NEU PRESS

Diş Hekimliği Dergisi

Vol: 6 Special Issue Year: 2024 Research Article e-ISSN: 2687-5535

https://doi.org/10.51122/neudentj.2024.110

Retrospective Radiographic Evaluation of Implant Complications: CBCT-Based Study

Didem DUMANLI[1*] Çiğdem ŞEKER[2] Gediz GEDUK[3]

[1] Res. Ass., Retrospective Radiographic Evaluation of Implant Complications, Zonguldak Bülent Ecevit University, Faculty of Dentistry, Oral Maxillofacial Radiology, Zonguldak, Türkiye, didem.dumanli@hotmail.com

[2] Asst. Prof., Retrospective Radiographic Evaluation of Implant Complications, Zonguldak Bülent Ecevit University, Faculty of Dentistry, Oral Maxillofacial Radiology, Zonguldak, Türkiye, cgdmdmrhn@gmail.com

[2] Assoc. Prof., Retrospective Radiographic Evaluation of Implant Complications, Zonguldak Bülent Ecevit University, Faculty of Dentistry, Oral Maxillofacial Radiology, Zonguldak, Türkiye, gedizgeduk@gmail.com

Article Info

Article History

Received: 23.06.2024
Accepted: 02.09.2024
Published: 15.10.2024

Keywords:
Implant,
Complication,
Cone beam computed tomography,
Maxillary sinus.

ABSTRACT

Aim: Dental implants are a popular treatment option for patients with one or more missing teeth. With the increase in dental implant treatments, the complications encountered have increased. Therefore, it is very important to plan the implant by evaluating the anatomy of the area where the implant will be placed in three dimensions with cone beam computed tomography (CBCT). The aim of this study is to evaluate the prevalence of implant complications seen in CBCT after implant applications.
Material and Methods: CBCT images of 500 patients obtained for different dental reasons were examined; among these, 300 dental implant images were evaluated retrospectively in terms of complications. The number, location and type of identified complications (perforation in the maxillary sinus, mandibular canal, cortical bone, nasal cavity, and mental canal; contact with the adjacent tooth root) were recorded. The data obtained were analyzed statistically using chi-square tests.
Results: At least one complication was detected in 65% of the 300 dental implants evaluated. A total of 272 complications (1.4 complications per implant) were observed in 195 dental implants with complications. The number of implants with complications per patient was found to be 3.9. The most observed complication was found to be vertical bone resorption around the implant (45%). Complications were most frequently detected in the maxillary posterior region (40%).
Conclusion: Three-dimensional CBCT evaluation of the area where the implant will be applied before and after treatment is very important to prevent possible complications.

İmplant Komplikasyonlarının Retrospektif Olarak Radyografik Değerlendirilmesi: KIBT Tabanlı Çalışma

Makale Bilgisi

Makale Geçmişi

Geliş Tarihi: 23.06.2024
Kabul Tarihi: 02.09.2024
Yayın Tarihi: 15.10.2024

Anahtar Kelimeler:
İmplant,
Komplikasyon,
Konik ışınlı bilgisayarlı tomografi,
Maksiller sinus.

