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Prevalence of dental implant positioning errors: A cross-sectional study

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ABSTRACT

Purpose: This study evaluated the prevalence of dental implant positioning errors and the most frequently affected oral regions.

Materials and Methods: A sample was obtained of CBCT images of 590 dental implants from 230 individuals who underwent diagnosis at a radiology center using cone-beam computed tomography from 2017 to 2020. The following variables were considered: thread exposure, violation of the minimum distance between 2 adjacent implants and between the implant and tooth, and implant contact with anatomical structures. Descriptive data analysis and the Pearson chi-square test ($P<0.05$) were performed to compare findings according to mouth regions.

Results: Most (74.4%) of the 590 implants were poorly positioned, with the posterior region of the maxilla being the region most frequently affected by errors. Among the variables analyzed, the most prevalent was thread exposure (54.7%), followed by implant contact with anatomical structures, violation of the recommended distance between 2 implants and violation of the recommended distance between the implant and teeth. Thread exposure was significantly associated with the anterior region of the mandible ($P<0.05$). The anterior region of the maxilla was associated with violation of the recommended tooth-implant distance ($P<0.05$) and the recommended distance between 2 adjacent implants ($P<0.05$). Implant contact with anatomical structures was significantly more likely to occur in the posterior region of the maxilla ($P<0.05$).

Conclusion: Many implants were poorly positioned in the posterior region of the maxilla. Thread exposure was particularly frequent and was significantly associated with the anterior region of the mandible. ***(Imaging Sci Dent 2022; 52: 343-50)***

KEY WORDS: Cone-Beam Computed Tomography; Diagnostic Imaging; Dental Implants

Introduction

Although edentulism has declined since 2002, it remains a global public health problem, affecting adults and the elderly.[1] Studies have indicated that the demand for rehabilitative treatments is increasing, since advances in life expectancy have resulted in a growing population of the elderly.[2]

Dental implants accompanied by prostheses, among various rehabilitative treatments, offer the most benefits to edentulous and partially edentulous people, achieving high aesthetic and functional indices after tooth loss.[3] However, although dental implant placement is a safe, predictable, and established procedure, with a success rate of over 90%, complications arising from implant installation are considered among the greatest challenges for dental surgeons.[4]

Among the main complications may be errors in the positioning of dental implants, such as violation of the minimum recommended distance between 2 adjacent implants or between an implant and a tooth, injuries to anatomical structures, and transfixation and/or exteriorization in the cortical bone. The positioning errors of dental implants, in addition to increasing the therapeutic time, adding costs to the treatment, and causing discomfort for the patient and embarrassment for the dentist, can lead to serious damage, ranging from loss of the implant due to lack of osseointe-

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gration to bleeding and airway obstruction.[5]

Cone-beam computed tomography (CBCT) is used for planning prior to implant placement and also assists in the detection of positioning errors of implants after their installation.[6] The 3-dimensional visualization of the bone crest provides dental surgeons with easy visualization of the anatomical structures and their anomalies, enabling the development of an individualized treatment plan and thereby drastically reducing the risk of complications at the time of implant placement.[7]

Few scientific studies have presented informative data related to the prevalence of errors in positioning dental implants in CBCT. Thus, the present study was conducted to report data from patients who attended a radiology center, observing the positioning errors of dental implants that occurred during the installation procedure, in order to identify the main problems and plan ways to avoid the situations described in this study.

The aim of this study was to evaluate the prevalence of errors in the positioning of dental implants and to identify the most commonly affected oral regions in individuals who underwent oral diagnosis at a radiology center through CBCT.

Fig. 1. Thread exposure on a cross-sectional image. The dental implant is positioned in the region at the right mandibular first molar, where it has no bone coverage in the cervical and middle thirds in the buccal region and in the cervical third of the lingual region. The mandibular canal is represented by the circle.

Materials and Methods

The reporting of this cross-sectional study followed the recommendations of the Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) guideline.[8] The research was approved by the Research Ethics Committee of Meridional Faculty (IMED), under opinion number 3.313.622.

Study design and sample

This quantitative study had a cross-sectional design, with the sample consisting of CBCT images and the respective reports from 2017 to 2020 from a radiology center in a city in southern Brazil.

After analyzing all documents, only CBCT images containing dental implants were selected, excluding all those that had only dentate areas or that did not allow a clear view of the entire implant. The sample totaled 590 dental implants from 230 individuals.

