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RESEARCH ARTICLE

Evaluation of the Relationship Between Marginal Bone Loss and Implant Angulation in All-on-Four System

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ABSTRACT

Purpose: The All-on-four concept is a reliable treatment modality for severely atrophic jaws. The aim of this study is to investigate the correlation between the marginal bone loss, length, and angulation of tilted implants inserted for full-arch rehabilitation according to the All-on-four concept using cone-beam computer tomography (CBCT) images.

Material and Methods: A retrospective study was conducted based on medical records including clinical and radiographical data of dental implant patients treated between September 2017 and September 2023. The patients were treated with dental implants according to the All-on-four concept with the same dental implant brand. Patients without any systemic conditions, non-smokers, and patients who received immediate prosthetic rehabilitation were included in this study. From the CBCT images, the average marginal bone loss was compared between implants according to their angle-length measurement.

Results: The mean follow-up time was 32.7±16.9 months. The angulation of the axial implants was between 73.07 to 98.41 degrees and lateral implants were tilted 50.45 to 86.46 degrees. The marginal bone loss increased as the angle of the implant increased. The resorption rate was not affected by gender, age, and follow-up duration.

Conclusion: Regarding this study's findings, it can be stated that the wide range of different implant angulations in the All-on-four concept is well tolerated in physiologic limits regarding marginal bone loss, thus it is a successful procedure for rehabilitation of edentulous patients. However, care must be taken for follow-ups and the cooperation of the patient is crucial for the prognosis.

Keywords: All-on-four, Implant agulation, Marginal Bone Loss, Marginal Bone Loss

INTRODUCTION

Implant treatment is one of the most common treatment options for partial or total edentulism. However, the outcome of implant therapy is determined by the length and width of residual bone level. Implants are suggested to ideally be positioned parallel to one another, to neighboring teeth, and vertically aligned with axial stresses.[1] The constraints of anatomical structures such as the maxillary sinus and inferior alveolar nerve often preclude implants from being placed axially. Although bone augmentation is a common surgical procedure aimed to increase bone height prior to or concurrently with the placement of dental implants, this procedure has limitations such as increased morbidity, possible surgical difficulties, high expense, and a longer healing period.[2] Alternative fixed restoration options for the atrophic jaw without augmentation procedure include implant-supported fixed partial dentures with a distal cantilever, the use of short implants or the zygomatic implants, implant placement in the pterygoid region, and the use of subperiosteal implants. Another option is the use of a distally tilted posterior implant anteriorly to avoid the maxillary sinus or mental foramina.[3,4]

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The all-on-four concept allows for the use of longer implants, enhances the greater implant-to-bone contact area and implant stability; creates distance between the anterior and posterior implants, resulting in greater load distribution; and significantly reduces the distal cantilever size or eliminates it.[5] Also, the patient satisfaction rate for All-on-four implants was reported to be very high.[6]

In clinical studies, the effect of implant angle on peri-implant bone resorption in the all-on-four concept has been controversial. In the studies in the literature to date, most authors divided the implants into two groups tilted and axial without considering the angulation degrees and reported their data comparing these two groups.[3,4,7,8,9,10,11,12] Also, the general tendency was toward evaluating the marginal bone loss (MBL) among tilted and axial implants with plain radiographs.[13] However, we used CBCT to accurately measure implant angulation and MBL and aimed to evaluate the correlation between the angulation degree of the implants and marginal bone loss for full-arch rehabilitation according to the All-on-four concept.

MATERIAL AND METHOD

Patient Selection:

Clinical and radiographic records of patients admitted to the hospital between 2017-2023 were evaluated and patients who underwent the procedure of the All-on-four concept either maxilla, mandible, or both in Baskent University, Department of Oral and Maxillofacial Surgery, Ankara, Turkey were included in this retrospective study. Inclusion criteria were having preoperative and postoperative CBCT images, having the same brand of dental implants (Nobel Biocare, Swiss), having operations carried out by the same surgical team with over 15 years of experience, patients who received immediate provisional prosthetic rehabilitation, not having any systemic conditions, and not smoking. Implants without sufficient primary stability for prosthetic rehabilitation, patients who need major grafting, and lack clinical and radiological data were excluded from the study.