ÖZET

Amaç: Dental implantlar, bir veya daha fazla diş eksikliği olan hastalar için popüler bir tedavi seçeneğidir. Dental implant tedavilerinin artmasıyla birlikte karşılaşılan komplikasyonlarda artmıştır. Bu yüzden implantın yerleştirileceği bölgenin anatomisini üç boyutlu olarak konik ışınlı bilgisayarlı tomografi (KIBT) ile değerlendirerek implant planlaması yapmak çok önemlidir. Bu çalışmanın amacı, implant uygulamaları sonrası KIBT'da görülen implant komplikasyonlarının prevalansının değerlendirilmesidir.
Gereç ve Yöntemler: Farklı dental nedenlerden dolayı elde edilmiş 500 hastaya ait KIBT görüntüleri incelendi; bunların içinden 300 dental implant tespit edilen görüntüler komplikasyonlar açısından retrospektif olarak değerlendirildi. Belirlenen komplikasyonların sayısı, lokalizasyonu ve tipi (maksiller sinüs, mandibular kanal, kortikal kemik, nazal kavite, ve mental kanalda perforasyon; komşu diş kökü ile temas) kaydedildi. Elde edilen veriler ki-kare testleriyle istatistiksel olarak analiz edildi.
Bulgular: Değerlendirilen 300 dental implantın % 65'inde en az bir komplikasyon tespit edildi. Komplikasyonlu 195 dental implantta toplam 272 komplikasyon (implant başına 1,4 komplikasyon) gözlendi. Hasta başına düşen komplikasyonlu implant sayısı 3,9 olarak bulundu. En fazla gözlenen komplikasyon implant çevresindeki vertikal kemik rezorpsiyonu (%45) olarak bulundu . En sık maksiller posterior bölgede (%40) komplikasyon tespit edildi.
Sonuç: İmplantın uygulanacağı bölgenin KIBT ile üç boyutlu olarak tedavi öncesi ve sonrası değerlendirilmesi meydana gelebilecek komplikasyonların önlenmesi açısından çok önemlidir.

To cite this article: Dumanlı D, Şeker Ç, Geduk G. Retrospective Radiographic Evaluation of Implant Complications: CBCT-Based Study. NEU Dent J. 2024;6(Special Issue):9-17. https://doi.org/10.51122/neudentj.2024.110

***Corresponding Author:** Didem DUMANLI, *didem.dumanli@hotmail.com*

INTRODUCTION

Nowadays, dental implants are a commonly favored treatment choice for patients with one or more missing teeth. Literature reports indicate that the survival rates of dental implants are exceedingly high.[1,2] However, the success rates are not as high as the survival rates. Implant survival is the presence of an implant in the relevant area after implant treatment.[3] Today, with the increase in dental implant treatments, the incidence of complications increases in direct proportion, affecting the implant's success. Survival and success regarding implants are different concepts. Implant success means the implant is healthy and fully functional in the mouth.[3,4]

Complications that may be encountered during and after implant treatment affect the success of the implant.[5] Before treatment, detailed evaluation of the anatomical structures and variations in the relevant region and an appropriate treatment plan are very important regarding complication.[3,5,6]

In implant treatment, buccal and lingual bone perforations may occur due to the thinness of the alveolar bone in the mandible anterior region. As a result, infection conditions such as osteomyelitis in the mandible and displacement of the implant into soft tissues outside the bone may occur.[7] In the mandibular posterior region, the mandibular canal and its contents may occur. There is a vascular nerve bundle. As a result of a perforation in the mandibular canal, hematoma, and edema may occur due to vascular damage, paraesthesia and hypoesthesia may occur in the soft tissues, teeth and bones in the relevant region due to damage to the mandibular nerve. Likewise, bleeding and paresthesia may occur as a result of perforation of the mental foramen in the mandibular premolar region.[8] Maxillary sinus perforation in the maxilla posterior region may cause sinus infection and nasal cavity floor perforation in the maxilla anterior region may cause nasal cavity infection, and as a result of perforations in the relevant regions, the implant may cause adjacency in the maxillary sinus and nasal cavity. It can displace anatomical structures.[5,9]

To enhance the efficacy of implant treatments, the utilization of cone beam computed tomography (CBCT), which enables three-dimensional imaging is advocated during treatment planning. CBCT proves to be a valuable radiographic technique for assessing implant positioning errors, especially when patients exhibit clinical symptoms like pain and implant mobility, as it furnishes additional insights beyond two-dimensional images.[10] Additionally, it's imperative to recognize that technical errors occurring during dental implant procedures might be associated with complications that don't manifest immediate symptoms. Hence, evaluating implants in CBCT scans obtained for other purposes may facilitate early detection of these errors in the pre-symptomatic phase.[10,11]

Understanding the prevalence of various implant positioning errors and their most common locations is cricial in notifying dentists to the necessity of meticulous surgical planning in dental implant procedures.[11]

This study aims to assess the prevalence of implant placement complications identified via CBCT after implant procedures.