Data collection

The CBCT scans were performed using an Orthopantomograph™ OP 3D Pro Device (Kavo Kerr Corp, Tuusula, Finland) and analyzed using the DentalSlice 2017G software (Bioparts, Brasília, Brazil). A high-quality, calibrated monitor was used (Monitor LG 24″ LED IPS Full HD, LG Electronics, São Paulo, Brazil). The analysis was performed using sagittal, axial, and coronal CBCT sections. To increase interobserver reliability, the CBCT images were evaluated at different times by 2 observers: a specialist in dental radiology and imaging, who also performed the reports of the respective tests, from the radiology center, and a trained operator who collected the data of interest for this study.

Variables

The variables analyzed were age, sex, the anatomical region of the mouth (anterior [incisors and canines] and posterior [premolars and molars] of the maxilla and mandible), and clinically relevant dental implant placement errors that were present in the CBCT reports and images. The following positioning errors were analyzed:

1. Thread exposure: presence of bone plate discontinuity (Fig. 1).
2. Violation of the minimum distance between the implant and adjacent tooth: any distance less than 1.5 mm (Fig. 2).
3. Violation of the minimum distance between 2 adjacent

Fig. 2. Violation of the minimum distance between an implant and a tooth on a panoramic reconstruction image. The dental implant is positioned in the region of the right maxillary first premolar, where there is 0.46 mm between it and the right maxillary canine.

Fig. 3. Violation of the minimum distance between 2 adjacent implants on a panoramic reconstruction image. The dental implants are positioned in the region of the right mandibular first and second premolars, and the distance between them is 1.04 mm.

implants: any distance less than 3 mm (Fig. 3).

4. Implant contact with anatomical structures:
   - 4.1 Nasal fossa: transfixation and exteriorization of the dental implant in the region (Fig. 4A).
   - 4.2 Maxillary sinus: transfixation and exteriorization of the dental implant in the region (Fig. 4B).
   - 4.3 Inferior alveolar nerve: transfixation of the dental implant in the mandibular canal, in contact with the inferior alveolar nerve (with or without rupture) (Fig. 4C).
   - 4.4 Mandibular fossa: transfixation and exteriorization of the dental implant in the region, breaking the cortical bone (Fig. 4D).
   - 4.5 Nasopalatine canal: transfixation of the dental implant in the region (Fig. 4E).

All implants identified were evaluated for all positioning errors described above; therefore, more than 1 error may have been identified in a single implant.

Data analysis

Data were organized in Microsoft Excel 2010 for Windows (Microsoft Corp, Redmond, WA, USA) and exported to SPSS version 20.0 (IBM Corp, New York, USA). Descriptive analyses of all variables were performed. The Pearson chi-square test was used to compare the findings according to the 4 regions of the mouth at a significance level of $P<0.05$.

Results

The final sample consisted of CBCT scans of 230 patients, of whom 64.3% (148) were women and 35.7% (82) were men. The mean age was 57 ± 11.7 years, with a minimum of 19 and a maximum of 86 years of age. The average number of dental implants was 2.6 per patient, totaling 590 dental implants analyzed. Of these, 74.4% (439) were poorly positioned and 25.6% (151) were well positioned.

Most poorly positioned implants were installed in the posterior region of the maxilla (177; 40.3%) (Table 1). The most prevalent positioning error found in the evaluated images was thread exposure, which was observed in 54.7% of implants (323), followed by implant contact with anatomical structures, violation of the recommended distance between 2 adjacent implants, and violation of the recommended distance between the implant and tooth (Table 2). The most common anatomical structure observed to be in contact with dental implants was the maxillary sinus (47; 50%), followed