This study was approved by Baskent University Institutional review board (Project no: D-KA23/27) and Baskent University Research Committee.

Data collection:

Preoperative, postoperative and post-prosthetic panoramic graphs of the patient rehabilitated with the "all on four" technique are given in Figures 1, 2 and 3. The CBCT (Morita 3D Accuitomo 170 (J Morita, Kyoto, Japan)) images from all patients were taken by the same operator and analyzed by one examiner. The same software program was used to measure the implant angulation and the marginal bone loss. To measure the implant angulation each image of tilted implants was adjusted to the sagittal section and each image of axial implants was adjusted to the frontal section. Anterior implants were considered as axial implants and posterior implants were considered as tilted implants. The angle created by the line tracing the alveolar bone ridge and a parallel line superimposed with the long axis of the implant is considered as angulation of the implant. The angles were measured between distal and mesial aspects from the long axis of the

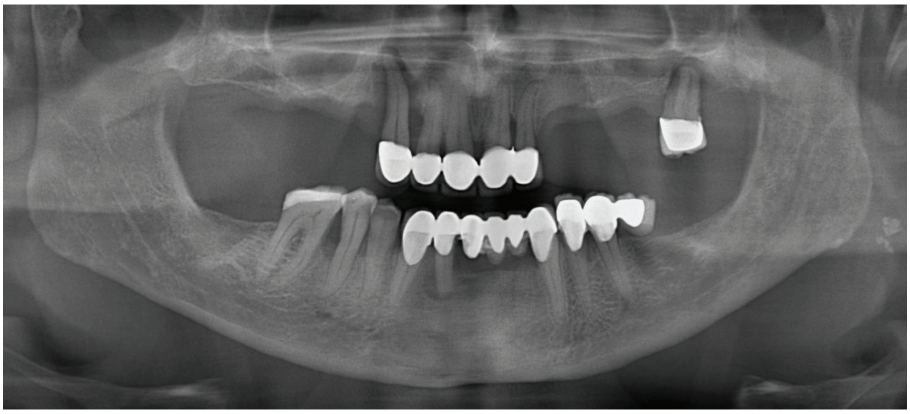

Figure 1. Representative pre-operative orthopantomography of a patient.

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implant and the crossing horizontal line, which indicates the alveolar bone level. To assess the marginal bone loss on the CBCT sagittal section, the interval between the implant neck to the most apical point of the alveolar bone around the implant neck was measured on both sides in millimeters. Distal and mesial measurements were averaged to obtain the mean marginal bone loss. (Figure 4)

To adjust for radiographic distortion, the actual length and width of the implants were compared to the measured implant dimensions on the CBCT sagittal sections.

Statistical Analyses:

All statistical data analyses were processed with the Statistical Package for the Social Sciences (SPSS) version 28.0 (IBM Corp., Armonk, NY, USA). The partial correlation analysis was carried out to evaluate the association between marginal bone loss on the distal and mesial side of the implant with explanatory variables such as gender, age, and follow-up controlled. The Pearson correlation coefficient analysis was performed to evaluate the correlating relation between mesial, distal, and mean marginal bone loss and implant angulation separately. Anterior implants are considered axial implants and posterior implants are considered tilted implants; the 2 groups of implants were equated on marginal bone loss level using a paired samples t-test. The resulting measurement p-value equal to or less than 0.05 was considered statistically significant.

