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Original Article

A Retrospective Evaluation of Anatomical Structure Perforations Associated with Dental Implants Using Cone Beam Computed Tomography

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ABSTRACT

This retrospective analysis examined the occurrence of perforations in adjacent anatomical structures caused by dental implants, using cone-beam computed tomography (CBCT). Cone-beam computed tomography scans of dental implants were examined for signs of perforations in the relevant anatomical structures. The collected data included demographic details and implant characteristics, such as the type, length, location, diameter, mesial and distal spacing, thread exposure, and whether a radiographic guide was used. Univariate and bivariate analyses were performed to determine the frequency of these perforations and their distribution across various factors. A total of 441 implants were included, of which 14.5% showed perforations in adjacent anatomical structures. The most common perforation was the inferior alveolar canal, followed by the maxillary sinus. Nearly half of the implants (47%) caused perforation of the cortical plate. Perforations were more common in the posterior region compared to the anterior region ($P = 0.03$). Insufficient mesial and distal spacing was significantly more frequent when the adjacent structure was an implant rather than a tooth ($P < .0001$). Dental implant-related anatomical perforations are relatively common, especially in the posterior region. This study highlights the importance of avoiding such perforations and underscores the necessity of careful presurgical planning using cone-beam computed tomography and implant planning software to ensure optimal clinical outcomes.

Keywords: Implant failure, Cone-beam computed tomography, Dental implants, CBCT

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Introduction

Dental implants, a widely used and reliable solution for replacing missing teeth, have a high survival rate of 98.8% and a success rate of 97.0% [1]. For optimal outcomes and to prevent future peri-implant complications, it is essential to consider all potential factors that may influence implant failure during the planning phase [2].

Several factors can contribute to dental implant complications, impacting their success. These include smoking, underlying systemic conditions or medications, poor oral hygiene leading to bacterial accumulation, infections, insufficient bone volume at the implant site, and operator-related issues, such as inexperience, improper equipment, inadequate implant selection, or challenges during the surgical placement of the implant [3, 4].

A further issue related to inadequate surgical planning and errors during surgery is the potential disruption of vital anatomical structures, including the inferior alveolar canal, incisive canal, and mental foramen. Such violations can lead to neurosensory disturbances caused by nerve damage from osteotomy or bone compression [5]. Incorrect angulation of the implant can adversely affect the blood supply to nearby teeth, resulting in tooth devitalization and bone necrosis.

In more severe cases, infections can cause implant mobility and eventual loss [6]. Hence, clinicians must possess a detailed understanding of the bone anatomy at the implant site and the surrounding structures to prevent any inadvertent damage to these anatomical features.

Before dental implant placement, the use of three-dimensional imaging techniques like cone beam computed tomography (CBCT) is strongly recommended for accurate pre-surgical assessment and planning [7]. These images must have sufficient diagnostic quality to ensure clear visualization of both the adjacent anatomical structures and the specific bone area intended for the implant. Volumetric analysis of the targeted site provides a precise evaluation of alveolar bone dimensions, morphology, density, and trabecular bone structure, along with surrounding anatomical features [8].

For post-surgical implant assessment, a panoramic or periapical radiograph is typically used to verify the implant's position. However, the European Association for Osseointegration advises the use of CBCT when complications arise, such as sinonasal infections, sensory changes, or nerve disturbances resulting from the implant's proximity to the inferior alveolar nerve [9]. Cone-beam computed tomography is also recommended for cases involving implant mobility where retrieval is anticipated. It is important to note that CBCT is not necessary for routine evaluation of clinically asymptomatic patients [10].