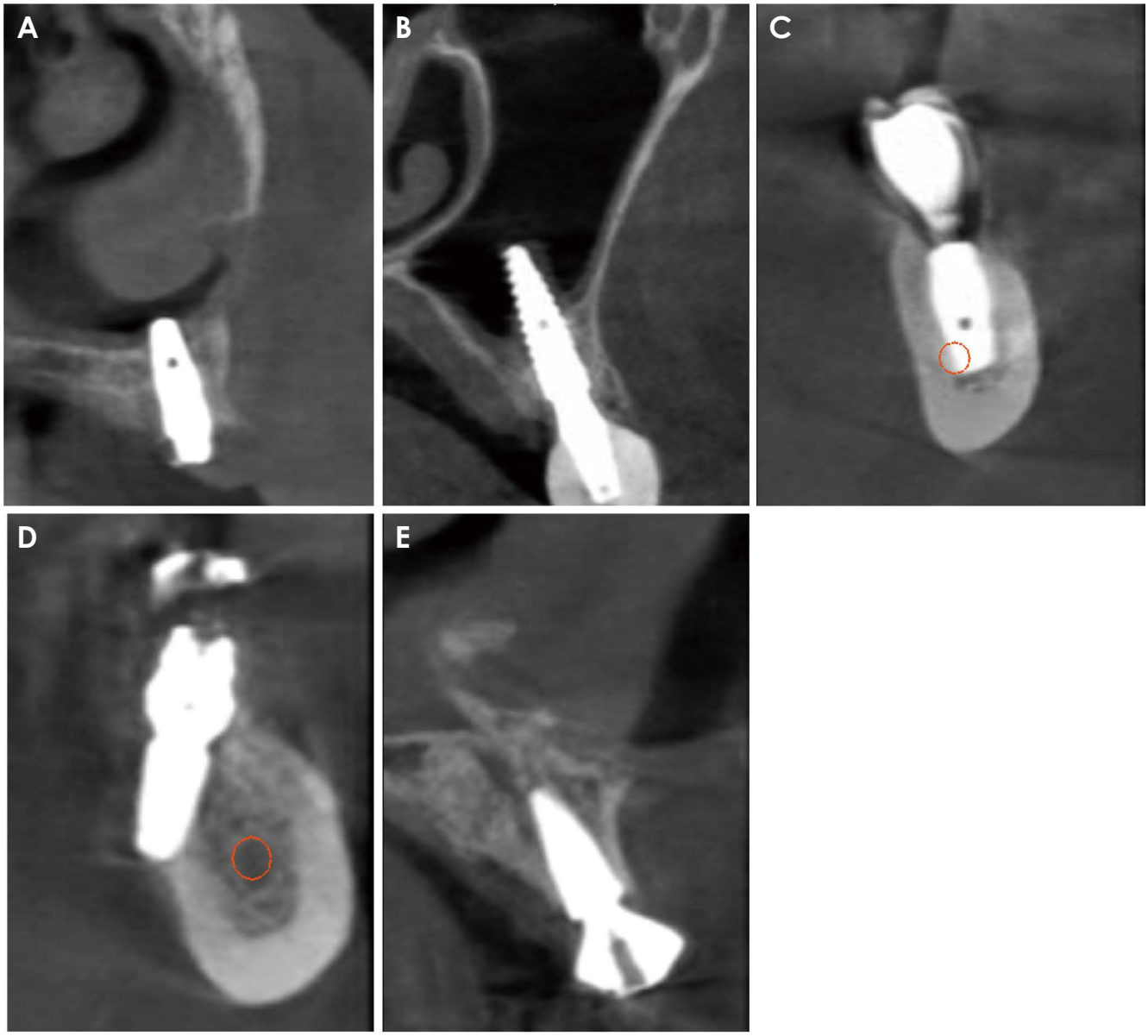

Fig. 4. Implant contact with anatomical structures on cross-sectional images. A. Dental implant positioned with the apical third inside the nasal cavity. B. Dental implant positioned with the middle/apical third inside the maxillary sinus. C. Dental implant positioned in direct contact with the inferior alveolar nerve (circle). D. Dental implant breaking the lingual cortical bone of the mandibular fossa. E. Dental implant positioned in communication with the nasopalatine canal.

Table 1. Positioning of dental implants according to oral regions

Mouth region	Well positioned	Poorly positioned	Total
Maxillary anterior	32 (21.2%)	146 (33.3%)	178 (30.2%)
Mandibular anterior	9 (6.0%)	31 (7.1%)	40 (6.8%)
Maxillary posterior	66 (43.7%)	177 (40.3%)	243 (41.2%)
Mandibular posterior	44 (29.1%)	85 (19.4%)	129 (21.8%)
Total	151 (25.6%)	439 (74.4%)	590 (100.0%)

by the nasal cavity (30; 31.9%) (Table 3).