MATERIALS AND METHODS

In this study, radiographic images of patients who applied to Zonguldak Bülent Ecevit University Faculty of Dentistry between 2023 and 2024 for various reasons and for whom CBCT was indicated were used. The CBCT images included in the study were obtained with a Veraviewepocs 3D R100/F40 (J Morita Mfg. Corp., Kyoto, Japan) tomography device using 90 kVp 5mA in 8x10 cm, 8x8 cm and 8x5 cm FOV areas.

Data from patients with syndromes or congenital anomalies, fractures in the jaw and

face, and data with artifacts that would prevent the evaluation of images were excluded from the study. Data collection and CBCT evaluations were performed by two oral and maxillofacial radiologists.

CBCT evaluations were performed simultaneously once by the radiologists by mutual agreement. Observation conditions were optimized by displaying all images on the same computer monitor. The viewing distance for the observers was kept at approximately 50 cm and the lights were dimmed during the examinations. 500 CBCT images were evaluated and CBCT images containing at least 1 dental implant were included in the study. A total of 300 CBCT images containing dental implants from 50 patients, 21 female and 29 male, aged 19-78 were retrospectively evaluated for complications. The mean age of the patients was found to be 56.94 years.

The collected data were examined in terms of patient's gender, implant placement site, number of implants placed per person and complications per implant. Types of implant complications include; the maxillary sinus, nasal cavity, mandibular canal, mental canal and buccal or lingual/palatal bone perforations were evaluated in terms of adjacent tooth contact and vertical bone resorption (Figure 1). Implants with dehiscence and fenestration in buccal or lingual/palatinal bones were considered as bone perforation.