A cross-sectional investigation conducted in Brazil found that 33.3% of dental implants experienced anatomical perforations, with a higher incidence in the maxilla compared to the mandible [11, 12]. In contrast, a study from Romania identified that only 6.89% of implants had placement-related issues, primarily affecting the maxillary sinus [13]. Despite the limited number of studies on dental implant-related anatomical perforations, there is a lack of such research in Saudi Arabia and other Middle Eastern countries. Therefore, this study aimed to determine the frequency of anatomical perforations linked to dental implants using CBCT. Additionally, the study sought to explore potential associations between implant-related perforations and various factors, including dental specialties, the level of dentist experience, preoperative CBCT scans with radiographic stents, as well as implant location, diameter, type, and thread exposure.

Materials and Methods

This study was reviewed and authorized by the Research Ethics Committee of King Abdulaziz University, Faculty of Dentistry (KAUFD), Jeddah, Saudi Arabia (Protocol number 135-12-20), and it adhered to the principles of the Helsinki Declaration of 1975, as amended in 2013. Since this was a retrospective study that only involved the review of dental records without any risk or harm to participants, the Committee waived the requirement for signed written consent.

Study sample

This retrospective cross-sectional study examined cone-beam computed tomography images from the database of a university-affiliated oral and maxillofacial radiology clinic. The imaging was performed using an iCAT scanner (Imaging Sciences International, Hatfield, PA, USA). Eligible CBCT scans included those with single or multiple dental implants that were of high diagnostic quality. Only scans with voxel sizes ranging from 0.3 to 0.4 mm were considered for inclusion. CBCT scans that showed artifacts or partial images of dental implants were excluded from the study. Sample size calculations were based on Krejcie and Morgan's table [14], determining that at least 364 implants were required for the study.

Image assessment

Data collection was performed by two trained examiners using OnDemand 3D imaging software (Cybermed, Seoul, South Korea). The reconstructions were adjusted into three planes (coronal, axial, and sagittal). The collected data encompassed the patient's gender, age, the specialty of the treating dentist (implant dentistry, periodontics, oral surgery, or prosthodontics), the dentist's level of experience (faculty or resident), and whether the implant was placed at KAUFD or another institution.

The implants were classified according to the following [11]:

- Implant location: Maxilla or mandible, and anterior or posterior.
- Diameter: < 3.0 millimeters, between 3.0 millimeters and < 3.75 millimeters, between 3.75 millimeters and < 5 millimeters, and ≥ 5 millimeters.
- Length: ≤ 6 millimeters, > 6 millimeters, and up to 10 millimeters, > 10 millimeters, < 13 millimeters, and ≥ 13 millimeters.
- Implant type: Straumann, Nobel, Astra, Zimmer, Prima, and Biohorizon.
- Prosthetic loading: Present or absent.
- Type of prosthesis: Single implant, implant-supported fixed dental prosthesis (FDP), FDP

supported by both an implant and a natural tooth, or not applicable (NA) in cases where prosthetic loading was absent.

- Angulation of implant/abutment: Normal or abnormal (> 30 degrees), or NA in cases without prosthetic loading.
- Cortical plate perforation: Absent, present on the buccal/labial side, present on the palatal/lingual side, or present on both buccal/labial and palatal/lingual sides.
- Perforation of adjacent anatomical structures: Absent, or involving the incisive canal, nasal cavity, maxillary sinus, mental foramen, inferior alveolar canal, or an adjacent tooth root.
- Thread exposure (≥ 1 millimeter): Present or absent.
- Spacing between the implant and adjacent implant/tooth (both mesial and distal): Adequate (implant-to-tooth spacing ≥ 1.5 millimeters; implant-to-implant spacing ≥ 3 millimeters), inadequate (implant-to-tooth spacing < 1.5 millimeters; implant-to-implant spacing < 3 millimeters), or NA in cases of an adjacent edentulous area.
- Cone-beam computed tomography before implant placement with a radiographic guide: Present, absent, or NA if the implant was placed outside KAUFD.

Statistical analysis

Statistical analyses were carried out using statistical analysis system (SAS) version 9.4 software. The reliability between examiners and within examiners was assessed through kappa statistics, yielding values of 1.0 ($P < 0.001$) and 0.7 ($P < 0.001$), respectively. A univariate analysis was conducted to outline the characteristics of the study sample. To evaluate the distribution of dental implant-related perforations, a Chi-squared test and Fisher's exact test with Monte Carlo simulation were utilized. A P-value of < 0.05 was considered statistically significant.