Table 4 shows a comparison of the positioning errors of dental implants according to the regions of the mouth. Thread exposure was significantly associated with the anterior region of the mandible, when compared with the posterior regions of the mandible and maxilla and the anterior region of the maxilla ($P<0.05$). The anterior region of the maxilla was associated with violation of the recommended distance between implant and tooth ($P<0.05$) and between 2 adjacent implants ($P<0.05$). Implant contact with anatomical structures was significantly related to the posterior region of the maxilla ($P<0.05$).

Discussion

This study that evaluated the prevalence of positioning errors of dental implants on CBCT showed that of the 590 implants, 74.4% were installed unsatisfactorily, with the posterior region of the maxilla being the region with the highest total frequency of errors of positioning (40.3%). This result may be linked to bone resorption, which occurs after the loss of dental structures, since molars are usually the teeth with the highest rate of early loss.[9] The absence of a dental structure allows pneumatization of the maxillary sinus, causing a challenge for dentists when installing implants in this region.[10]

The prevalence of errors in implant positioning observed in this study was similar to that in the study by Ribas et al. in 2020,[11] who reported a prevalence of 82.9% of errors in positioning dental implants, with the main finding being violation of the minimum distance between the implant and adjacent teeth/implants. In this study, the highest prevalence of errors in implant positioning was exposure of the dental implant thread, which was responsible for more than half of the findings (54.7%). Studies have reported that implant exposure is commonly linked to areas that present thin and scant keratinized mucosa in situations where the depth of the installed implant is unsatisfactory.[12-15] Despite the high number of cases, thread exposure may not have been due only to poor implant positioning. Renvert et al.[16] pointed out that peri-implant diseases resulting from the accumulation of biofilm, such as peri-implantitis, cause loss

Table 2. Distribution of descriptive variables found in cone-beam computed tomography

Variables	N	%
Exposed thread		
Yes	323	54.7
No	267	45.3
Implant contact with structures		
Yes	94	15.9
No	496	84.1
Distance between two adjacent implants		
Violated	90	15.3
No violated	500	84.7
Distance between implant and tooth		
Violated	64	10.8
No violated	526	89.2
Total	590	100

Table 3. Description of the frequencies of anatomical structures violated by dental implants

Implant contact with anatomical structures	N	%
Maxillary sinus	47	50.0
Nasal cavity	30	31.9
Nasopalatine canal	4	4.3
Mandibular fossa	9	9.6
Lower alveolar nerve	4	4.3
Total	94	100.0

Table 4. Comparison between the errors in positioning of dental implants according to the regions of the mouth (Pearson's chi-square test)

Variables	Maxillary anterior	Maxillary posterior	Mandibular anterior	Mandibular posterior	Total	*P* value
Exposed thread	103 (57.9%)	118 (48.6%)	28 (70.0%)	74 (57.4%)	323 (54.7%)	<0.05
Violated distance between implant and tooth	25 (14.0%)	30 (12.3%)	1 (2.5%)	8 (6.2%)	64 (10.8%)	<0.05
Violated distance between implants	44 (24.7%)	32 (13.2%)	8 (2.5%)	6 (4.7%)	90 (15.3%)	<0.05
Contact implant and structures	26 (14.6%)	55 (22.6%)	2 (5.0%)	11 (8.5%)	94 (15.9%)	<0.05

of the bone tissue that covers the implant and give rise to thread exposure. In addition, the trauma caused by implant-supported prostheses can also lead to this problem. These factors may explain the association found in the present study between this positioning error and the anterior region of the mandible.

Implant contact with anatomical structures, which had the second-highest prevalence among the observed positioning errors, was significantly associated with the posterior region of the maxilla. The frequency of violation of structures in the posterior maxilla has been shown to be high.[17] The maxillary sinus was the most frequently affected (50%), followed by the nasal cavity (31.9%), mandibular fossa, inferior alveolar nerve, and nasopalatine canal. The installation of dental implants in the maxilla can present challenges, as the frequency of violation of structures in this region has been shown to be high.[17] Implants displaced or with transfixation inside the maxillary sinus and nasal cavity are interpreted as foreign bodies, favoring the occurrence of complications such as sinusitis and oroantral fistula, which may even lead to death.[18,19] The larger the diameter of the nasopalatine canal, the greater the incidence of perforation, which can lead to damage to the nasopalatine nerve and sensory loss in the region.[20] One of the most frequent events at dental clinics is compression or laceration of the inferior alveolar nerve during the installation of dental implants,[21] which diminishes the patient's quality of life, influencing daily orofacial activities, as well as causing issues such as persistent sensory loss, chronic pain, and even depression.[22] A lack of adequate planning, a lack of knowledge on how to interpret diagnostic images and the anatomy of the region, surgical inexperience, and the characteristic low bone density of the maxilla seem to contribute to accidents in these regions.[23,24]

