Journal of Dentomaxillofacial Radiology, Pathology and Surgery

Winter 2024, Volume 13, Number 4

Research Paper: Frequency of Peri-implant Bone Loss and Related Factors in an Iranian Population

Farnaz Hanafi[1], Farzaneh Ostovarrad[2], Hadi Ranjzad[3], Amin Rajabzadeh[4], Maryam Latifi Douabsari[5*]

1. School of Dentistry, Gulian University of Medical Sciences, Rasht, Iran
2. Department of Oral and Maxillofacial Radiology, School of Dentistry, Gulian University of Medical Sciences, Rasht, Iran
3. Department of Dental Prosthesis, School of Dentistry, Gulian University of Medical Sciences, Rasht, Iran
4. Department of Periodontics, School of Dentistry, Gulian University of Medical Sciences, Rasht, Iran
5. Department of Oral and Maxillofacial Radiology, School of Dentistry, Gulian University of Medical Sciences, Rasht, Iran

Use your device to scan and read the article online

Citation Hanafi F, Ostovarrad F, Ranjzad H, Rajabzadeh A, Latifi Douabsari M. Frequency of Peri-implant Bone Loss and Related Factors in an Iranian Population. Journal of Dentomaxillofacial Radiology, Pathology and Surgery. 2024; 13(4): 18-27

https://doi.org/10.22034/3DJ.13.4.18

Article info:
Received: 01 Oct 2024
Accepted: 22 Oct 2024
Available Online: 19 Nov 2024

Keywords:
*Bone Resorption
*Dental Implants
*Radiography

ABSTRACT

Introduction: Bone loss can lead to aesthetic complications, impaired hygiene, excessive forces, improper occlusion and severe cases of implant loss and severe bone damage. Multiple factors contribute to bone loss around implants. This study aims to assess the frequency of peri-implant bone loss and its associated factors in Bandar Anzali in 2023.

Materials and Methods: This analytical cross-sectional study was conducted on 207 panoramic radiographs of patients with dental implants retrieved from the archives of an oral radiology clinic in Bandar Anzali, Iran, in 2023. The radiographs were evaluated by a calibrated dental student under the supervision of a radiologist for presence/absence of peri-implant bone loss. Additionally, patients were contacted and surveyed regarding related factors. The data were analyzed using the Chi-square test, with a significant level of P<0.05.

Results: Gender, age, tooth type, implant prosthesis design, opposing occlusion, history of bone grafting, and time passed since prosthetic treatment showed no statistically significant association with peri-implant bone loss (P>0.05). However, bone loss was significantly greater around maxillary implants (P=0.012), in smokers (P=0.024), in patients with underlying systemic diseases (P<0.05), and in those with a history of sinus floor augmentation surgery (P<0.05). A direct correlation was observed between bone loss and time elapsed since surgery (P<0.05).

Conclusion: The results revealed a higher prevalence of peri-implant bone loss in the maxilla and among smokers within the study population. Additional influential factors included a history of sinus floor augmentation, time elapsed since surgery, and underlying systemic diseases.

*** Corresponding Authors:**
Maryam Latifi Douabsari
Address: *Department of Oral and Maxillofacial Radiology, School of Dentistry, Gulian University of Medical Sciences, Rasht, Iran*
Tel: *+989116042984*
E-mail: *maryamlatifi2ab@gmail.com*

1. Introduction

Dental implants are commonly used for replacing missing teeth, with a high success rate. Nonetheless, similar to other surgical procedures, dental implant placement may be associated with complications such as bone loss, periodontal pocket formation, puss discharge and exudation, mobility, sensitivity to percussion, and peri-implant pain and bleeding, which can ultimately result in treatment failure (1). Peri-implant bone loss may lead to aesthetic complications, complicate oral hygiene practice, cause overloading and improper occlusion, and even lead to implant failure and severe alveolar bone destruction (2).

Dental implant survival rates vary across studies, ranging from 73.4% to 100%, with a mean survival rate of 94.6% (3). The primary criteria for evaluating dental implant success include implant stability, absence of peri-implant radiolucency, minimal bone loss (defined as an average vertical bone loss of less than 0.2 mm per year after the first year of function), absence of pain or infection, and no evidence of nerve damage (4). Ross et al. (5) reported a maximum marginal bone loss (MBL) of 1 mm during the first year for successful implants.

The success and survival of dental implants depend on multiple parameters, including patient-related factors, surgical technique-related factors, prosthesis-related factors, and implant-related factors (3). Patient-related factors encompass genetic susceptibility, bone quality, age, diabetes mellitus, smoking, and occlusal forces, among others. Recent studies emphasize the critical role of these factors in influencing implant outcomes. For instance, dental implants placed immediately after tooth extraction demonstrate survival rates as high as 98.5%, while those placed in healed sockets exhibit comparable rates of 98.9%. Moreover, conditions such as diabetes and smoking can negatively impact healing and osseointegration (3,6-9). Implant-related factors include the implant surface, macro-design, and dimensions (length and diameter). Prosthesis type can also affect the type and rate of complications and failure. For instance, single crowns are different from fixed partial dentures, and removable dentures differ from fixed prosthetic restorations in this regard.

