The present study has several limitations. First, the relatively small sample size and single-center recruitment may restrict the generalizability of the findings to the broader population. Additionally, potential confounding factors such as oral hygiene practices, dietary habits, and medication used were not fully controlled and may have influenced the results. Another limitation of this study is its cross-sectional design, which limits the ability to establish causal relationships among the variables studied. Also, salivary biomarker levels can be affected by physiological and environmental factors such as saliva flow rate. The absence of longitudinal follow-up limits the ability to assess changes in biomarker levels and periodontal status over time. Finally, the study lacks a comparison of inflammatory markers.

Conclusion

This study reveals that salivary JAK1 and SLPI levels do not significantly differ across those individuals with varying glycemic control, suggesting limited diagnostic value of these biomarkers for diabetes detection or oral disease evaluation. Nonetheless, their positive correlation shows a possible interaction in local immune regulation within the oral cavity. Clinically, diabetic patients- particularly those with poor glycemic control- exhibited greater clinical attachment loss, higher DMFT scores, and lower salivary pH, emphasizing the detrimental impact of hyperglycemia on oral health. These findings reinforce the importance of maintaining optimal glycemic control and strict oral hygiene practices to prevent caries progression and periodontal deterioration in patients with diabetes.

Declarations

Ethics Approval and Informed Consent (Institutional Review Board) Statement: This research was approved by the Ethics Committee of the College of Dentistry, University of Sulaimani, Iraq, under application No. (COD-EC-24-0033), Issued on 16/12/2024. Informed consent statement: Written informed consent was obtained from all participants prior to their inclusion in the study.

Author Contributions: RAS; Conceptualization, Writing the manuscript, software and validation, data collection and curation, and project administration. FAK: Writing and Supervision. All authors have read and agreed to the published version of the manuscript.

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Data Availability Statement: The data that support the findings of this study are available from the corresponding author upon reasonable request.

Additional information: No additional information is available for this paper.

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References

1. Leite RS, Marlow NM, Fernandes JK, Hermayer K. Oral health and type 2 diabetes. Am J Med Sci. 2013 Apr;345(4):271-3.
2. Petersmann A, Nauck M, Müller-Wieland D, Kerner W, Müller UA, Landgraf R, et al. Definition, classification and diagnosis of diabetes mellitus. Exp Clin Endocrinol Diabetes. 2018;126(7):406-10.
3. Nazir MA, AlGhamdi L, AlKadi M, AlBeajan N, AlRashoudi L, AlHussan M. The burden of diabetes, its oral complications and their prevention and management. Open Access Maced J Med Sci. 2018 Aug 15;6(8):1545-53.
4. Mahmood TJ, Zardawi1 FM. Evaluation of salivary biomarkers and their correlation to periodontal status and BMI. Sulaimani Dent J. 2025 Feb 16;7(2):25–35. doi:10.17656/sdj.10113
5. Casanova L, Hughes FJ, Preshaw PM. Diabetes and periodontal disease. BDJ Team. 2015;1(1):7-11. doi:10.1038/bdjteam.2015.7
6. Daniel R, Gokulanathan S, Shanmugasundaram N, Lakshmigandhan M, Kavin T. Diabetes and periodontal disease. J Pharm Bioallied Sci. 2012;4(Suppl 2):S280-2.
7. Kamaran S, Sha AM. Antibacterial and Antibiofilm Potency of Ziziphora clinopodioides Essential Oil: An In Vitro Study. Sulaimani Dent J. 2025;12(3):21-30.
8. Seethalakshmi C, Reddy RCJ, Asifa N, Prabhu S. Correlation of salivary pH, incidence of dental caries and periodontal status in diabetes mellitus patients: A Cross-sectional Study. J Clin Diagn Res. 2016;10(3):ZC12-4.
9. Spinelli FR, Colbert RA, Gadina M. JAK1: Number one in the family; number one in inflammation? Rheumatology (Oxford). 2021;60(Suppl 2):i3-10.
10. Afacan B, Öztürk VÖ, Emingil G, Köse T, Mitsakakis K, Bostanci N. Salivary secretory leukocyte protease inhibitor levels in patients with stage 3 grade C periodontitis: a comparative cross-sectional study. Sci Rep. 2022 Dec 8;12:21267.
11. Pateel D, Seema H, Kale A. Role of salivary leukocyte protease inhibitor in periodontal disease progression. J Indian Soc Periodontol. 2010;14(2):109-13.
12. Borgnakke WS. IDF Diabetes Atlas: Diabetes and oral health – A two-way relationship of clinical importance. Diabetes Res Clin Pract. 2019;157:107839.
13. Zhang C, Yang J. Personalizing physical activity for glucose control among individuals with type 2 diabetes: Are we there yet? Diabetes Care. 2024;47(2):196-8.
14. Salehi M, Mesgarani A, Karimipour S, Pasha SZ, Kashi Z, Abedian S, et al. Comparison of salivary cortisol level in type 2 diabetic patients and pre-diabetics with healthy people. Open Access Maced J Med Sci. 2019;7(14):2321-7.
15. Hoseini A, Mirzapour A, Bijani A, Shirzad A. Salivary flow rate and xerostomia in patients with type I and II diabetes mellitus. Electron Physician. 2017;9(9):5244-9.
16. Ahmed RF, Al-Jubouri RH. Oral health status, salivary MMP-8& secretory leukocyte peptidase inhibitor (SLPI) among uncontrolled type-I diabetes mellitus In Iraqi patients. JBCD. 2017;29(2):2.
17. World Health Organization, editor. Oral health surveys: basic methods. 5th edition. Geneva: World Health Organization; 2013. 125 p.
18. Pihlstrom BL. Measurement of attachment level in clinical trials: probing methods. J Periodontol. 1992;63(12 Suppl):1072-7.
19. Tonetti MS, Greenwell H, Kornman KS. Staging and grading of periodontitis: Framework and proposal of a new classification and case definition. J Periodontol. 2018;89(S1):S159-72.
20. Agho ET, Owotade FJ, Kolawole BA, Oyetola EO, Adedeji TA. Salivary inflammatory biomarkers and glycated haemoglobin among patients with type 2 diabetic mellitus. BMC Oral Health. 2021;21:101.
21. Rohani B. Oral manifestations in patients with diabetes mellitus. World J Diabetes. 2019;10(9):485-9.
22. Jiao LL, Dong HL, Liu MM, Wu PL, Cao Y, Zhang Y, et al. The potential roles of salivary biomarkers in neurodegenerative diseases. Neurobiol Dis. 2024;193:106442.
23. Hu CC, Wang SG, Gao Z, Qing MF, Pan S, Liu YY, et al. Emerging salivary biomarkers for early detection of oral squamous cell carcinoma. World J Clin Oncol. 2025;16(4):103803.
24. Al-Maweri SA, Altayyar MO, AlQahtani KW, Bamasud MS, AlGhamdi OY, Ashraf S, et al. Xerostomia, salivary flow, and oral health status among Saudi diabetic patients: A Comparative Cross-Sectional Study. CCIDE. 2021;13:451-8.
25. Shiau HJ, Reynolds MA. Sex differences in destructive periodontal disease: a systematic review. J Periodontol. 2010;81(10):1379-89.
26. O'Shea JJ, Schwartz DM, Villarino AV, Gadina M, McInnes IB, Laurence A. The JAK-STAT pathway:

impact on human disease and therapeutic intervention. Annu Rev Med. 2015;66:311-28.
27. Sun W, Yang H, Zhang J, Wei S, Wu Q, Yang J, et al. Secretory leukocyte protease inhibitor as a novel predictive biomarker in patients with diabetic kidney disease. Front Endocrinol (Lausanne). 2024;15:1334418.
28. Yang P, Shi F, Zhang Y. Baricitinib alleviates lipopolysaccharide-induced human periodontal ligament stem cell injury and promotes osteogenic differentiation by inhibiting JAK/STAT signaling. Exp Ther Med. 2023;25(2):1-10.
29. Paqué PN, Herz C, Wiedemeier DB, Mitsakakis K, Attin T, Bao K, et al. Salivary biomarkers for dental caries detection and personalized monitoring. J Pers Med. 2021;11(3):3.
30. Latti BR, Kalburge JV, Birajdar SB, Latti RG. Evaluation of relationship between dental caries, diabetes mellitus and oral microbiota in diabetics. J Oral Maxillofac Pathol. 2018;22(2):282.
31. Shiferaw A, Alem G, Tsehay M, Kibret GD. Dental caries and associated factors among diabetic and nondiabetic adult patients attending Bichena Primary Hospital’s Outpatient Department. Front Oral Health. 2022;3:938405.
32. Nassar M, Nassar O, Abosheaishaa H, Elhakim N. Association between type 1 diabetes mellitus and dental caries: A systematic review and meta-analysis. Dent Rev. 2024;4(2):100088.
33. Singh I, Singh P, Singh A, Singh T, Kour R. Diabetes an inducing factor for dental caries: A case control analysis in Jammu. J Int Soc Prev Community Dent. 2016;6(2):125-9.
34. Alqadi SF. Diabetes mellitus and its influence on oral health: Review. DMSO. 2024 ;17:107-20.
35. Chen H, Hill R, Baysan A. Systematic review on dental caries preventive and managing strategies among type 2 diabetic patients. Front Oral Health. 2022;3:998171.
36. Chung YL, Lee JJ, Chien HH, Chang MC, Jeng JH. Interplay between diabetes mellitus and periodontal/pulpal-periapical diseases. J Dent Sci. 2024;19(3):1338-47.
37. Rajhans NS, Kohad RM, Chaudhari VG, Mhaske NH. A clinical study of the relationship between diabetes mellitus and periodontal disease. J Indian Soc Periodontol. 2011;15(4):388-92.
38. Ibraheem LM, Ahmmad BZ, Dhafer AM, Dhafer JM. Effect of diabetes mellitus on periodontal health status, salivary flow rate and salivary pH in patients with chronic periodontitis. JBCD. 2020;32(2):2.
39. Luong A, Tawfik AN, Islamoglu H, Gobriel HS, Ali N, Ansari P, et al. Periodontitis and diabetes mellitus co-morbidity: A molecular dialogue. J Oral Biosci. 2021;63(4):360-9.
40. Prathibha KM, Johnson P, Ganesh M, Subhashini AS. Evaluation of salivary profile among adult type 2 diabetes mellitus patients in South India. J Clin Diagn Res. 2013;7(8):1592-5.

Original Article

Correlation between Upper Airway Volume and Morphology with Skeletal Malocclusions in Adults with Normal Sagittal Position of the Mandible Using Cone Beam Computed Tomography

Khamgen T. Taha[*1], Ranj A. Jalal[1]*

Abstract

Objectives: To investigate the effects of Class I, II, and III malocclusions on upper airway (UA) volume and shape in adult normal mandibular position subjects using a Cone Beam Computed Tomography (CBCT).

Methods: This cross-sectional study recruited 60 adults (20 per group) with Class II and III skeletal malocclusions (SM) and a normal sagittal mandibular position (Class I) between November 2024 and April 2025 at the Oral and Maxillofacial clinics, Dental Clinic, College of Dentistry, University of Sulaimani, Sulaymaniyah, Kurdistan Region, Iraq. The 3D images of the upper airway were obtained via CBCT, and the volumes of the nasopharynx, oropharynx, and hypopharynx were measured and statistically compared.

Results: Among individuals, 35 were women, and 25 were men, yielding a gender ratio of 1.4:1. Ages ranged from 19 to 38 years, with a mean of 28.82 ± 5.87 years. The nasopharyngeal volumes for Class III patients were significantly larger (12.97 ± 2.04 cm^3) compared to Class I (8.96 ± 1.55 cm^3) and Class II (7.89 ± 0.96 cm^3) ($p < 0.001$). Significant differences were reported between the oropharynx and hypopharynx, with the most essential volumes in Class III patients, who had a higher prevalence of elongated airway morphology (35%). In contrast, Class II patients had a higher proportion of collapsed airway morphology (15%).