Results and Discussion

A total of 1102 CBCT scans obtained at KAUFD were randomly selected for evaluation. Among these, 152 CBCT scans met the inclusion criteria, encompassing 441 dental implants placed in 301 female and 140 male patients, ranging in age from 21 to 80 years, with a mean age of 49.3 ± 13.1 years.

Based on anatomical distribution, 34 implants (7.71%) were positioned in the anterior mandible, 168 implants (38.1%) in the posterior mandible, 73 implants (16.55%) in the anterior maxilla, and 166 implants (37.64%) in the posterior maxilla. The maxilla contained more implants than the mandible, with 237 implants (53.7%) in the maxilla and 204 implants (46.3%) in the mandible. Among the total 441 implants, only 171 implants (38.8%) had a prosthetic component in place. Of these, 13 implants (3%) exhibited an abnormal implant-abutment angulation exceeding 30°.

The overall prevalence of dental implant-related anatomical perforations was 14.5%, with the inferior alveolar canal being the most frequently affected structure, followed by the maxillary sinus. A comprehensive breakdown of perforated anatomical structures is presented in Table 1, with no additional structures involved beyond those listed. Cortical plate perforation was identified in nearly half of the implants (210 implants, 47.6%), with the most common pattern involving both buccal and palatal cortical plates of the same implant (96 implants, 21.8%). Buccal plate perforation was the next most frequent, while palatal/lingual plate perforation occurred least often **(Table 1).**

Table 1. Sample characteristics

Characteristics	Total implants (n = 441) N (%)
Gender	
Male	140 (31.8)
Female	301 (68.3)
Nationality	
Saudi	385 (87.3)
Non-Saudi	56 (12.7)
Placed at KAUFD	
Yes	305 (69.2)
No	136 (30.8)
Anatomical structure perforation	
Yes	64 (14.5)
No	377 (85.5)
Perforated anatomical structure	
Absent	377 (85.5)
Nasal cavity	1 (0.2)
Maxillary sinus	21 (4.8)
Mental foramen	7 (1.6)

Inferior alveolar canal	27 (6.1)
Adjacent tooth root	8 (1.8)
Cortical plate perforation	
Absent	231 (52.4)
Present–Buccal	88 (19.9)
Present–Palatal/Lingual	26 (5.9)
Present–Buccal + Palatal/Lingual	96 (21.8)
Perforation	
Absent	193 (43.76)
Both cortical plate and adjacent structure	27 (6.12)
Cortical plate without adjacent structure	183 (41.5)
Adjacent structure without cortical plate	38 (8.62)
Angulation of implant/abutment	
Abnormal (> 30°)	13 (3.0)
Normal	159 (36.0)
N/A	269 (61.0)
Prosthetic loading	
Yes	171 (38.8)
No	270 (61.2)
Type of prosthesis	
Single implant	88 (20.0)
Implant/implant FDP	77 (17.5)
Implant/tooth FDP	9 (2.0)
N/A	267 (60.5)
Thread exposure	
Yes (≥ 1mm)	210 (47.6)
No	231 (53.4)
Implant's radiographic guide present in CBCT	
Yes	119 (27.0)
No	186 (42.2)
N/A	136 (30.8)
Mesial spacing	
Inadequate spacing	63 (14.3)
Adequate spacing	270 (61.2)
N/A- edentulous area	108 (24.5)
Distal spacing	
Inadequate spacing	55 (12.5)
Adequate spacing	215 (48.8)
N/A-edentulous area	171 (38.8)
Implants length	
≤ 6 mm	2 (0.5)
> 6 mm to < 10 mm	72 (16.3)
≥10 mm to < 13 mm	279 (63.3)
≥ 13 mm	88 (19.9)
Implants diameter	
< 3.0 mm	3 (0.7)
≥ 3.0 mm to < 3.75 mm	86 (19.5)
≥ 3.75 mm to < 5 mm	243 (55.1)
≥ 5 mm	109 (24.7)