As previously discussed, MBL is an important parameter is a critical parameter in evaluating dental implant success. Progressive bone loss leads to peri-implantitis and ultimately results in implant failure. Crestal bone loss may occur at any stage post-implant placement either before or after restoration and arises from multiple etiologies. These factors may include local inflammation or infection, as well as mechanical stresses on the bone surrounding the implant. Traditional clinical indicators such as bleeding on probing or probing depths often fail to accurately reflect the extent of crestal bone loss (CBL). Several strategies can help minimize CBL. Platform switching, which involves using a narrower abutment compared to the implant platform, has been shown to reduce marginal bone resorption (10,11).

Early marginal bone loss (MBL) is a significant concern in both dental implantology and periodontics. It refers to the initial bone loss surrounding dental implants or natural teeth, typically occurring within the first year after implant placement or in the early stages of periodontal disease (8). The significance of early MBL lies in its potential impact on long-term implant stability and success, aesthetic outcomes in dental restorations, overall oral health and function, and the etiology of early marginal bone loss. Key causes of early MBL in dental implants include surgical trauma during implant placement, excessive occlusal loading, microgap formation between the implant and abutment, peri-implantitis (bacterial infection), poor implant positioning, and inadequate bone quality or quantity (13,14).

Evidence shows that peri-implant soft tissue thickness, the location of the implant-abutment connection, and the position of the border between the rough and smooth parts of the implant relative to the bone crest affect the location of biologic width formation and subsequent bone loss. A systematic review conducted by Lombardi et al. (15) investigated the factors influencing early marginal bone loss around dental implants confirmed that peri-implant soft tissue thickness significantly affects early MBL. Implants with thicker, soft tissues (>2 mm) showed less bone loss compared to those with thinner tissues (16). Furthermore, subcrestal placement of the implant-abutment connection resulted in less early MBL compared to equicrestal placement. This supports the observation about thicker biologic width in subcrestally placed implants (15). However, a comparative study on early MBL in maxillary versus mandibular implants confirmed that early MBL is more common in the maxilla than in the mandible. This difference was attributed to variations in bone density and quality between the two jaws (17).

The microgap between the implant and transmucosal component (abutment) is a significant factor contributing to early marginal bone loss. Kim et al. (18) found that the presence of a microgap can lead to bacterial colonization and subsequent inflammation. Also, microgaps as small as 10 µm can harbor bacteria, leading to peri-implant inflammation and implant systems with tighter connections showed less marginal bone loss over time. Other reasons for peri-implant bone loss include occlusal trauma, implant placement timing, bone grafting at the implant site, implant macro-design, implant neck design, implant surface topography, implant shape, implant-abutment connection design, prosthesis design, and soft tissue thickness (19).

Radiographic imaging is essential for assessing bone loss in dental implantology. Cone-beam computed tomography (CBCT) is utilized for preoperative evaluation and treatment planning. Subsequently, panoramic and periapical radiographs are employed for follow-up assessments. For single implants, periapical radiography is preferred due to its lower radiation dose and higher precision, particularly in areas of bone resorption. Conversely, panoramic radiography offers a comprehensive overview for patients with multiple implants across the dental arch, despite its lower accuracy in specific regions (20).

Considering the issues raised and the conditions that may cause bone loss around the implants post-placement, this study aims to determine the frequency of peri-implant bone loss in patients referred to a specialized oral and maxillofacial radiology center. Panoramic radiography was selected due to its common clinical use and ethical considerations regarding radiation exposure. Additionally, the frequency of bone resorption, if present, was assessed. It should be noted that due to the artifact resulting from the implant in CBCT images and the subsequent reduction in accuracy in assessing bone resorption, this modality will not be used in this study.

2. Materials and Methods

This analytical cross-sectional study (approved under ethical code IR.GUMS.REC.1402.442) was conducted on 207 panoramic radiographs of patients with dental implants, retrieved from the archives of a radiology clinic in Bandar Anzali, Iran, in 2023. The sample size was calculated to be 161 based on a study by Merheb et al. (21), assuming an alpha level of 0.05, a beta level of 0.2, and a margin of error (d*d*) of 0.07.

$$p = \frac{20}{28} = 0.71 \qquad q = 0.29 \qquad z = 1.96 \qquad d = 0.07$$

$$n = \frac{z^2\, p(1-p)}{d^2} = \frac{(1.96)^2(0.71)(0.29)}{(0.07)^2} = 161$$

The inclusion criteria for the study consist of all patients with dental implants who have been prescribed panoramic radiography. The minimum time elapsed since implant placement or prosthetic lading was less than 12 months. Additionally, all patients with implants were questioned regarding influencing factors such as diabetes, hypertension, and osteoporosis. These conditions can significantly impact the healing process and stability of dental implants.