Conclusions: SM in Class III are associated with larger nasopharyngeal, oropharyngeal, and hypopharyngeal volumes than in other classes, reflecting anatomical associations rather than causation.

Keywords: *Airway morphology, Cone Beam Computed Tomography, Skeletal malocclusion, Upper airway.*

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Introduction

A relationship has been established between craniofacial morphology and the UA, with significant implications for respiration. Alterations in UA volume are known to be associated with different forms of SM studied experimentally, such as Classes II and III, which may be linked to their functions regarding breathing performance and health[1]. Dental bite classifications, including Class I, II, and III malocclusions, are based on the relationship between the upper and lower first molars. A Class I bite has a normal molar relationship, a Class II bite shows the lower jaw is behind the upper jaw, and a Class III bite shows the lower jaw is in front of the upper jaw[2].

Cone Beam Computed Tomography (CBCT) is a recent imaging modality for the accurate delineation of skeletal configurations and airway dimensions. Its three-dimensional (3D) volumetric measurements provide information on airway morphology and its structural correlation to skeletal malocclusions (SM)[3,4]. The sagittal area of the mandible is commonly a baseline reference for evaluating airway size differences in adults[5]. Differences in airway volume may be correlated to the distinct outlines of vertical growth, palatal inclinations, and maxillary widths. Considering these associations is important for orthodontists, chiefly in patients with a history of orthognathic surgery and/or management of an occlusal discrepancy, to recover craniofacial growth and development, preferably serving to normalize airway-linked physiological function[6]. Volumetric CBCT studies demonstrate differences in upper-airway dimensions across skeletal patterns, even when the mandibular sagittal position is normal. To limit confounding from mandibular prognathism/retrognathism, SNB (sella [S], nasion [N], and point B is a cephalometric angle measured on a lateral skull X-ray to determine the position of the mandible relative to the anterior cranial base and is constrained to a normative range (78°–82°) between-class comparisons[7].

Studies suggest that individuals with either increased vertical proportions of the face or retrognathic maxillae have lower pharyngeal airway volumes and may be more prone to airway obstruction. Volumetric assessment of the airway on CBCT provides a standardized method for characterizing airway constrictions and can serve as a tool for early intervention among persons at risk[8]. Thus, efforts were made to restrict the latter by using an adult sample with normal mandibular position and to exclude confounding factors by separately assessing the effects of skeletal and dental morphology on airway dimensions. This offers a better appreciation of the craniofacial aspects that impact respiration[9]. An accurate assessment of the airway is increasingly appreciated in both orthodontic and oral/maxillofacial surgery treatment planning. Traditional cephalometry cannot accurately represent the 3D morphology of the UA; therefore, CBCT is required for a more accurate assessment[10]. This study aimed to determine the effects of SM on airway dimensions and morphology in patients with a normal mandibular position, Class II, and Class II SM without temporomandibular disorder (TMD), using CBCT, with a specific focus on molar and canine relationships.

Patients and methods

Research design and setting

This cross-sectional study was conducted from December 2024 to April 2025. Ethical approval was obtained from the College of Dentistry, University of Sulaimani, with approval No: 24-257 on December 16, 2024. Sixty adult participants with skeletal Class I, II, and III malocclusions (n=20 each) were recruited from the Oral and Maxillofacial Clinic, College of Dentistry, University of Sulaimani, Sulaymaniyah, Iraq. Imaging was done when participants were placed in a standardized sagittal mandibular position. With emphasis on the nasopharynx, oropharynx, and hypopharynx, the interrelation between the SM and the UA volume was also assessed. Examining the effects of malocclusion on UA size and its relationship to molar and canine relationships was the primary goal.

Inclusion criteria

Participants aged ≥18 years who were diagnosed with SM Class II or III or confirmed normal sagittal mandibular position through clinical and radiographic assessments. Patients included in this study were those who attended the clinic for full-skull radiographic examination based on a clear clinical indication. Before inclusion, each patient underwent a clinical assessment for TMD, including history taking for jaw pain, joint sounds, limited or deviated mouth opening, chewing pain, and temporal headache, followed by a standardized examination of the temporomandibular joint and masticatory muscles. Patients without clinical signs or symptoms of TMD were included.

Exclusion criteria

Individuals with craniofacial abnormalities, a history of thumb-sucking beyond age 5 years old, chronic tonsillitis, significant airway obstruction, facial reconstructive surgery or fillers, smoking history, cancer (particularly head and neck cancers), obesity (body mass index of ≥30), sleep apnea, and TMD (to ensure the focus on the effects of malocclusion on airway volume).

CBCT acquisition and processing

All CBCT scans were performed using a Carestream 9600 machine with a field of view (16×17 cm) and exposure settings (120 kV, 5.0 mA, 40 seconds). Patients were positioned in a standard head posture, with their teeth in maximum intercuspation, and instructed to breathe normally without swallowing during the scan to ensure consistency across scans. The isotropic voxel size was 0.30 cm, and volumes were reconstructed with standardized head orientation and verified in multiplanar reformats.

Airway segmentation

Nasopharynx (hard-palate plane to C1), oropharynx (posterior nasal spine [PNS]–odontoid plane to antero-inferior C2), and hypopharynx (C2 plane to the superior hyoid margin) were segmented with a semi-automatic region-growing workflow plus manual refinement on axial/coronal/sagittal views using predefined planes.

Airway volume measurement

The nasopharynx was superior at the level of the hard palate (high pharynx level). It was inferior at the first cervical vertebra (C1). At the same time, the oropharynx was delineated with the superior border as the line from the PNS to the odontoid process and the inferior border as the line from the antero-inferior border of the C2 vertebra. The superior border for the hypopharynx was the line from the antero-inferior border of C2, and the inferior border was the horizontal line contacting the most superior margin of the body of the hyoid bone (Figure 1). Total airway volume and minimal cross-sectional area (cm^3) were obtained for each subject for nasopharynx, oropharynx, and hypopharynx (Table 1). The airway was also segmented and outlined with reference lines and measurement points, likely corresponding to the nasopharynx, oropharynx, and hypopharynx (Figure 2).