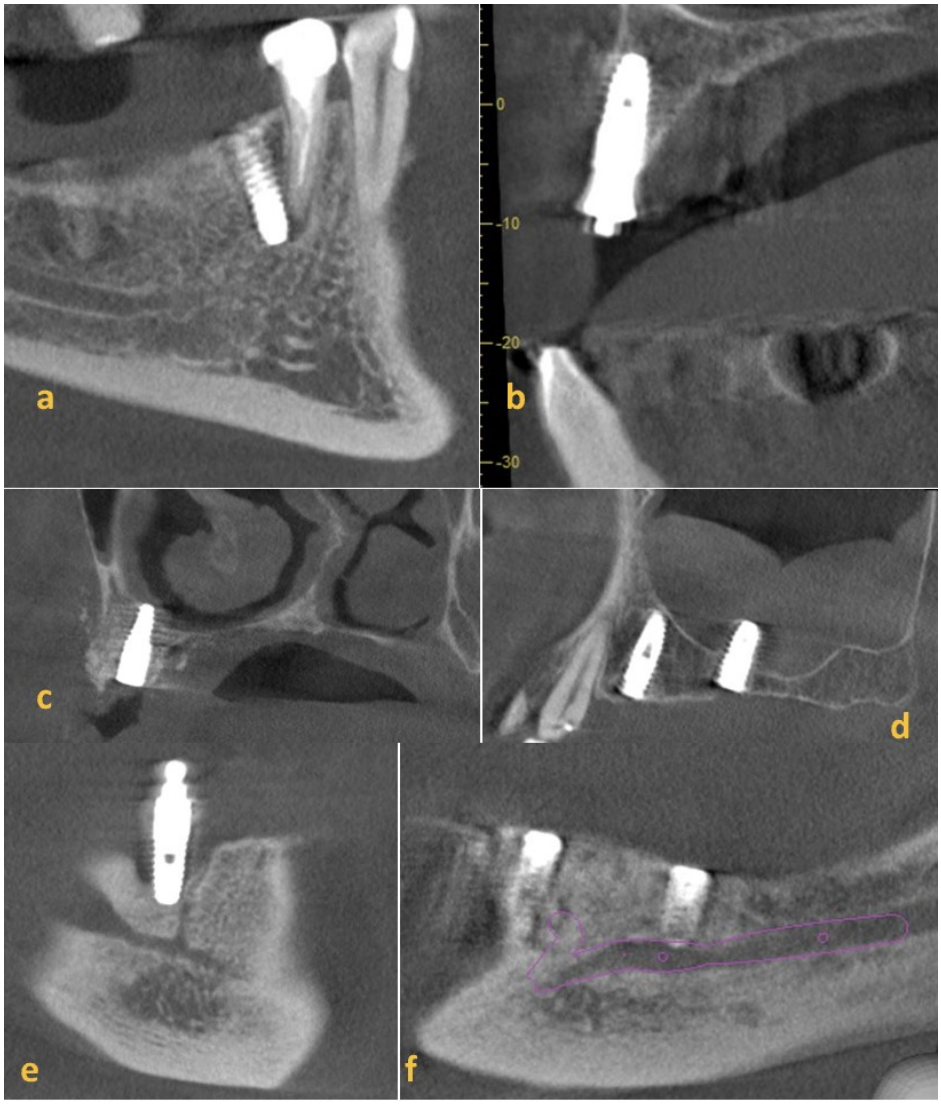

Figure 1: Complication type; a: adjacent tooth contact, b: buccal bone perforation, c: nasal cavity perforation, d: maxillary sinus perforation, e: vertical bone resorption, f: mandibular canal perforation

Statistical analysis

Statistical analysis was conducted using IBM Corp. Released 2013. IBM SPSS Statistics for Windows, Version 22.0. Armonk, NY: IBM Corp. Descriptive statistics and chi-square tests were employed for the statistical analysis of the data. According to the tests performed, cases where the p value was "$p<0.05$" were interpreted as there was a statistically significant difference and cases where "$p>0.05$" were interpreted as there was no statistically significant difference.

Ethical approval

The necessary ethical approval for this study was obtained from the Zonguldak Bülent Ecevit University Non-Interventional Clinical Research Ethics Committee (2023/04).

RESULTS

Dental implants were detected in 300 of the 500 CBCT images evaluated. A total of 272 complications were observed in 195 dental implants with complications. In 65% of dental implant cases, at least one complication was detected. There were 1.4 complications per implant. The number of implants with complications per patient was found to be 3.9.

The most common complication observed was found to be vertical bone resorption around the implant (45%). This was followed by buccal bone perforation (24%), lingual bone perforation (23%) and maxillary sinus perforation (23%) (Figure 2). Other less frequent complications included palatal/lingual bone perforation (18%), nasal cavity perforation (3%), perforation of the mandibular canal (2%) and perforation of the mental canal (2%) (Table 1).