The exclusion criteria including poor-quality radiographs that did not clearly visualize the implant site and the adjacent marginal bone. The acceptable resolution for panoramic radiographs should be sufficient clarity that details of the bone and structures surrounding the implant are clearly visible and the images should be free of noise. Patient positioning and the radiation angle is important. In addition, patients with active infections or inflammation in the implant area that could affect the study results. Patients with severe underlying diseases that could impact healing and bone resorption processes.

The confounding variables for the present may include surgical techniques, prosthetic factors, implant characteristics such as the type, length, and material of the implant, and time variables (the duration since surgery and the time elapsed since prosthetic placement) can influence the assessment of bone resorption. Also, differences in patient compliance with oral hygiene can affect peri-implant health and bone loss.

Panoramic radiographs were evaluated for the presence or absence of peri-implant bone loss. Exposure of implant threads at the mesial and distal surfaces served as an indicator of bone loss. Patients were surveyed (via questioning) with potential influential factors, including age, gender, smoking status (current smokers), underlying systemic diseases (diabetes, hypertension, osteoporosis), time elapsed since surgery (months), time elapsed since prosthetic treatment (months).

The jaw type, tooth type, prosthesis type, occlusal relationship of the opposing tooth, history of sinus lift, and history of bone grafting were identified via panoramic radiography.

The radiographs were initially evaluated by a radiologist. Subsequently, the radiologist trained a dental student in the detection of peri-implant bone loss. Following calibration of the dental student, who demonstrated proficiency and accuracy exceeding 90%, the remaining radiographs were evaluated by the student under the radiologist's supervision.

The analysis was done at two descriptive and inferential levels. At the descriptive level of qualitative variables, frequency indicators and frequency percentage, and in quantitative variables, average indicators, standard deviation were reported. At the inferential level, if the normality of the data from Chi-square test is used and otherwise, the non-parametric Mann–Whitney test is applied. The tests were performed using SPSS software version 26 (SPSS Inc., IL, USA) and P< 0.05 was considered statistically significant.

3. Results

Of 207 patients, 115 (55.6%) were males and 92 (44.4%) were female. The mean age was 51.81±11.23 years (range 24-73 years). Age distribution showed 29.5% (n=61) between 40–50 years (Figure 1). Molars were the most common type of replaced teeth with dental implants (n=102, 49.3%), followed by premolars (n=62, 30%) and anterior teeth (n=43, 20.8%). Implant placement occurred in the maxilla for 53.6% (n=111) and the mandible for 46.4% (n=96). Opposing occlusion types included natural teeth (59.9%, n=124), opposing implants (33.3%, n=69), and no opposing occlusion (6.8%, n=14). Prosthetic treatments comprised no treatment (34.3%, n=71), overdentures (10.6%, n=22), prosthetic bridges (12.1%, n=25), and single crowns (43%, n=89). A history of sinus floor augmentation was reported in 24.2% (n=50), while 52.2% (n=108) had undergone bone grafting.

Figure 2 shows the frequency of different underlying diseases. Hypertension was the most common condition found in 39.6% (n=82) of cases. Smoking prevalence was 30.9% (n=64).