Cephalometric analysis

Lateral cephalograms were reconstructed from the CBCT data and analyzed manually by the examiner using WebCeph software. All measurements were visually inspected and verified by the examiner using standard diagnostic criteria to minimize error and ensure accuracy. The analysis was fully clinician-driven and not dependent on automated AI-based interpretation.

Skeletal classification

Skeletal Class was defined primarily by ANB (Class I: 0°–4°; Class II: >4°; Class III: <0°) and corroborated by Wit's appraisal (Class I: −1 to +1 cm^3; Class II: > +1 cm^3; Class III: < −1 cm^3). To isolate skeletal-pattern effects independent of extreme mandibular displacement, the mandibular sagittal position was constrained to a normative range (SNB of 78°–82°); subjects outside this window were excluded.

Patient examination

A complete clinical examination was performed to assess skeletal discrepancies and mandibular position. This included medical and dental history, extraoral and intraoral examinations, and evaluation of occlusion and temporomandibular joint function. All findings were recorded using a standardized protocol to reduce examiner bias and ensure consistency among patients.

Volumetric measurements

WebCeph software was used to determine the volume of the nasopharynx, oropharynx, and hypopharynx in cm^3. The key measurements were nasopharynx volume from the back of the nasal cavity to the soft palate, and oropharynx volume from the soft palate to the epiglottis. To ensure consistency in clinical evaluation, CBCT, volumetric measurement, and clinical examination were completed by a single examiner.

Sample size calculation

Power calculations for gender differences estimated a priori for an omnibus test (ANOVA/Kruskal–Wallis) with a medium effect (f=0.25), α=0.05, three groups, and 80% power needed (n=159). Because of resource limitations, this study aimed to recruit 60 patients (20/group), which was considered exploratory with an emphasis on effect sizes and 95% CIs. This estimate can be used to inform a future definitive sample-size calculation.

Statistical analysis

The data were analyzed using the Statistical Package for the Social Sciences (IBM, Chicago, USA, version 26). For descriptive statistics, data were presented as numbers, percentages, means ± SD, and 95% CIs. The Shapiro-Wilk test was used to determine the normality of the data. Age was then compared among groups using the Kruskal-Wallis test, while gender and airway morphology distribution were assessed using the Chi-Square test. Airway measurements were compared using the Mann–Whitney U test, with Bonferroni correction applied for three pairwise comparisons (adjusted α = 0.017).

Results

Participant characteristics

Participants' age ranged from 19 to 38 years, with a mean of 28.82 ± 5.87 years and a 95% CI of 27.22–30.4 years. Class I participants were aged 20 - 38 years, with a mean age of 29.10 ± 5.72 years and a 95% CI of 26.42 - 31.78 years. Class II participants were aged 19 to 38 years, with a mean of 29.65 ± 5.90 years and a 95% CI of 26.89 - 32.41 years. In Class III, ages ranged from 19 to 38 years (mean 27.44 ± 6.13 years; 95% CI, 24.17-30.7 years). Gender was equally distributed between the Class I and II groups (12 females and eight males each), while Class III included 11 females (55%) and nine males (45%). The male-to-female ratio was 1.5:1 for Classes I and II and 1.22:1 for Class III. There was no significant difference in age group (p=0.539) or gender distribution (p=0.934) among the classes (Table 2).

Airway volumetric measurements and SMs

For the nasopharynx, the mean volumes for Classes I, II, and III were 8.96±1.55, 7.89±0.96, and 12.97±2.04 cm³, respectively, with a non-significant reduction in the nasopharyngeal volume in Class I compared to II (p=0.036). At the same time, a noticeable increase in Class III (p<0.001) was observed, showing a prolonged nasopharyngeal space in Class III.

For the oropharynx, the mean volumes for Classes I, II, and III were 9.35± 3.48, 8.61±3.95, and 12.0± 5.48 cm³, respectively, with no significant differences between Class I and II (p=0.587). In addition, no significant differences were observed between Class II vs. III (p=0.049) and Class I vs. III (p=0.03), with Class III showing greater oropharyngeal space construction, indicating a prolonged airway volume in this Class. The mean volumes for Classes I, II, and III were 9.49±2.97, 7.95±5.03, and 12.28±4.14 cm³, respectively, in the hypopharynx; the only significant difference was observed between Class II and Class III (p=0.002). Class III had a prolonged hypopharyngeal space, meaning a larger airway volume than Classes I/II (Table 3).

Airway morphology and SMs

In Class I, 18 patients (90%) exhibited normal airway morphology, 2 patients (10%) displayed an elongated airway, and none had a collapsed airway. In Class II, 16 patients (80%) had a normal airway, 3 patients (15%) had a collapsed airway, and 1 patient (5%) had an elongated airway. In Class III, 12 patients (60%) had a normal airway, 1 (5%) had a collapsed airway, and 7 (35%) had an elongated airway. The analyses between Class I and II and between Class I and III did not reach statistical significance (p>0.05), whereas the analysis between Class II and Class III was significant (p=0.048) (Figure 4 and Table 4).