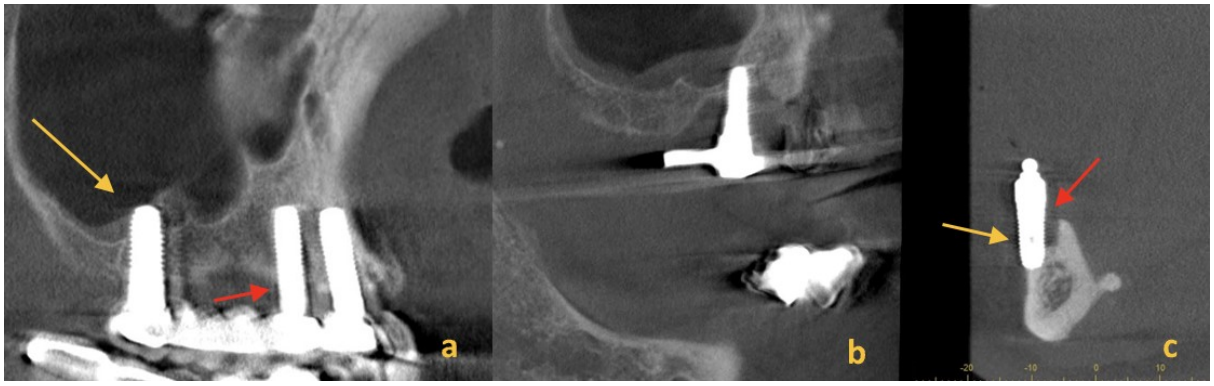

Figure 2: The most common types of complications; a: orange arrow: maxillary sinus perforation; red arrow: vertical bone resorption, b: maxillary sinus perforation from a different patient, c: orange arrow: buccal bone perforation; red arrow: vertical bone resorption.

Table 1: Numerical data of complication localizations

Complication localization	Percentage (%)	Number
Maxilla posterior	40%	76
Maxilla anterior	12%	24
Mandible posterior	30%	59
Mandible posterior	18%	36

Implant complications occurred most commonly in the maxillary posterior region (40%), followed by the mandibular posterior region (30%), mandibular anterior region (18%) and maxillary anterior region (12%) (Table 2). Upon evaluation of implant complications by gender, no significant difference was found between male and female (Table 3).

Table 2: Numerical data on types of complications

Complication type	Complication number	Complication percentage (%)
Maxillary sinus perforation	44	23
Nasal cavity perforation	6	3
Mandibular canal perforation	5	**2**
Buccal bone perforation	47	24
Palatinal/lingual bone perforation	34	18
Adjacent tooth contact	44	23
Mental canal perforation	4	**2**
Vertical bone resorption	88	**45**

Table 3: Distribution of complication types by gender

Complication type	Female		Male		Total		P value
	available	unavailable	available	unavailable	Female	Male	
Maxillary sinus perforation	11	10	11	18	21	29	0.829
Nasal cavity perforation	4	17	1	28	21	29	0.174
Mandibular canal perforation	2	19	3	26	21	29	0.924
Buccal bone perforation	13	8	11	18	21	29	0.333
Palatinal/lingual bone perforation	5	16	15	14	21	29	0.166
Adjacent tooth contact	8	13	19	10	21	29	0.116
Mental canal perforation	2	19	2	27	21	29	0.872
Vertical bone resorption	12	9	17	12	21	29	0.738

chi square test, $p>0.05$

DISCUSSION

In the literature, numerous studies explore complications linked to dental implants. Typically, these complications include penetration into anatomical structures, perforation and angulation errors of dental implants within the bone.[3,11] In this study, vertical bone resorption was identified as the most prevalent implant complication. Vertical bone resorption can occur as a result of various situations such as placing the implant at the wrong angle, excessive and unbalanced occlusal loading, and poor oral hygiene of the patient.[4,10,11] Periimplantitis is observed in patients with poor oral hygiene, leading to vertical bone loss occurs. Quiryen et all. reported that the frequency of periimplantitis increased in the long term and implant losses along with vertical bone loss.[12] The healing mechanisms are compromised in certain systemic conditions like diabetes and cardiovascular diseases.[13,14] Studies have shown that bone healing is acceptable in patients with controlled diabetes in contrast to those with uncontrolled diabetes.[15,16]

For the appropriate hard and soft tissue thickness to be formed between the implants and the adjacent teeth, there must be a distance

of 2 mm or at least one mm between the adjacent natural tooth and the implant.[17] If the bur is not used with the correct parallelism and angle during implant treatment, it may cause damage to adjacent teeth. Therefore, the anatomy of the adjacent teeth and the area, where the implant will be applied, should be carefully evaluated before the treatment. Adjacent teeth should be examined for root dilatation, malposition or anomalies.[18]

There should be a minimum distance of one millimeter between the implant and the buccal and lingual/palatal bone.[6] There is arteria palatinus major in the palatal part of the maxilla. It is an important artery and provides nutrition to the palatal part of the maxilla with its branches. There is also a nerve with the same name as the artery in the relevant region. Perforation of the implant in the palatal bone may cause damage to this artery and nerve, loss of sensation and severe bleeding. These complications are intraoperative and early implant complications and are very rare. These types of complications were not detected in this study.