N/A: not applicable

Cases of implants exhibiting cortical plate perforation and/or perforation of various anatomical structures are illustrated in **(Figure 1)**. A presurgical cone-beam computed tomography incorporating a radiographic stent was performed for only 119 implants (27%). Among the total implants, 193 implants (43.76%) were positioned appropriately without any perforation of the cortical plate or adjacent anatomical structures. In contrast, 27 implants (6.12%) exhibited both cortical plate perforation and perforation of a neighboring anatomical structure **(Table 1)**. Perforation of adjacent anatomical structures was observed more frequently in the posterior region compared to the anterior (P = 0.03); however, no statistically significant difference was found when comparing occurrences between the maxilla and mandible. A comprehensive breakdown of perforation occurrences based on anatomical location is presented in **Table 2**.

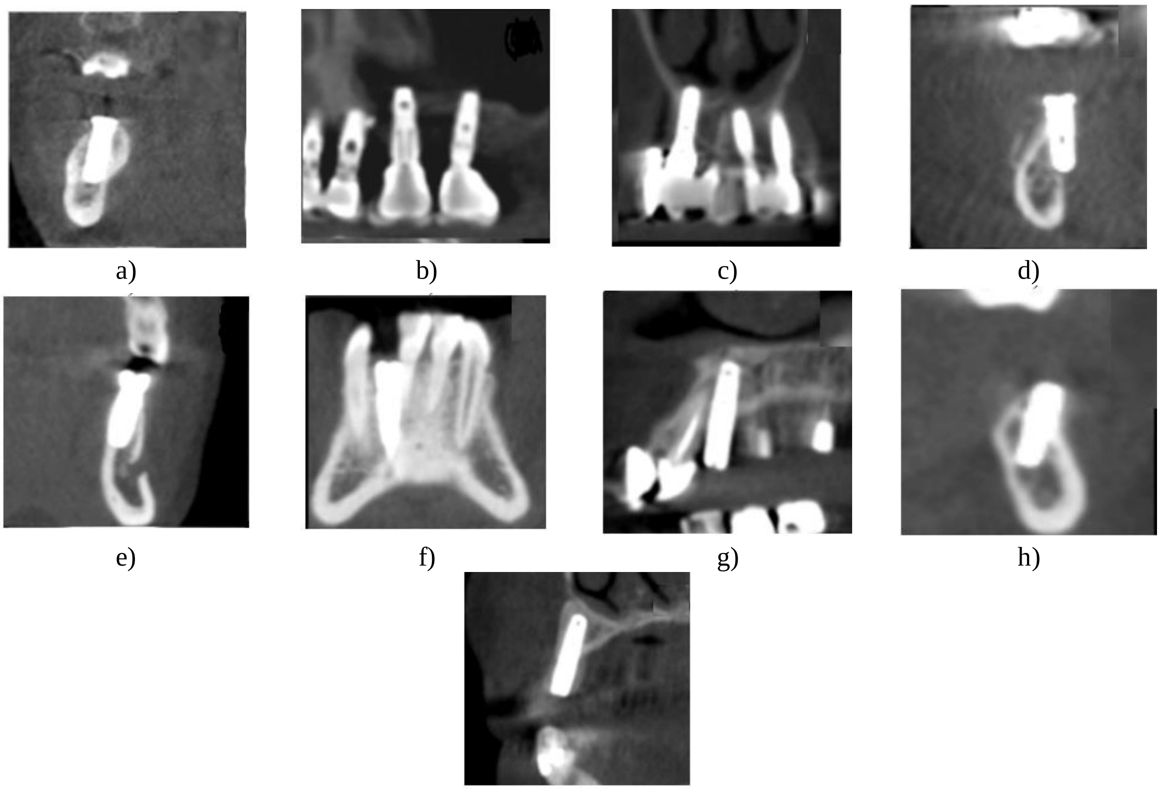

Figure 1. CBCT images depicting various implant cases with cortical plate perforation and/or perforation of other anatomical structures include (a) inferior alveolar nerve canal, (b) maxillary sinus, (c) nasal fossa, (d, e) cortical plate, (f, g) adjacent tooth root, (h) inferior alveolar nerve canal with cortical plate perforation and thread exposure, and (i) buccal and palatal cortical plate perforation along with thread exposure.

Table 2. Anatomical perforations related to dental implants are based on their anatomical locations.

	Arch			**Anatomical location**		
	Maxilla n (%)	**Mandible n (%)**	***P*-value**	**Anterior n (%)**	**Posterior n (%)**	***P*-value**