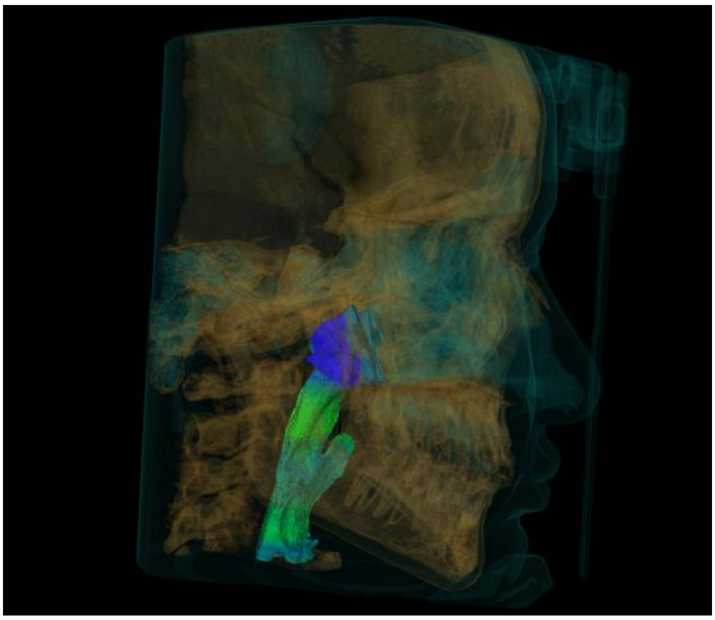

Figure 1: Sagittal Three-Dimensional Cone Beam Computed Tomography (CBCT) image of class I upper airway anatomy presents a patient's upper airway anatomy with a Class I skeletal relationship, characterized by ordinary anteroposterior alignment in the maxilla and mandible.

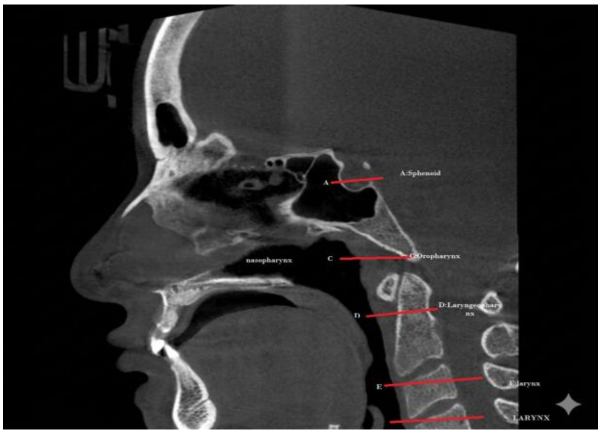

Figure 2: Three-dimensional cone beam computed tomography (CBCT) reconstruction of a patient with a Class II skeletal relationship. The airway segments are colour-coded for clarity, distinguishing the nasopharynx, oropharynx, and hypopharynx. The Class II profile typically features a protruded maxilla, which may impact airway patency. The anatomical landmarks used for determining upper airway volume are identified as follows: point A represents the center of the sphenoid, point B indicates the nasopharynx, region C denotes the oropharynx, region D identifies the hypopharynx, and point E marks the larynx. All these identified points are utilized in the calculation of the total upper airway volume.

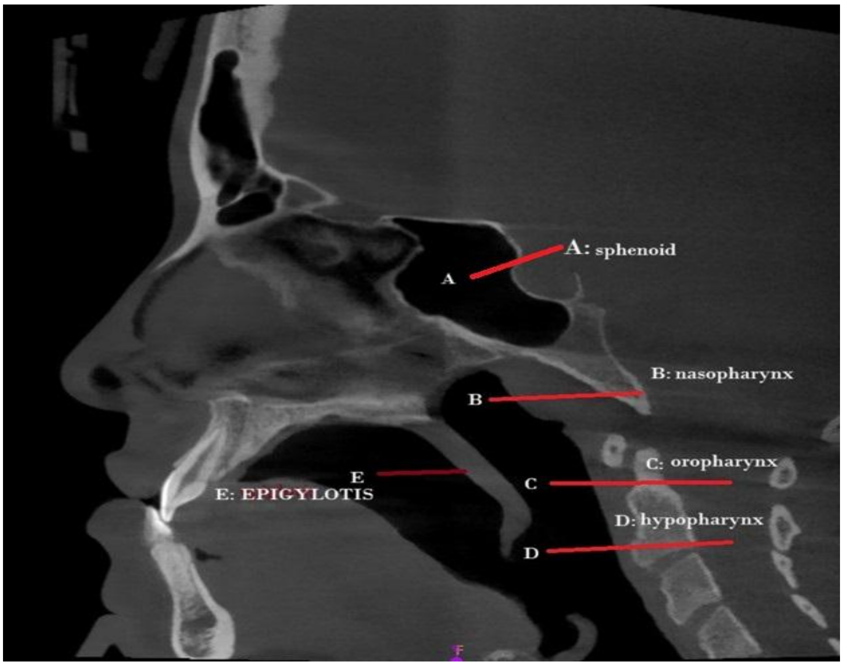

Figure 3: Three-dimensional cone beam computed tomography (CBCT) construction of a patient with a Class Ill skeletal relationship. The Class III profile typically features a retrud maxilla, which may impact airway patency. The anatomical landmarks used for airway volume measurement are identified as follows: point A represents the centre of the sphenoid (which is not included in the upper airway volume calculation), point B indicates the nasopharyngeal region, region C denotes the oropharyngeal area, region D identifies the hypopharyngeal region, and point E marks the epiglottis. All these identified points are utilized in the measurement of the total airway volume.

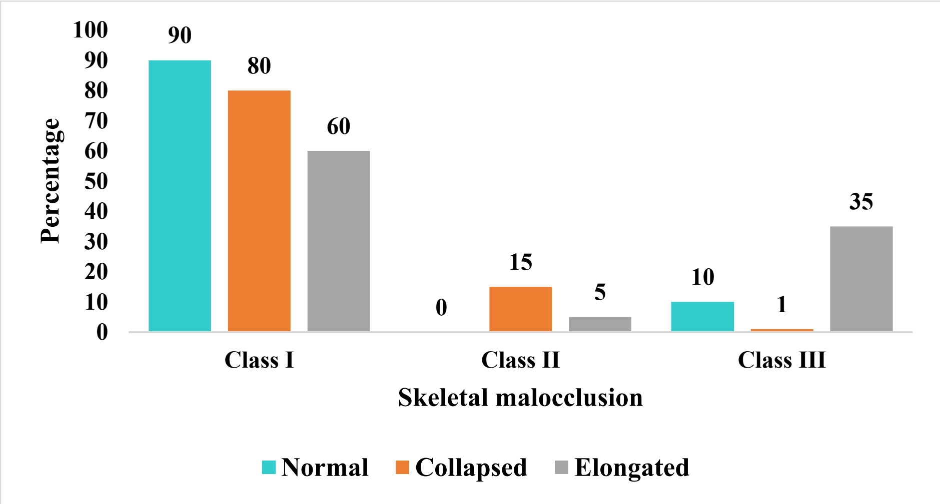

Figure 4: Shows airway morphology across skeletal malocclusion classes.