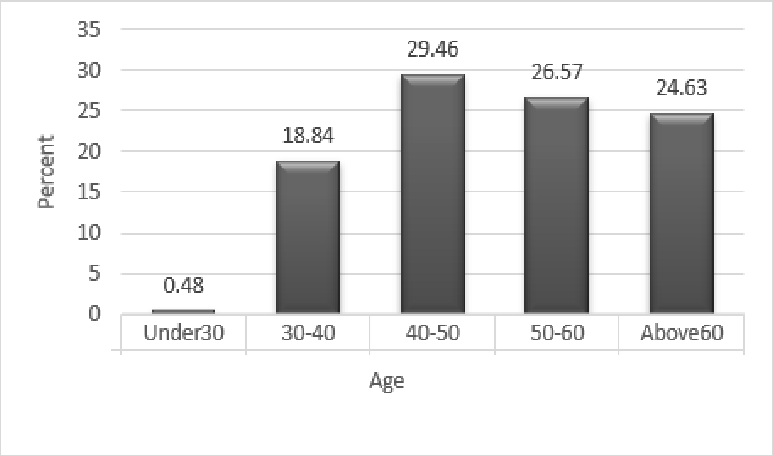

Figure 1. Frequency of different age groups in the study population

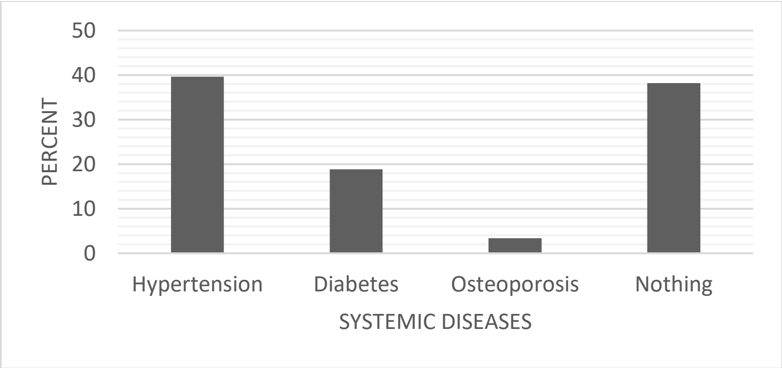

Figure 2. Frequency of different underlying diseases

Figure 3 displays the frequency of time elapsed since surgery, with a mean of 24.85±18 months (range 5-60 months). The frequency of time passed since prosthetic treatment is represented in Figure4, averaging 24.85±18 months (range 1-55 months). The results revealed that 41.5% of the cases (n=86) exhibited peri-implant bone loss.

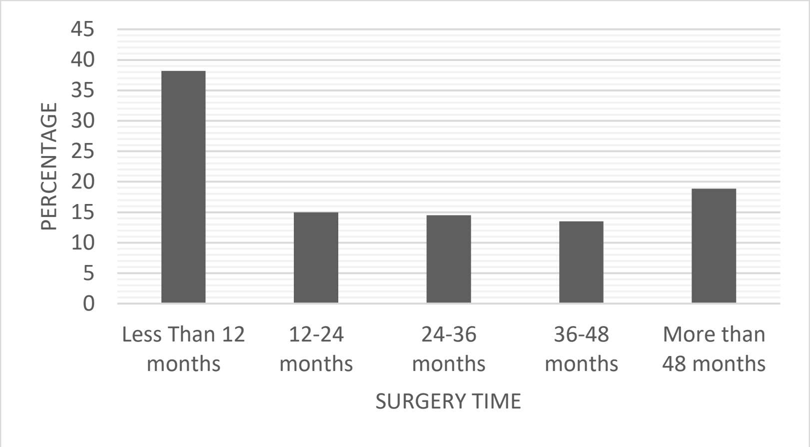

Figure 3. Frequency of time passed since implant surgery

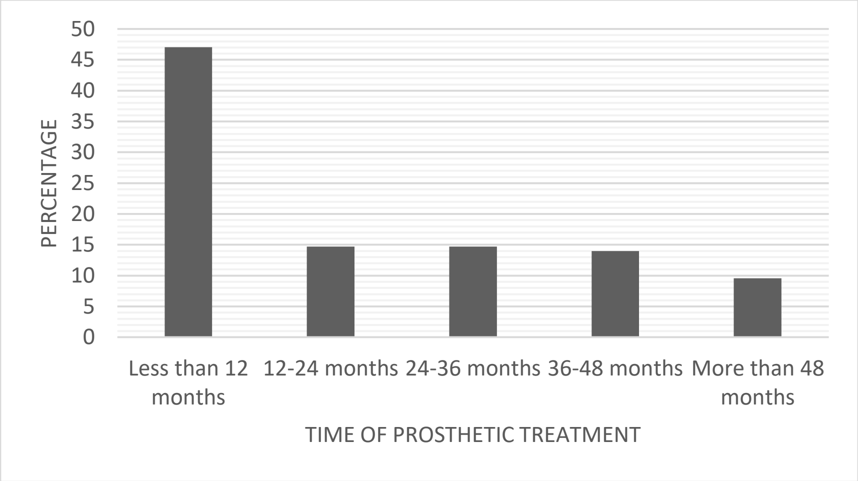

Figure 4. Frequency of time passed since prosthetic treatment

Table 1 examines the association between peri-implant bone loss and variables including gender, age, jaw, tooth type, prosthesis type, and opposing occlusion. As shown, gender (P=0.138), age (P=0.297), tooth type (P=0.316), prosthesis type (P=0.135) and opposing occlusion (P=0.471) demonstrated no significant association with peri-implant bone loss. However, maxillary implants showed a significant higher frequency of bone loss (P=0.012).

Table 2 evaluates the relationship between peri-implant bone loss and smoking, underlying diseases, history of sinus floor augmentation, and history of bone grafting. As indicated, peri-implant bone loss was significantly associated with smoking (P=0.024), while underlying diseases (P=0.049) and history of sinus floor augmentation (P=0.049) showed borderline significance. No significant association was observed with bone grafting (P=0.244).

Table 3 assessed the association between peri-implant bone loss with time elapsed since surgery and prosthetic treatment. A borderline significant association emerged with time since surgery (P=0.049), whereas time since prosthetic treatment (P=0.178) showed no significance.