Cortical plate perforation						
Absent	122 (51.5)	109 (53.7)		56 (51.4)	175 (52.9)	
Present: Buccal	46 (19.4)	41 (20.2)	0.9	27 (24.8)	60 (18.1)	0.4
Present: Palatal/Lingual	14 (5.9)	12 (5.9)		5 (5.0)	21 (6.3)	
Present: Buccal + Palatal/Lingual	55 (23.2)	41 (20.2)		21 (19.3)	75 (22.6)	
Adjacent structure perforation						
Yes	115 (48.5)	95 (46.6)	0.7	9 (8.3)	55 (16.6)	0.03*
No	122 (51.5)	109 (53.4)		100 (91.7)	277 (83.4)	
Thread exposure						
Yes (≥ 1mm)	115 (48.5)	95 (46.6)	0.7	53 (48.6)	157 (47.3)	0.8
No	122 (51.5)	109 (53.4)		56 (51.4)	175 (52.7)	

*Statistically significant

Our study included a variety of dental implants: 79 Straumann, 48 Nobel Biocare, 13 Astra Tech, 9 Zimmer Biomet, 44 Prima, and 4 Biohorizons. Among these, Straumann implants had the highest incidence of cortical plate perforation, followed by Nobel Biocare and Prima implants. For perforation of adjacent anatomical structures, Straumann implants were also the most common, followed by Nobel Biocare implants.

In terms of implant length, over a third (63.3%) were between ten mm and less than thirteen mm, while only 0.5% were shorter than 6 mm. Regarding diameter, more than half (55.1%) of the implants had a diameter between 3.75 mm and less than five mm, with just 0.7% having a diameter smaller than three mm **(Table 1)**. When examining cortical plate perforation, implants with lengths between 10 mm and 13 mm were more likely to experience perforation compared to other lengths (P=0.002). However, no significant relationship was found regarding implant diameter **(Table 3)**.

Table 3. Dental implant-related anatomical perforations concerning different dental implant categories.