Table 1: Anatomic landmarks of the upper airways[24].

	Superior Limit	Inferior Limit
Oropharynx	Line extending from the PNS to the tip of the odontoid process.	Line extending from the antero-inferior border of the C2 vertebra.
Hypopharynx	Line extending from the antero-inferior border of the C2 vertebra.	Line extending from the horizontal line coming into contact with the most superior margin of the body of the hyoid bone.

Table 2: Sociodemographic features of the research sample (N=60).

Sociodemographic characteristic			**Skeletal malocclusion**			**Statistics**
			Class I (N=20)	**Class II (N=20)**	**Class III (N=20)**	
Age	Minimum		20	19	19	p= 0.539 ns η2= 0.024
	Maximum		38	38	38	
	Mean		29.10	29.65	27.44	
	SD		5.72	5.90	6.13	
	95% C I		26.42 – 31.78	26.89 – 32.41	24.17 – 30.70	
Gender	Male	N	12	12	11	p= 0.934 ns V= 0.048
		%	60	60	55	
	Female	N	8	8	9	
		%	40	40	45	
Male to Female Ratio			1.5 to1	1.5 to 1	1.22 to 1	

N: Number; %: Percentage; ns: no significant difference; Cramer's V effect size; η2: eta-squared for ANOVA; CI: Confidence Interval; SD: Standard Deviation.

Table 3: Airway volume data across skeletal malocclusion categories (N=60).

Airway measure (cm^3)		Skeletal malocclusion			Statistics		
		Class I (N=20)	Class II (N=20)	Class III (N=20)	I vs II	I vs III	II vs III
Nasopharynx	Mean	8.96	7.89	12.97	p=0.036*	p<0.001*	p=0.001*
	SD	1.55	0.96	2.04	r=0.33	r=0.81	r=0.86
Oropharynx	Mean	9.35	8.61	12.00	p=0.587 ns	p=0.030*	p=0.049*
	SD	3.48	3.95	5.48	r=0.09	r=0.34	r=0.31
Hypopharynx	Mean	9.49	7.95	12.28	p=0.044 ns	p=0.033*	p=0.002*
	SD	2.97	5.03	4.14	r=0.32	r=0.34	r=0.48

N: Number; SD: Standard deviation; *: statistically significant; ns: No significant difference; r: Mann-Whitney U effect size; cm: Centimeter. After Bonferroni correction (adjusted α = 0.017 for three pairwise comparisons).

Table 4: Distribution of airway morphology across skeletal malocclusion classes (N=60).

Airway morphology		Skeletal malocclusion			Statistics		
		Class I (N=20)	Class II (N=20)	Class III (N=20)	I vs II	I vs III	II vs III
Normal	N	18	16	12	p=0.178 ns	p=0.083 ns	p=0.048*
	%	90%	80%	60%	V=0.294	V=0.353	V=0.390
Collapsed	N	0	3	1			
	%	0	15%	5%			
Elongated	N	2	1	7			
	%	10%	5%	35%			

N: Number; %: Percentage; ns: no significant difference; *: significant difference; V: Cramer's V effect size; After Bonferroni correction (α = 0.017 for three pairwise comparisons).

Discussion

The relation between craniofacial morphology and UA measurements has arisen an outstanding interest in orthodontics, maxillofacial surgery, and sleep medicine[8]. Notably, SM, dental arch structure, and maxillomandibular alignment affect the volume and morphology of the UA[11]. Sagittal skeletal discrepancies, or those related to Class I, II, and III SM, affect airway size and shape through displacement of a posteriorly positioned mandible, maxilla, and associated soft tissues [12]. However, the CBCT has revolutionized the examination of these relationships through high-resolution 3D imaging of skeletal and soft-tissue structures. Also, CBCT is instrumental for measuring the aerodynamics of the craniofacial system that cannot be seen with traditional radiographs. Many studies have used CBCT to evaluate associations between individual skeletal malocclusion and nasopharyngeal, oropharyngeal, and hypopharyngeal size, as well as shape descriptors, such as elongated or collapsed airway[12,13]. Also, patients with a normal sagittal mandibular position may have problems with airway volume and morphology, dependent on skeletal classification. This emphasizes the importance of examining airway parameters not only in retrognathic/prognathic populations, but also in those without marked mandibular sagittal displacement[14].

This study aimed to compare volumetric UA measurements across different SM classes in a normal mandibular position using CBCT. Consequently, nasopharyngeal, oropharyngeal, and hypopharyngeal volumes were compared across the three SM classes (I, II, and III), and airway morphology types (normal, collapsed, and elongated) were analyzed within these classes. The mean participant age in this study was 28.82 ± 5.87 years, with no significant differences among the classes (p=0.422); therefore, age is not a confounding factor in these results. Although airway dimensions can vary with age, the age ranges across groups were similar, suggesting that any age-related bias was minimized. The male and female rates were nearly equal across classes (p=0.934), and the male:female ratio was similar across all groups, indicating that this population was not gender-biased. The age and sex distributions did not differ significantly between the SM classes, suggesting that these findings are valid. The minimal differences in age and gender between the groups would provide greater assurance that airway measurements and morphological differences are attributable to SM rather than to demographic differences. This homogeneity lends confidence to these conclusions, indicating that differences in airway structure are predominantly SM-dependent and minimally affected by age or gender. For instance, Ronen et al. studied the gender and age roles in the development of UA length and explained that although UA dimensions are known to be affected by age and gender; especially after the onset of puberty; muscle-nerve sectioning studies demonstrate that this can be dependent on both age and gender combination and that its effect should be controlled in study design to differentiate their influence from other variables, such as SM. This study minimizes potential confounding effects by demonstrating that there are no significant differences in age or gender among the groups[15].