Table 1. Association of peri-implant bone loss with gender, age, jaw, tooth type, prosthesis type, and opposing occlusion

Parameter	Category	Presence of bone loss		Absence of bone loss		Total		P value*
		Number	Percentage	Number	Percentage	Number	Percentage	
Gender	Male	53	46.1	62	53.9	115	100	0.138
	Female	33	35.9	59	64.1	92	100	
Age (yrs)	<30	1	100	0	0	1	100	0.297
	30-40	12	30.8	27	69.2	39	100	
	40-50	29	47.5	32	52.5	61	100	
	50-60	25	45.5	30	54.5	55	100	
	>60	19	37.3	32	62.7	51	100	
Jaw	Maxilla	55	49.5	56	50.5	111	100	0.012
	Mandible	31	32.3	65	67.7	96	100	
Tooth type	Anterior	20	46.5	23	53.5	43	100	0.316
	Premolar	29	46.8	33	53.2	62	100	
	Molar	37	36.3	65	63.7	102	100	
Prosthesis Type	Single crown	32	43.8	50	56.2	89	100	0.135
	Bridge	11	44	14	56.0	25	100	
	Overdenture	4	18.2	18	81.8	22	100	
	None	32	45.1	39	54.9	71	100	
Opposing Occlusion	Natural Tooth	50	40.3	74	59.7	124	100	0.471
	Implant	28	40.6	41	59.4	69	100	
	No occlusion	8	57.1	6	42.9	14	100	

*Chi-square test

Table 2. Association of peri-implant bone loss with smoking, underlying diseases, history of sinus floor augmentation, and history of bone grafting

Parameter	Category	Presence of bone loss		Absence of bone loss		Number		P value*
		Number	Percentage	Number	Percentage	Number	Percentage	
Smoking	Yes	34	53.1	30	46.9	64	100	0.024
	No	52	36.4	91	63.6	143	100	
Underlying disease	Present	44	34.4	84	65.6	128	100	0.049
	Absent	42	53.2	37	46.8	79	100	
Sinus floor augmentation	Yes	15	30	35	70	50	100	0.049
	No	71	45.2	86	54.8	157	100	
Bone grafting	Yes	49	45.4	59	54.6	108	100	0.244
	No	37	37.4	62	62.6	99	100	

*Chi-square test

Table 3. Association of peri-implant bone loss with time passed since surgery and prosthetic treatment

Parameter	Category	Presence of bone loss		Absence of bone loss		Total		P value*
		Number	Percentage	Number	Percentage	Number	Percentage	
Time passed since surgery (months)	<12	23	29.1	56	70.9	79	100	0.049
	12-24	14	45.2	17	54.8	31	100	
	24-36	14	46.7	16	53.3	30	100	
	36-48	16	57.1	12	42.9	28	100	
	>48	19	48.7	20	51.3	39	100	
Time passed since prosthetic treatment (months)	<12	21	32.8	43	67.2	64	100	0.178
	12-24	8	40	12	60	20	100	
	24-36	9	45	11	55	20	100	
	36-48	12	63.2	7	36.8	19	100	
	>48	4	30.8	9	69.2	13	100	

*Chi-square test

4. Discussion

This study assessed the frequency of peri-implant bone loss and the related factors in an Iranian population using panoramic radiography. The results showed that 41.5% of cases (n=86) exhibited peri-implant bone loss. Gender showed no significant association with peri-implant bone loss, which was in line with the results of Galindo-Moreno et al. (8). However, Negri et al. (2)

reported higher frequency of peri-implant bone loss in females compared to males, which contrasted with the present findings probably because of higher number of females in their study and their higher mean age compared to the current study. Additionally, menopause may contribute to reduced bone density and osteoporosis in females, potentially influencing peri-implant outcomes (2).

In the present study, peri-implant bone loss showed a higher frequency in patients aged 40-60 years; nonetheless, age demonstrated no significant association with bone loss. Earlier studies reported a significant association between aging and bone loss/osteoporosis, attributed to decreased calcium and minerals in the elderly populations (2,11). These findings contrast with our results due to genetic/nutritional differences or variations in female to male ratios across study populations. Notably, females over 60 years exhibit a higher likelihood of bone loss and osteoporosis compared to males, which may explain discrepancies in reported results across literature (2).

According to the present results, peri-implant bone loss in the maxilla was significantly higher than that in the mandible, which was in line with findings by Negri et al. (2), despite their larger sample size. Di Fiore et al. (23) reported higher peri-implant bone loss compared to the mandible than maxilla, contrasting with the present findings, probably because of their smaller sample size. In contrast, Galindo-Moreno et al. (8) showed that jaw had no significant effect on peri-implant bone loss. Beyond sample size variations, this difference can be due to variations in duration of edentulism, implant height, genetic factors, and dietary habits, all of which profoundly influence bone density (8,11).