There are submandibular and sublingual fossae on the lingual side of the mandible. These fossae contain important arteries, veins, nerves, submandibular and sublingual salivary glands.[5,19] As a result of perforation of the lingual bone, the implant may be displaced into these fossae and damage important anatomical structures in the relevant region.

It has been reported that if the perforation depth caused by the dental implant in the maxillary sinus is two mm or less, the sinus floor regenerates itself. If the maxillary sinus perforation cannot regenerate itself, the implant may migrate within the sinus. This situation can lead to sinusitis in the maxillary, ethmoid and sphenoid sinuses potentially causing meningitis in the middle skull base and orbital infections as it progresses to the orbit.[20,21] In 2024, a case of an implant displaced to the middle skull base in Turkey was reported in the literature.[21]

In studies assessing nerve damage resulting from perforation of the mental and mandibular canal, which are among the types of complications associated with implants, temporary and permanent damage rates vary between 6.5% to 36%.[3,22,23] In the studies, patients were followed at intervals such as 6 months, 1, 2, 3, and 4 years.[22,23,24] The prevalence of mental and mandibular canal perforation ranges between 4-7% in the literature.[25] In this study, the prevalence of mental and mandibular canal perforation was evaluated separately and both were found to be 2%. In studies evaluating mandibular canal perforation in the literature, the change in sensation varies between 10-15%.[3,22,23] When the topography of the maxilla and mandible is examined, the mandible anterior region consists largely of cortical bone, while the mandible posterior and maxilla anterior regions consist partly of cortical and partly of cancellous bone, while the maxilla anterior region consists largely of spongious bone. Implant success is higher in cortical bone than in cancellous bone. In this study, we found that there were fewer complications in the anterior region of the mandible compared to the posterior region of the maxilla, which supports this observation.[6,26]

A few studies are reporting nasal cavity perforation.[27,28] In this, it was also found at a low rate (3%). The nasal cavity floor, like the maxillary sinus floor, can repair itself at small perforation depths.[7,27] The data obtained in this study were found to be consistent with other similarly structured studies in the literature. Clark et all. and Pamukcu et all. also found the most common complication type to be vertical bone resorption and the area with the most complications to be the maxilla posterior region in both studies. McDermott et all. also found the most complications in the maxilla posterior region.[3,5]

Since this study is retrospective, it is not known whether any complications occurred due to the systemic conditions and oral hygiene of

the patients; it is unclear whether complicated implants caused any anatomical structure damage or infection, and these situations are among the limitations of the study. Another limitation of this study is the beam hardening artifact that occurs around the implant in CBCT. This artifact can be visualized as any bone loss or perforation around the implant. In order to minimize this situation, evaluations can be made by using some metal artifact reduction (MAR) algorithms and keeping the field of view (FOV) of the relevant region as small as possible. The material the implant is made of and the location of the implant in the jaw affect the amount of artifact. MAR is effective in reducing zirconia implant artifacts, while it fails to bar presence of titanium implant artifacts.[29,30]

The probability of perforation with a bone thickness of less than 1 mm is quite high. González-Martín et all. reported that the probability of detecting a bone wall of 0.5 mm and below is less than 20% and that the chance of detecting bone increases by 30.6% with each mm increase in bone thickness.[31] However, Corpos et all. reported that there are statistically significant correlations between radiographic images obtained with CBCT and histological sections and that the standard deviation of the defect amount is less than 0.5 mm in 50% of bone defects.[32,33]

CONCLUSION

The number of dentists is increasing day by day in our country and in the world and dentists perform implant treatments without sufficient knowledge and experience. This situation increases the incidence of complications. As seen in this study, implant complication rates are high. The most common implant complication is vertical bone perforation, and more attention should be paid to vertical angulation and occlusal loading during implant applications. Complications were most frequently seen in the maxillary posterior region. A more careful evaluation of the relevant region with CBCT would be beneficial for physicians.