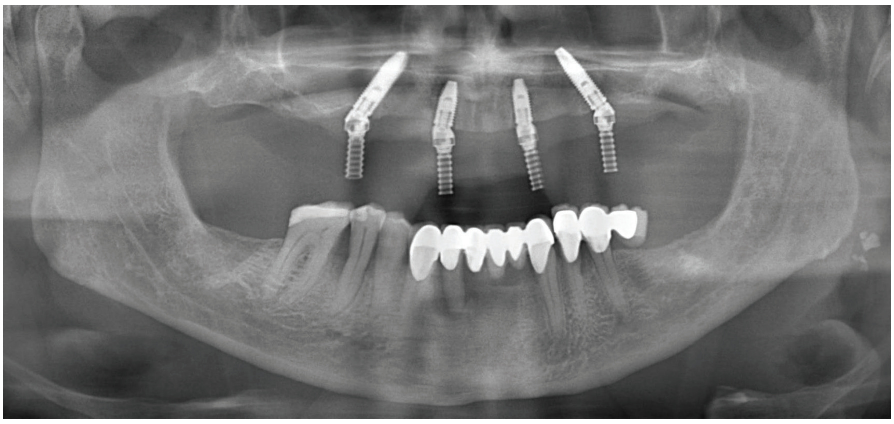

Figure 2. Representative post-operative orthopantomography of the same patient rehabilitated with a maxillary All-on-four.

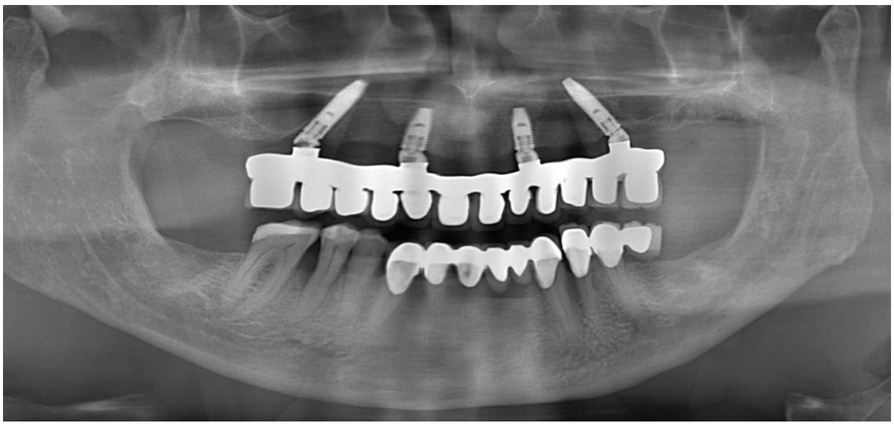

Figure 3. Representative post-loading of orthopantomography of the same patient rehabilitated with a maxillary All-on-four.

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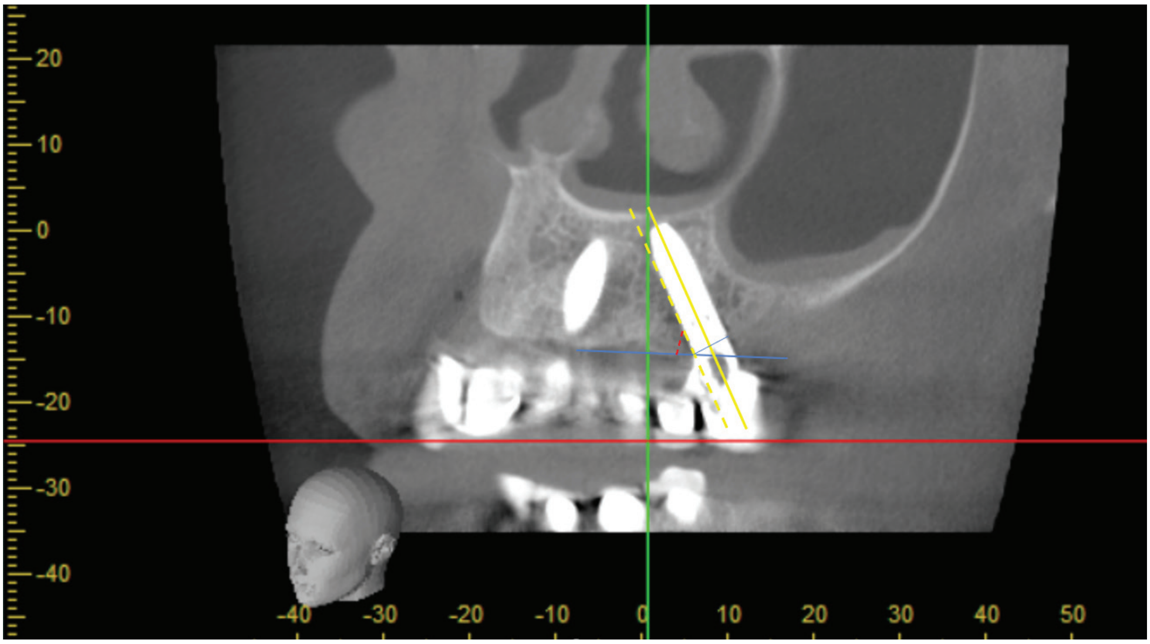