Occlusal overload plays an important role in peri-implant bone loss, often due to premature contacts and occlusal interferences. This condition may be clinically aggravated in cases involving poor bone quality, inadequate soft/hard tissue volume, suboptimal implant position, or mucosal inflammation. Consequently, parafunctional habits, and soft/hard tissue volume should be assessed preoperatively. Additionally, mild occlusal contacts, minimizing lateral forces, equal distribution of occlusal forces on natural teeth (if present), and occlusal class should be precisely considered in prosthesis design. In the current study, the type of implant prosthesis showed no significant effect on peri-implant bone loss. Galindo-Moreno et al. (24) reported that external connection of prosthesis played a role in peri-implant bone loss. However, our findings revealed comparable bone loss levels between overdenture and single crowns, with the lowest rates observed around bridges, though no statistically significant differences were detected.

Cigarette smoke-elicited cellular senescence may play a crucial role in the development and progression of periodontal disease. Furthermore, cigarette smoke-induced cellular senescence may hinder the repair processes and lead to abnormal wound healing following periodontal treatments. This phenomenon of smoking-induced cell senescence significantly contributes to the pathogenesis of periodontal disease (25).

The study conducted by Tatsumi et al. (26) demonstrates that long-term repeated exposure to nicotine or cigarette smoke condensate (CSC) significantly suppresses cell proliferation in human gingival fibroblasts (HGFs), reduces their wound healing ability, modulates extracellular matrix (ECM) protein homeostasis, stimulates the inflammatory response, and induces a senescent phenotype. These findings imply that chronic and repeated exposure to cigarette smoke may play a critical role in cellular senescence within HGFs.

In the present study, smoking had a significant association with peri-implant bone loss which can be due to the presence of multiple toxic compounds and cytotoxic materials in cigarette smoke that impair blood circulation and tissue healing. Clementini et al. (27) reported that smoking increased the peri-implant bone loss by 0.164 mm per year, consistent with the present results. Thus, smoking can be considered an influential factor in peri-implant bone loss. However, a history of bone grafting and time elapsed since prosthetic treatment showed no significant association with peri-implant bone loss.

Underlying diseases such as diabetes mellitus and osteoporosis affect alveolar bone density and increase the risk of crestal bone loss around dental implants (28). Underlying diseases showed a borderline significant association with peri-implant bone loss in the present study. Al Zahrani et al. (29) reported greater bone loss in diabetic patients compared to non-diabetic patients over a 7-year period. A literature search by the authors revealed no prior studies investigating the association between hypertension and peri-implant bone loss. Due to the small number of patients with osteoporosis in the present study, no definitive conclusion could be reached regarding its association with peri-implant bone loss.

Reduction in bone volume due to resorption (especially in long-term tooth loss), poor bone quality, and anatomical problems such as sinus pneumatization in the posterior maxilla complicate dental implant placement or compromise its long-term success (30-32). Galindo-Moreno et al. (22) in their 12-month study, pointed to the negative effect of sinus floor augmentation on peri-implant bone loss. Thus, their results were in line with the present findings regarding significant association of sinus floor augmentation and peri-implant bone loss.

In the current study, the highest bone loss was noted in patients who had undergone implant surgery less than 12 months earlier, and a borderline significant association was found between the time passed since surgery and peri-implant bone loss. Galindo-Moreno et al. (8,11) reported an increase in peri-implant bone loss over time, which can be due to a number of factors such as history of bone grafting, implant height, connection design, smoking, and underlying bone condition. It appears that time passed since surgery cannot serve as an influential factor in bone loss around dental implants, and some other factors are also involved in this process.

This study was limited to a single city and relied solely on panoramic radiographs, which may not capture subtle bone changes as precisely as CBCT. Additionally, patient-related factors were self-reported, and economic variables influencing treatment outcomes were not evaluated. The exclusion of patient perspectives also limits the comprehensiveness of the findings. Future research should include multicenter data, incorporate objective clinical measures, and explore financial, behavioral, and patient-reported outcomes to better understand peri-implant bone loss.

5. Conclusion

The results highlighted a higher frequency of peri-implant bone loss in the maxilla and among smokers within the study population. Other influential factors included a history of sinus floor augmentation, time elapsed since surgery, and underlying diseases.

Ethical Considerations

The study was approved by the internal ethical review board of the Guilan University of Medical Sciences (IR.GUMS.REC.1402.442).

Funding

None.

Authors' Contributions

Farnaz Hanafi: Writing – original draft, Investigation **Farzaneh Ostovarrad:** Conceptualization, Funding acquisition, Project administration, Validation, Visualization **Hadi Ranjzad:** Supervision **Amin Rajabzadeh:** Supervision, Methodology **Maryam Latifi Douabsari:** Resources, Writing – review and editing.

Conflict of Interests

The authors declare no conflict of interest.