Ethical Approval

The required ethical approval for this study was received by the Zonguldak Bülent Ecevit University Non-Interventional Clinical Research ethics committee (2023/04).

Financial Support

The authors declare that this study received no financial support.

Conflict of Interest

The authors deny any conflicts of interest related to this study.

Author Contributions

Design: DD, Data collection or data entry: DD, ÇŞ, Analysis and interpretation: DD, GG, Literature review: ÇŞ, DD, Writing: DD, ÇŞ.

REFERENCES

1. Balshi TJ, Wolfinger GJ, Stein BE, Balshi SF. A long- term retrospective analysis of survival rates of implants in the mandible. Int J Oral Maxillofac Implants. 2015;30:1348-54.
2. DeAngelis F, Papi P, Mencio F, Rosella D, DiCarlo S, Pompa G. Implant survival and success rates in patients with risk factors: results from a long-term retrospective study with a 10 to 18 years follow-up. Eur Rev Med Pharmacol Sci. 2017;21:433-7.
3. Pamukcu U, Ispir GN, Alkurt MT, Altunkaynak B, Peker İ. Retrospective evaluation of complications in dental implants using cone beam computed tomography. Selcuk Dent J. 2021;8:367-371.
4. Kohavi D, Azran G, Shapiral C, Casap N. Retrospective clinical review of dental implants placed in a university training program. J Oral Implantol. 2004;30:23-9.
5. Clark D, Barbu H, Lorean A, Mijiritsky E, Levin L. Incidental findings of implant complications on postimplantation cbcts: a cross-sectional study. Clin İmplant Dent Relat Res. 2017;19:776-782.
6. Misch K, Wang H-L. Implant surgery

complications: etiology and treatment. Implant Dent. 2008;17:159-68.