	Cortical plate perforation		***P*-value**	**Adjacent structure perforation**		***P*-value**
	Yes n (%)	**No n (%)**		**Yes n (%)**	**No n (%)**	
Placed at KAUFD						
Yes	111 (36.5)	193 (63.5)	<0.0001*	50 (16.4)	255 (83.6)	0.09
No	98 (72.1)	38 (27.9)		14 (10.3)	122 (89.7)	
Gender						
Male	67 (32.1)	73 (31.6)	0.9	23 (35.9)	117 (31.0)	0.4
Female	142 (68.0)	158 (68.4)		41 (64.1)	260 (67.0)	
Dentist's specialty						
Implant Dentistry	37 (30.1)	46 (26.9)		18 (36.7)	65 (26.5)	
Periodontics	54 (43.9)	76 (44.4)	0.1	26 (53.1)	104 (42.5)	0.03*
Oral surgery	24 (19.5)	46 (26.9)		5 (10.2)	65 (26.5)	
Prosthodontics	8 (6.5)	3 (1.75)		0 (0.0)	11 (4.5)	
Dentist's experience						
Consultant/specialist	45 (34.9)	84 (65.1)	0.03*	29 (22.5)	100 (77.5)	0.01*
Resident	78 (47.3)	87 (52.7)		20 (12.1)	145 (87.9)	
Implant Type						
Straumann	22 (31.0)	57 (45.2)		19 (40.4)	60 (40.0)	
Nobel	17 (23.9)	31 (24.6)		18 (38.3)	30 (20.0)	
Astra	9 (12.7)	4 (3.2)	0.08	2 (4.3)	11 (7.3)	0.08
Zimmer	5 (7.1)	4 (3.2)		3 (6.4)	6 (4.0)	
Prima	16 (22.5)	28 (22.2)		5 (10.6)	39 (26.0)	
Biohorizon	2 (2.8)	2 (1.6)		0 (0.0)	4 (2.7)	
Radiographic guide						
Yes	25 (12.0)	93 (40.3)		31 (48.4)	88 (23.3)	
No	86 (41.2)	100 (43.3)	<0.0001*	19 (29.7)	167 (44.3)	0.0002*
N/A	98 (46.9)	38 (16.5)		14 (21.9)	122 (32.4)	
Thread exposure						
Yes	209 (100.0)	0 (0.0)	<0.0001*	26 (40.6)	184 (48.8)	0.2
No	0 (0.0)	231 (100.0)		38 (59.4)	193 (51.2)	
Mesial spacing						
Inadequate	28 (13.4)	35 (15.2)		11 (17.2)	52 (13.8)	
Adequate	141 (67.5)	128 (55.4)	0.02*	38 (59.4)	232 (61.5)	0.8
N/A	40 (19.1)	68 (29.4)		15 (23.4)	93 (24.7)	
Distal Spacing						
Inadequate	30 (14.4)	25 (10.8)		10 (15.6)	45 (11.9)	
Adequate	98 (46.9)	116 (50.2)	0.5	31 (48.4)	184 (48.8)	0.7
N/A	81 (38.8)	90 (38.7)		23 (35.9)	148 (39.3)	
Implants length						
≤ 6 mm	1 (0.5)	1 (0.4)		0 (0.0)	2 (0.5)	0.5
> 6 mm to < 10 mm	24 (11.5)	48 (20.8)	0.002*	14 (21.9)	58 (15.4)	
≥10 mm to < 13 mm	129 (61.7)	149 (64.5)		40 (62.5)	239 (63.4)	
≥ 13 mm	55 (26.3)	33 (14.3)		10 (15.6)	78 (20.7)	
Implants diameter						
< 3.0 mm	3 (1.4)	0 (0.0)		0 (0.0)	3 (0.8)	
≥ 3.0 mm to < 3.75 mm	38 (18.2)	48 (20.8)	0.3	13 (20.3)	73 (19.4)	0.6
≥ 3.75 mm to < 5 mm	118 (56.5)	124 (53.7)		39 (60.9)	204 (54.1)	
≥ 5 mm	50 (23.9)	59 (25.5)		12 (18.8)	97 (25.7)	

N/A: not applicable, *statistically significant

In terms of practitioner experience, dental residents were more likely to be associated with cortical plate perforations (P = 0.03), whereas faculty members were more frequently linked to perforation of adjacent anatomical structures (P=0.01). Regarding the practitioners' specialties, both cortical plate perforations and adjacent anatomical structure perforations were more commonly seen when implants were placed by periodontists, followed by implant specialists (P = 0.1 and P = 0.03, respectively) **(Table 3).**

Out of the 444 implants, 136 (30.8%) were placed outside KAUFD. When comparing implants placed at KAUFD with those placed externally, cortical plate perforations were more common among implants placed outside KAUFD (72.1% vs. 36.5%), while adjacent anatomical structure perforations occurred more frequently in KAUFD implants (16.4% vs. 10.3%) **(Table 3)**. Additionally, over half of the implants showed thread exposure, and all implants with cortical plate perforations also exhibited thread exposure **(Table 3)**.