Availability of Data and Materials

The datasets used and/or analyzed during the current study will be available from the corresponding author upon reasonable request.

Acknowledgments

None.

References

1. Astrand P, Engquist B, Anzén B, Bergendal T, Hallman M, Karlsson U, et al. A three-year follow-up report of a comparative study of ITI Dental Implants and Brånemark System implants in the treatment of the partially edentulous maxilla. Clin Implant Dent Relat Res. 2004;6(3):130-41. [DOI: 10.1111/j.1708-8208.2004.tb00213.x] [PMID]
2. Negri M, Galli C, Smerieri A, Macaluso GM, Manfredi E, Ghiacci G, et al. The effect of age, gender, and insertion site on marginal bone loss around endosseous implants: results from a 3-year trial with premium implant system. Biomed Res Int. 2014;2014:369051. [DOI: 10.1155/2014/369051][PMID] [PMCID]
3. Moraschini V, da C Poubel LA, Ferreira VF, dos SP Barboza E. Evaluation of survival and success rates of dental implants reported in longitudinal studies with a follow-up period of at least 10 years: a systematic review. Int J Oral Maxillofac Surg. 2015;44(3):377-88. [DOI: 10.1016/j.ijom.2014.10.023] [PMID]
4. Halpern LR, Adams DR. Medically complex dental implant patients: controversies about systemic disease and dental implant success/survival. Dent Clin North Am. 2021;65(1):1-9. [DOI: 10.1016/j.cden.2020.08.001] [PMID]
5. Roos J, Sennerby L, Lekholm U, Jemt T, Gröndahl K, Albrektsson T. A qualitative and quantitative method for

evaluating implant success: a 5-year retrospective analysis of the Brånemark implant. Int J Oral Maxillofac Implants. 1997;12(4):504-14. [PMID]

6. Dereka X, Akcalı A, Trullenque-Eriksson A, Donos N. Systematic review on the association between genetic polymorphisms and dental implant-related biological complications. Clin Oral Implants Res. 2022;33(2):131-41. [DOI: 10.1111/clr.13882] [PMID]

7. Moraschini V, Barboza Ed. Success of dental implants in smokers and non-smokers: a systematic review and meta-analysis. Int J Oral Maxillofac Surg. 2016;45(2):205-15. [DOI: 10.1016/j.ijom.2015.08.996][PMID]

8. Galindo-Moreno P, Catena A, Pérez-Sayáns M, Fernández-Barbero JE, O'Valle F, Padial-Molina M. Early marginal bone loss around dental implants to define success in implant dentistry: A retrospective study. Clin Implant Dent Relat Res. 2022;24(5):630-642. [DOI: 10.1111/cid.13122] [PMID] [PMCID]

9. Rammelsberg P, Lorenzo-Bermejo J, Kappel S. Effect of prosthetic restoration on implant survival and success. Clin Oral Implants Res. 2017;28(10):1296-1302. [DOI: 10.1111/clr.12974] [PMID]

10. Pardal-Peláez B, Flores-Fraile J, Pardal-Refoyo JL, Montero J. Implant loss and crestal bone loss in immediate versus delayed load in edentulous mandibles: A systematic review and meta-analysis. J Prosthet Dent. 2021;125(3):437-444. [DOI: 10.1016/j.prosdent.2020.01.032] [PMID]

11. Galindo-Moreno P, León-Cano A, Ortega-Oller I, Monje A, Valle FO, Catena A. Marginal bone loss as success criterion in implant dentistry: beyond 2 mm. Clin Oral Implants Res. 2015;26(4):e28-34. [DOI: 10.1111/clr.12324] [PMID]

12. Arai Y, Takashima M, Matsuzaki N, Takada S. Marginal bone loss in dental implants: A literature review of risk factors and treatment strategies for prevention. J Prosthodont Res. 2024;69(1):12-20. [DOI: 10.2186/jpr.JPR_D_23_00223] [PMID]

13. Albrektsson T, Jemt T, Mölne J, Tengvall P, Wennerberg A. On inflammation-immunological balance theory—A critical apprehension of disease concepts around implants: Mucositis and marginal bone loss may represent normal conditions and not necessarily a state of disease. Clin Implant Dent Relat Res. 2019;21(1):183-189. [DOI: 10.1111/cid.12711] [PMID]

14. Lombardi T, Berton F, Salgarello S, Barbalonga E, Rapani A, Piovesana F, et al. Factors influencing early marginal bone loss around dental implants positioned subcrestally: a multicenter prospective clinical study. J Clin Med. 2019;8(8):1168. [DOI: 10.3390/jcm8081168] [PMID] [PMCID]

15. Nimbalkar S, Dhatrak P, Gherde C, Joshi S. A review article on factors affecting bone loss in dental implants. Materials Today Proceedings. 2021;43:970-976. [DOI:10.1016/j.matpr.2020.07.428]