The primary study's finding was a significant difference in airway volumetric measurements in the SM classes. For Class III, the mean volumes were significantly larger in the nasopharynx than in Class I and Class II. These results are consistent with and discordant with the literature. Recent methodological advancements employing quadrant-based experimental designs have introduced controlled ambiguity, enabling researchers to challenge and reconsider long-standing theoretical assumptions. Sfondrini et al. (2024) found that, by cephalometric analysis, the nasopharyngeal length and depth were shorter in most of the Class III SM patients compared to other classifications. They also concluded that Class III patients had significantly shorter superior pharyngeal airway space than Class II patients. In contrast, Class I patients had significantly shorter mean airway spaces than Class II patients[16].

In contrast, another group noted that the nasopharyngeal, oropharyngeal, and Class III hypopharyngeal volumes were greater than those in Classes I and II[17]. This disparity may be due to differences in methods (cephalometric analysis and volumetric measures), populations, and ethnicity. The inclusion of volumetric measurements in this study may allow for a better characterization of the airway space than linear cephalometric measurements.

Rodrigues et al. (2024) studied Class II and III SM to show their impact on the pharyngeal airway. Their findings were based on extremely small sample sizes, rather than on direct data analysis, the findings showed that patients with Class III malocclusion had significantly larger volume and area measurements than Class II[1]. This correlates with our findings of larger nasopharyngeal, oropharyngeal, and hypopharyngeal volumes in Class III subjects. Similarly, Ahmed et al. (2024) showed that treatment of Class II SM with functional appliances, such as the Frankel II, resulted in a significant increase in UA volume, supporting the idea that airway patency is directly related to skeletal positioning[18]. In contrast, Anis et al. (2026) found no significant difference in oropharyngeal airway volume across SM classifications. However, they noted discrepancies concerning sex for the regional airway area[19].

Furthermore, Oğuz et al. (2025) emphasized the role of vertical growth patterns in airway morphology, noting that hyperdivergent individuals, often associated with Class II skeletal malocclusion, tend to have lower airway volumes [20]. This supports the reduced airway dimensions observed in our Class II group and underscores the multifactorial nature of airway constriction, involving both sagittal and vertical skeletal relationships. The morphologic differences noted in the current study, specifically a greater number of long airway phenotypes in Class III components and a greater number of collapsed phenotypes in Class II, are in line with another study that identified the influence of skeletal malocclusion on UA morphology.

Sana et al. (2022) found that the superior pharyngeal airway of Class III subjects was significantly longer than usual, even after correcting for the acute anteroposterior advancement of the mandible and maxillofacial structures, indicating that the posterior airway space elongation is allowed by the anterior displacement of the mandible and maxillofacial structures[21]. They also noted a tendency toward airway collapse with Class II profiles, particularly in hyperdivergent patients, where skeletal features predispose the mandible to an apparent position and narrow the oropharyngeal segment. Similarly, Ravelo et al. (2020) showed that Class II SM had a reduced pharyngeal airway space and a minimum cross-sectional area, suggesting a structural predisposition to functional impairment[12]. Similar findings were reported by Rodrigues et al. (2025, which showed that Class III subjects continuously displayed the widest nasopharyngeal and/or oropharyngeal areas, while Class

II showed distinctly reduced airway dimensions[22].

The observation of between-group differences in the correlation of skeletal positioning with airway morphology supports the anatomical dependence of airway form on sagittal skeletal positioning. It suggests that skeletal discrepancies may predispose to specific airway shapes with functional consequences. Tseng et al. (2021) demonstrated that pharyngeal airway volume varies significantly across skeletal classes I, II, and III, with class III subjects presenting the largest dimensions and class II the smallest. These findings corroborate the results of the present study, highlighting that sagittal skeletal discrepancies exert a measurable influence on pharyngeal airway morphology[23]. Also, Zheng et al. (2017) demonstrated UA asymmetry in Class III SM with mandibular deviation. It also highlighted the close relationship between various craniofacial skeletal features and the pharyngeal airway space revealed by 3D imaging. Thus, the intricate nature of the airway and its direct correlation to craniofacial skeletal differences was stated[7].

This study has several limitations. First, its cross-sectional design precludes causal inference and allows identification of associations only at a single time point. Second, the sample size was relatively small, which may reduce statistical power and limit generalizability, particularly after adjustment for multiple comparisons. Third, because each scan was measured only once, formal intra-examiner reliability could not be assessed, a limitation to consider when interpreting the precision of the measurements. Finally, the study included only adults; therefore, the findings cannot be generalized to growing patients.

Conclusion

Class III malocclusion was related to significantly increased nasopharyngeal volumes compared to Class I and II, and significantly increased hypopharyngeal volumes compared to Class II. Although oropharyngeal differences were observed at the conventional 0.05 level, they did not remain significant after Bonferroni correction. Class III also demonstrated a higher frequency of airway elongation. Skeletal malocclusion should be considered when assessing airway status and planning orthodontic treatment, particularly in Class II cases, which are at higher risk of airway narrowing. Subsequent studies should investigate the potential dynamic and functional consequences of airway variation using measures such as polysomnography or airflow analysis.

Declarations

Ethics Approval and Informed Consent (Institutional Review Board) Statement: The study protocol was reviewed and approved by the Ethical Committee of the College of Dentistry, University of Sulaimani, Sulaymaniyah, Iraq (No. 24-257 dated December 16, 2024). The study was conducted in accordance with the Declaration of Helsinki. Participants' written informed consent was obtained before the research, and they were free to withdraw at any time.