Regarding the spacing between the implant and adjacent tooth or implant, most implants had adequate mesial and distal spacing. However, 63 (14.3%) implants had insufficient mesial spacing, and 55 (12.5%) had inadequate distal spacing. Mesial and distal spacing was significantly more inadequate when the adjacent structure was another implant rather than a tooth (73.0% and 90.9%, respectively; P < .0001) **(Table 4)**.

Table 4. Detailed distribution of the horizontal distancing related to dental implants.

	Mesial spacing		*P*-value	Distal spacing		*P*-value
	Adequate	Inadequate		Adequate	Inadequate	
Tooth	169 (62.8%)	17 (27.0%)	< .0001*	133 (62.1%)	5 (9.1%)	< .0001*
Implant	100 (37.2%)	46 (73.0%)		81 (37.9%)	50 (90.9%)	
Edentulous area	0 (0.0%)	0 (0.0%)		0 (0.0%)	0 (0.0%)	

*Statistically significant

The findings of this study indicated that approximately 14.5% of the evaluated dental implants showed perforation of adjacent anatomical structures. Posterior perforations were more frequent than anterior ones, a result consistent with a previous study [11], which found the maxilla had more anatomical perforations than the mandible. However, our study did not show a significant difference between the maxilla and mandible. The inferior alveolar canal was the most frequently perforated anatomical structure, followed by the maxillary sinus, which contradicts earlier studies that identified the maxillary sinus as the most commonly perforated structure [11, 13].

In one study, inferior alveolar canal perforation was found in 14% of dental implants [13], while another study reported only 1.1% [11]. The perforation of the inferior alveolar canal has been linked to a range of complications, from altered sensation or paresthesia to severe pain in the affected region [15]. This sensory disturbance can also lead to aesthetic issues such as lip ptosis and drooling of saliva [16]. A management protocol has been suggested for handling such perforations after dental implant placement, tailored to the severity of the associated damage [15].

In our research, maxillary sinus perforation occurred less frequently than in previous studies, which reported rates of 34% and 13.3% [11, 13]. The complications arising from maxillary sinus perforation can range from mild sinusitis [17] to more severe localized infections within the affected sinus [18]. In some cases, extensive infections can spread to vital structures, including the cranial fossae, orbital cavity, and paranasal sinuses [19-21]. However, an experimental study investigating the impact of maxillary sinus perforation by dental implants found no significant negative effects [22]. On the other hand, a systematic review and meta-analysis suggested that maxillary sinus perforation could play a role in dental implant failure [23].

Only 1 implant in our study caused nasal cavity perforation. This is in contrast to other reports, which have shown nasal cavity perforation rates of 31% in 1 research [13] and 4.4% in another [11]. Patients with nasal cavity perforations often report symptoms such as impaired breathing and pain, which tend to appear later [24].

In our study, cortical plate perforation was observed more frequently than in previous research. One study reported that 11.1% of the dental implants had buccal cortical plate perforation, while 2.3% experienced lingual cortical plate perforation [11]. Another study found the prevalence of lingual cortical plate perforation in dental implants to be 21% upon CBCT evaluation [13].

Cortical plate perforation can have aesthetic implications, as it may lead to the loss of supporting gingival tissue around the implant due to bone resorption, eventually resulting in peri-implantitis [25]. Additionally, perforation of the lingual cortical plate in the mandible near the submandibular fossa can lead to severe, life-threatening complications, such as difficulty breathing caused by hematoma and significant bleeding from injury to the submandibular and sublingual arteries [26, 27].

The failure of dental implants has been notably linked to narrow and short implants [28, 29]. However, contrasting studies have suggested that the survival rate of dental implants is not dependent on implant dimensions [30, 31]. There is a lack of research examining the impact of various implant lengths and diameters on adjacent structures, as most studies have focused on implant failure or survival rather than their effect on nearby anatomical areas.