7. Urvasızoglu G, Turen T. Prevalence and treatment methods of intraoperative and early complications encountered in dental implant applications: a retrospective clinical study. Curr Res Dent Sci. 2019;29:259-67.
8. Park SH, Wang HL. Implant reversible complications: classification and treatments. Implant Dent. 2005;14:211-20.
9. Elhamruni LM, Marzook HA, Ahmed WM, Abdul-Rahman M. Experimental study on penetration of dental implants into the maxillary sinus at different depths. Oral Maxillofac Surg. 2016;20:281-7.
10. White S, Pharoah's M. Oral Radiology Principles and Interpretation. 8th ed. St. Louis: Mosby; 2018. p. 325-515.
11. Froum S. Implant complications: scope of the problem. In Froum S. Dental implant complications. New York: John Wiley & Sons; 2010. p. 2-6.
12. Quirynen M, Abarca M, Assche VN, Nevins M, Steenberghe DV. Impact of supportive periodontal therapy and implant surface roughness on implant outcome in patients with a history of periodontitis. J Clin Periodontol. 2007;34:805-15.
13. Moy PK, Medina D, Shetty V, Aghaloo TL. Dental implant failurerates and associated risk factors. Int J Oral Maxillofac Implants. 2005;20:569-77.
14. Palma-Carrió C, Maestre-Ferrín L, Peñarrocha-Oltra D, Peñarrocha-Diago MA, Peñarrocha-Diago M. Risk factors associated with early failure of dental implants. A literature review Med Oral Patol Oral Cir Bucal. 2011;16:514-7.
15. Balshi TJ, Wolfinger GJ. Dental implants in the diabetic patient: A retrospective study. Implant Dent. 1999;8:355-9.
16. Javed F, Romanos GE. Review impact of diabetes mellitus and glycemic control on the osseointegration of dental ımplants: A Systematic Literature Review. J Periodontol. 2009; 80:1719-30.
17. Zetu L, Wang HL. Management of inter-dental/inter-implant papilla. J Clin Periodontol. 2005;32:831–9.
18. Kim SG. Implant-related damage to an adjacent tooth: a case report. Implant Dent. 2000;9:278-80.
19. Balaguer-Marti JC, Penarrocha-Oltra D, Balaguer-Martinez J, Penar- rocha-Diago M. Immediate bleeding complications in dental implants: a systematic review. Med Oral Patol Oral Cir Bucal. 2015;20:e231-8.
20. Felisati G, Lozza P, Chiapasco M, Borloni R. Endoscopic removal of an unusual foreign body in the sphenoid sinus: an oral implant. Clin Oral Implants Res. 2007:18;776-80.
21. Ozmarasali AI, Kaplan DA, Eser P, Yilmazlar S. Dental implant misplacement into the anterior cranial fossae: a unique case and review of literature. Neurochirurgie. 2024;70:101533.
22. Al-Sabbagh M, Okeson JP, Khalaf MW, Bhavsar I. Persistent pain and neurosensory disturbance after dental implant surgery: pathophysiology, etiology, and diagnosis. Dent Clin North Am. 2015;59:131-42.
23. Politis C, Agbaje J, Van Hevele J, Nicolielo L, De Laat A, Lambrichts I, et all. Report of neuropathic pain after dental ımplant placement: a case series. Int J Oral Maxillofac Implants. 2017;32:439-44.
24. Ribas BR, Nascimento HL, Freitas DQ, dos Anjos PA, dos Anjos ML, Perez DEC, et all. Positioning errors of dental implants and their associations with adjacent structures and anatomical variations: a CBCT-based study. Imaging Sci Dent. 2020;50:281-90.
25. Juodzbalys G, Wang HL, Sabalys G. Injury of the inferior alveolar nerve during implant placement: a literature review. J Oral Maxillofac Res. 2011;2:e1.
26. Peterson LJ, Ellis E, Hupp JR, Tucker MR. Contemporary Oral and Maxillofacial Surgery. 4th ed. St. Louis: Mosby; 2003. p. 310-313.

27. Wolff J, Karagozoglu KH, Bretschneider JH, Forouzanfar T, Schulten EA. Altered nasal airflow: an unusual complication following implant surgery in the anterior maxilla. Int J Implant Dent. 2016;2:6.

28. Greenstein G, Cavallaro J, Romanos G, Tarnow D. Clinical recommendations for avoiding and managing surgical complications associated with implant dentistry: a review. J Periodontol. 2008;79:1317-29.

29. Seghers D, Berkus T, Oelhafen M, Munro P, Star-Lack J. Comparison of state of the art interpolation-based metal artifact reduction (MAR) algorithms for cone beam computed tomography (CBCT). Med Phys. 2012;39:3628.

30. Mancini AX, Santos MU, Gaêta-Araujo H, Tirapelli C, Pauwels R., Oliveira-Santos C. Artefacts at different distances from titanium and zirconia implants in cone-beam computed tomography: effect of tube current and metal artefact reduction. Clin Oral Investig. 2021;25:5087-94.

31. González-Martín O, Oteo C, Ortega R, Alandez J, Sanz M, Veltri M. Evaluation of peri-implant buccal bone by computed tomography: an experimental study. Clin Oral Implants Res. 2016;27:950-5.

32. Fienitz T, Schwarz F, Ritter L, Dreiseidler T, Becker J, Rothamel D. Accuracy of cone beam computed tomography in assessing peri-implant bone defect regeneration: a histologically controlled study in dogs. Clin Oral Implants Res. 2012;23:882-7.

33. Hilgenfeld T, Juerchott A, Deisenhofer UK, Krisam J, Rammelsberg P, Heiland S, et all. Accuracy of cone-beam computed tomography, dental magnetic resonance imaging, and intraoral radiography for detecting peri-implant bone defects at single zirconia implants an in vitro study. Clin Oral Implants Res. 2018;29:922-30.