The prevalence of adjacent implants violating the minimum recommended distance was observed in 15.3% of the cases analyzed. Tarnow et al.[25] suggested that the minimum and safe distance between 2 implants was at least 3 mm, contributing to the creation of an interimplant papilla. When this distance was violated, the mean crestal bone height loss was 1.04 mm, compared to 0.45 mm when the distance was respected. Bone loss also occurs in the mesial and distal portions of implants. In another study on the subject, the authors observed that the bone loss between the edge of the implant platform to the bone crest did not show a significant difference in implants placed 2 or 3 mm apart.[26] Thus, to avoid complications, in areas where the use of several implants is necessary, using smaller-diameter implants is suggested.[27]

This suggestion can also be followed in cases where there is little space for implant placement and adjacent teeth are present. In this study, the violation of the minimum recommended distance between implants and between implants and teeth was statistically associated with the anterior region of the maxilla (14%), corroborating the study carried out by Ribas et al.[11] Lops et al.[28] demonstrated that when the distance between implant and tooth was less than 2.5 mm, the papilla was absent in 70% of cases, which prompted those researchers to recommend a horizontal distance between the implant and tooth of 2.5 to 4 mm. However, Wang et al.[29] found no significant relationship between the implant-tooth distance and crestal bone changes, instead reporting that factors such as surgical procedure, prosthetic management, implant choice, and crown quality contributed to soft and hard tissue modification around implants.

The detection of errors in the positioning of dental implants becomes a difficult task when using only conventional dental radiography, due to the limitations of 2-dimensional projections of 3-dimensional structures. In this aspect, the introduction of CBCT in dentistry has become an important resource for dentists. In implantology, in addition to identifying iatrogenesis and failures, CBCT enables better planning by allowing more accurate measurements of height, width and bone quality, thereby making it possible to better differentiate the analyzed tissues and avoid several complications.[30,31]

It is important to highlight that the patients who sought care at the radiology center were looking for a diagnosis; in particular, the poor positioning of implants may have been the cause of the examinations, unlike what would be the case in a population-based analysis. Nonetheless, the errors in positioning presented herein highlight the need for clinical improvement of dental surgeons, since this type of failure in implant dentistry can lead to treatment failure and implant loss. It is also suggested that implant dentists use CBCT in the planning and diagnosis stages and utilize predictable techniques, such as reverse planning associated with guided surgery, for greater safety and precision at the time of implant placement.

However, a limitation typical of CBCT is its susceptibility to artifact generation. Metallic objects significantly impair CBCT image quality due to scattering, beam hardening, and streak artifacts that hinder proper visualization of peri-implant bone and osseointegration.[32] Some factors that may influence the formation of artifacts are the implant material, bone type, evaluated regions, distance, type of CBCT, field of view (FOV) size, milliamperage, peak kilovoltage (kVp), and voxel size. Artifacts can be minimized in

protocols with smaller FOVs, larger voxel size, and higher kVp, improving image quality.[33] Because the CBCT examinations in the present study had already been performed together with their respective reports, it was not possible to adequately control these factors. This should be considered in future studies to avoid the presence of artifacts and possible diagnostic errors.

In addition, the quality of the images displayed by the tomographic device limited certain analyses, not being possible to observe all the variables necessary for the inclusion of data in the study, leading to their exclusion. Another limitation of the present study was the fact that the data were obtained through CBCT images and their respective reports, making it impossible to evaluate the patients' clinical data or present fundamental elements for the definitive formation of a diagnosis. However, the results and descriptive prevalence data obtained in this work can be used in future studies to test hypotheses and answer questions.

In conclusion, this study obtained relevant findings for dental practice. Many implants are still poorly positioned, with the posterior region of the maxilla being the most commonly affected area. The most frequent positioning error was thread exposure, which was significantly associated with the anterior region of the mandible. There is a need to encourage the improvement of implant dentists, as well as the use of CBCT to improve case planning, thus allowing greater safety and precision at the time of implant placement.

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Conflicts of Interest: None

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