A study examining the relationship between different dental implant lengths and anatomical structure perforation found that short and extra-short implants (≤ 6 mm) had a lower incidence of perforations compared to standard (≥ 10 mm to < 13 mm) and long implants (≥ 13 mm) combined [11]. Our findings align with this conclusion, as shorter implants were associated with fewer perforations of nearby anatomical structures.

Previous research has primarily focused on the impact of a dental surgeon's experience on overall implant success and failure rates, rather than the frequency of adjacent anatomical perforations [32-35]. Some studies suggest that more experienced surgeons are less likely to encounter implant failure [32], while others have disputed this connection [34]. Our study, however, specifically addressed the prevalence of anatomical perforations among clinicians with varying levels of experience. The results indicated that dental residents were more likely to cause cortical plate perforations, while specialists and consultants were more prone to causing perforations in adjacent anatomical structures. Notably, no prior studies have specifically investigated anatomical perforations across different specialties. In our findings, periodontists had the highest prevalence of anatomical perforations, followed by implant specialists. This trend may be linked to the higher volume of implant cases performed by these specialists, as reflected in our sample.

Our findings indicated that more than half of the dental implants exhibited thread exposure, which was associated with cortical plate perforation. This result aligns with a previous study, which also found a high prevalence of thread exposure in implants that perforated adjacent anatomical structures [11].

In terms of horizontal spacing, a prior study observed that the majority of dental implants maintained adequate distance from adjacent teeth or implants [11]. Our findings echoed this, showing that inadequate horizontal spacing was more common when the neighboring structure was another dental implant rather than a tooth. Insufficient spacing between dental implants can lead to significant bone loss, which may contribute to peri-implant diseases and negatively affect aesthetics. A study examining the impact of varying inter-implant distances on bone loss revealed that implants placed ≤ 3 mm apart had an average bone loss of 1.04 mm, while those with > 3 mm of spacing experienced only 0.45 mm of bone loss. The study concluded that a minimum horizontal distance of 3 mm between adjacent implants is essential to prevent bone loss and promote peri-implant health [36].

This study has several limitations. The specific reasons for the cone-beam computed tomography scans were not documented, meaning that these scans were likely conducted for purposes other than post-surgical dental implant evaluation. As a result, some of the anatomical perforations associated with dental implants may be incidental findings. Additionally, the interpretation of our results is constrained by the lack of clinical data, such as information on the patient's symptoms, any surgical complications during implant placement, and whether bone augmentation procedures were used. It is also possible that some patients underwent presurgical CBCTs for implant planning at locations other than KAUFD. Furthermore, the sample may be biased, as certain implant categories were overrepresented compared to others.

Despite these limitations, our results underscore the importance of conducting a comprehensive evaluation of the anatomical structures at the implant site, taking into account variations and potential risk factors, using cone-beam computed tomography. Furthermore, this study emphasizes the value of employing modern techniques in digital implant treatment planning, including virtual implant planning and fully guided implant surgery, as these approaches can lead to more accurate implant placement in the intended location [37].

Conclusion

Perforations of anatomical structures related to dental implants are more commonly observed in the posterior region, with the inferior alveolar nerve canal being the most frequently affected structure, followed by the maxillary sinus. In our research, cortical plate perforation was also prevalent. It is essential to conduct comprehensive preoperative planning using CBCT to accurately assess the anatomical site and ensure proper implant placement, taking into account both prosthetic and anatomical considerations.

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Conflict of Interest: None

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Ethics Statement: This study received approval from the Research Ethics Committee at King Abdulaziz University, Faculty of Dentistry (KAUFD), Jeddah, Saudi Arabia (Protocol number 135-12-20) and adhered to the principles outlined in the Helsinki Declaration of 1975, as revised in 2013. All participants provided verbal informed consent through phone calls, as the study was retrospective and involved only a review of dental records, posing no risk or harm to participants. Therefore, the Committee waived the requirement for signed written consent.

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