Author Contributions: KTT: Investigation, data curation, formal analysis, validation, visualization, writing—original draft preparation, writing—review and editing, project administration, manuscript submission, correspondence with the journal, response to editors' and reviewers' comments, Writing and editing.

RAJ: Conceptualization, methodology, and reviewing.

All authors have read and agreed to the published version of the manuscript.

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Additional information: No additional information is available for this paper.

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References

1. Rodrigues J, Evangelopoulos E, Anagnostopoulos I, Sachdev N, Ismail A, Samsudin R, et al. Impact of class ii and class III skeletal malocclusion on pharyngeal airway dimensions: A systematic literature review and meta-analysis. Heliyon. 2024;10(6):e27284.

2. Mageet AO. Classification of skeletal and dental malocclusion: Revisited. Stoma Eduj. 2016;3(2):38-44.
3. Dawood S. Cone beam computed tomography evaluation of the clinical correlation between the stature of the patient and tooth anatomic odontometry in Iraqi subpopulation (a cross-sectional study). Sulaimani Dent J. 2025;12(2):31-43.
4. Mini AHI, Wegner H, Lonic D, Loeffelbein DJ. Cone beam computed tomography based upper airway measurement after orthognathic surgery: A comparative evaluation of different imaging software. Sci Rep. 2025;15(1):6638.
5. Firwana A, Wang H, Sun L, Wang J, Zhang W-B. Relationship of the airway size to the mandible distance in chinese skeletal class i and class ii adults with normal vertical facial pattern. Indian J Dent Res. 2019;30(3):368-74.
6. Paul P, Thakur A, Mathur A, Chitra P. Airway dimensions and mandibular position in adults with different growth patterns: A cone-beam computed tomography study. J Stomatol Oral Maxillofac Surg. 2022;75(2):87-92.
7. Zheng DH, Wang XX, Ma D, Zhou Y, Zhang J. Upper airway asymmetry in skeletal class iii malocclusions with mandibular deviation. Sci Rep. 2017;7(1):12185.
8. Neelapu BC, Kharbanda OP, Sardana HK, Balachandran R, Sardana V, Kapoor P, et al. Craniofacial and upper airway morphology in adult obstructive sleep apnea patients: A systematic review and meta-analysis of cephalometric studies. Sleep Med Rev. (2017);31:79-90.
9. Palomo JM, El H, Palomo L, Strohl KP. Upper airway, cranial morphology, and sleep apnea. Orthodontics: Current Principles and Techniques: First SA Edn. 2016:319.
10. Polizzi A, Serra S, Leonardi R. Use of CBCT in orthodontics: A scoping review. J Clin Med. 2024;13(22):6941.
11. Golchini E, Rasoolijazi H, Momeni F, Shafaat P, Ahadi R, Jafarabadi MA, et al. Investigation of the relationship between mandibular morphology and upper airway dimensions. J Craniofac Surg. 2020;31(5):1353-1361.
12. Ravelo V, Olate G, Moya MP, Brito L, Garay I, Olate S. 3-d airway analysis related to facial morphology. Int J Morphol. 2020;38(2):423-26.
13. Baban MTA, Mohammad DN. The accuracy of sex identification using CBCT morphometric measurements of the mandible, with different machine-learning algorithms-a retrospective study. Diagnostics (Basel). 2023;13(14):2342.
14. El H, Palomo JM. An airway study of different maxillary and mandibular sagittal positions. Eur J Orthod. 2013;35(2):262-70.
15. Ronen O, Malhotra A, Pillar G. Influence of gender and age on upper-airway length during development. Pediatrics. 2007;120(4):e1028-34.
16. Sfondrini MF, Gallo S, Pascadopoli M, Gandini P, Roncoroni C, Scribante A. Upper airway dimensions among different skeletal malocclusions: A retrospective observational study by cephalometric analysis. Dent J. 2024;12(1):12.
17. Nath M, Ahmed J, Ongole R, Denny C, Shenoy N. Cbct analysis of pharyngeal airway volume and comparison of airway volume among patients with skeletal class I, class II, and class III malocclusion: A retrospective study. J Craniomandib Sleep Pract. 2021;39(5):379-90.
18. Ahmed MJ, Diar-Bakirly S, Deirs N, Hassan A, Ghoneima A. Three-dimensional computed tomography analysis of airway volume in growing class ii patients treated with frankel ii appliance. Head Face Med. (2024);20(1):1-9.
19. Anis DG, Elmasry RY, Amer ME, Abdelhaleem NA, Mohamed NA. Age and gender based variations in upper pharyngeal airway space: A retrospective study on the upper egypt population. Dentomaxillofac Radiol. 2026;55(3):301-13.
20. Oğuz F, Bor S, Khanmohammadi A, Kıranşal M. Evaluation of condylar and airway volume in skeletal class i patients with different vertical growth patterns. Appl Sci. 2025;15(5):2794.
21. Sana S, Kondody RT, Swamy K, Fatima A. Evaluation and correlation between pharyngeal space, mandible, and tongue in two different facial patterns. J Indian Orthod Soc. 2022;56(4):351-8.
22. Rodrigues J, Samsudin AR, Ismail A, Bayatti SA, Pattanaik S, Kamath V, et al. Cephalometric evaluation of pharyngeal airway space among different skeletal malocclusions in residents of the United Arab Emirates: A cross-sectional study. Pesqui Bras Odontopediatria Clin Integr. 2025;25:e230173.
23. Tseng Y-C, Tsai F-C, Chou S-T, Hsu C-Y, Cheng J-H, Chen C-M. Evaluation of pharyngeal airway volume for different dentofacial skeletal patterns using cone-beam computed tomography. J Dent Sci. 2021;16(1):51-7.
24. Pop SI, Procopciuc A, Arsintescu B, Mitariu M, Mitariu L, Pop RV, et al. Three-dimensional assessment of upper airway volume and morphology in patients with different sagittal skeletal patterns. Diagnostics (Basel). 2024;14(9):903.

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