16. Donati M, Ekestubbe A, Lindhe J, Wennström JL. Marginal bone loss at implants with different surface characteristics-a 20-year follow-up of a randomized controlled clinical trial. Clin Oral Implants Res. 2018;29(5):480-487. [DOI: 10.1111/clr.13145] [PMID]

17. Kim YM, Lee JB, Um HS, Chang BS, Lee JK. Long-term effect of implant-abutment connection type on marginal bone loss and survival of dental implants. J Periodontal Implant Sci. 2022;52(6):496. [DOI: 10.5051/jpis.2200960048][PMID] [PMCID]

18. Sargolzaie N, Zarch HH, Arab H, Koohestani T, Ramandi MF. Marginal bone loss around crestal or subcrestal dental implants: Prospective clinical study. J Korean Assoc Oral Maxillofacial Surg. 2022;48(3):159-66. [DOI: 10.5125/jkaoms.2022.48.3.159] [PMID] [PMCID]

19. Costa JA, Mendes JM, Salazar F, Pacheco JJ, Rompante P, Câmara MI. Analysis of peri-implant bone defects by using cone beam computed tomography (CBCT): an integrative review. Oral Radiology. 2023;39(3):455-466. [DOI: 10.1007/s11282-023-00683-w] [PMID] [PMCID]

20. Merheb J, Graham J, Coucke W, Roberts M, Quirynen M, Jacobs R, et al. Prediction of implant loss and marginal bone loss by analysis of dental panoramic radiographs. Int J Oral Maxillofac Implants. 2015;30(2):372-7. [DOI: 10.11607/jomi.3604] [PMID]

21. Di Fiore A, Vigolo P, Sivolella S, Cavallin F, Katsoulis J, Monaco C, et al. Influence of crown-to-implant datio on long-term marginal bone loss around short implants. Int J Oral Maxillofac Implants. 2019;34(4):992-998. [DOI: 10.11607/jomi.7161] [PMID]

22. Galindo-Moreno P, Fernández-Jiménez A, Avila-Ortiz G, Silvestre FJ, Hernández-Cortés P, Wang HL. Marginal bone loss around implants placed in maxillary native bone or grafted sinuses: a retrospective cohort study. Clin Oral Implants Res. 2014;25(3):378-84. [DOI: 10.1111/clr.12122] [PMID]

23. Vermehren MF, Wiesmann N, Deschner J, Brieger J, Al-Nawas B, Kämmerer PW. Comparative analysis of the impact of e-cigarette vapor and cigarette smoke on human gingival fibroblasts. Toxicol In Vitro. 2020;69:105005. [DOI: 10.1016/j.tiv.2020.105005] [PMID]

24. Tatsumi M, Yanagita M, Yamashita M, Hasegawa S, Ikegami K, Kitamura M, et al. Long-term exposure to cigarette smoke influences characteristics in human gingival fibroblasts. J Periodontal Res. 2021;56(5):951-963. [DOI: 10.1111/jre.12891] [PMID]

25. Clementini M, Rossetti PH, Penarrocha D, Micarelli C, Bonachela WC, Canullo L. Systemic risk factors for peri-implant bone loss: a systematic review and meta-analysis. Int J Oral Maxillofacial Surg. 2014;43(3):323-34. [DOI: 10.1016/j.ijom.2013.11.012] [PMID]

26. Temmerman A, Rasmusson L, Kübler A, Thor A, Merheb J, Quirynen M. A prospective, controlled, multicenter study to evaluate the clinical outcome of implant treatment in women with osteoporosis/osteopenia: 5-year results. J Dent Res. 2018;98(1):84-90. [DOI: 10.1177/0022034518798804] [PMID]

27. Al Zahrani S, Al Mutairi AA. Crestal bone loss around submerged and non-submerged dental implants in individuals with type-2 diabetes mellitus: a 7-year prospective clinical study. Me Princ Pract. 2019;28(1):75-81. [DOI: 10.1159/000495111] [PMID] [PMCID]

28. Ragucci GM, Elnayef B, Del Amo FS, Wang HL, Hernández-Alfaro F, Gargallo-Albiol J. Influence of exposing dental implants into the sinus cavity on survival and complications

rate: a systematic review. Int J Implant Dent. 2019;5(1):6. [DOI: 10.1186/s40729-019-0157-7] [PMID] [PMCID]

29. Shihab OI. Intentional penetration of dental implants into the maxillary sinus: a retrospective study. Zanco J Med Sci. 2017;21(1):1536-9. [DOI:10.15218/zjms.2017.001]

30. An JH, Park SH, Han JJ, Jung S, Kook MS, Park HJ, et al. Treatment of dental implant displacement into the maxillary sinus. Maxillofac Plast Reconstr Surg. 2017;39(1):35. [DOI: 10.1186/s40902-017-0133-1] [PMID] [PMCID]