Figure 4. Measurement of angulation of implants on CBCT.

RESULTS

Nine out of 20 patients were eligible for inclusion in this study. Five females and four males with a mean age of 59 years (range 36-71 years). A total of 36 implants were placed, 28 implants were in the maxilla while 8 implants were in the mandible. The mean follow-up was 32.7 months (range 25-67 months). Maximum mean marginal bone resorption in the tilted implants was measured as 1.83 mm and implant angulation differed between 50.45° to 86.46°, and maximum mean marginal bone resorption in the axial implants was measured as 1.96 mm and implant angulation differed from 73.07° to 98.41°. The length of the distal implants differs between 13 to 16 mm and the axial implants differ between 10 to 13 mm (Table 1).

There was no correlation between angulation and distal marginal bone loss (r=-0.019) (Table 2) (Figure 5), with no significant correlation (P →0.966) when gender, age, and follow-up duration were controlled separately with the partial correlation test (Table 3).

Table 1. Data of implants regarding position, diameter, length, follow-up, and angulation.

Gender	Age	Follow up \month\	Jaw	Implants																			
				1. Implant					2. Implant					3. Implant					4. Implant				
				Diameter /mm/	Length /mm/	Implant angulation	MBL		Diameter /mm/	Length /mm/	Implant angulation	MBL		Diameter /mm/	Length /mm/	Implant angulation	MBL		Diameter /mm/	Length /mm/	Implant angulation	MBL	
							Mesial \mm\	Distal \mm\				Mesial \mm\	Distal \mm\				Mesial \mm\	Distal \mm\				Mesial \mm\	Distal \mm\
Female	63	25	Maxilla	4.3	16	85	0.4	0.35	3.5	13	91	0.3	0.1	3.5	13	89	0.2	0.25	4.3	16	62	0.1	0
Male	71	27	Maxilla	4.3	16	61.43	0.3	0.37	4.3	13	81.12	0.4	0	4.3	13	78.69	0.17	0.27	4.3	15	59.9	0.09	0.06
Male	48	67	Maxilla	4.3	15	81	1.5	1.4	4.3	13	94	1.2	1	4.3	11.5	90	0.5	0.5	4.3	15	79	0.8	0.1
Female	60	50	Maxilla	3.5	16	86.46	1.33	0.64	3.5	11.5	73.07	1.22	0.98	3.5	13	98.41	0.52	1	3.5	16	59.34	1.49	0.97
Male	61	21	Maxilla	4.3	16	50.45	1.39	1.09	4.3	11.5	96.05	0	0.1	4.3	11.5	88.23	0	0	4.3	16	66.26	1.65	0.97
Male	61	21	Mandibula	4.3	13	59.38	1.83	0.43	4.3	11.5	90	0.8	0	4.3	11.5	90	1.59	1.96	4.3	13	50.47	1.06	1.39
Female	36	22	Maxilla	4.3	13	61.19	0.5	0	3.75	11.5	79.26	0.4	0	3.75	11.5	90	0.4	0	4.3	13	54.84	0.3	0
Female	36	22	Mandibula	4.3	13	79.99	0.3	0.2	3.75	11.5	89.24	0.4	0.5	3.75	11.5	88.75	0.4	0.28	4.3	13	58.45	0.4	0.2
Female	67	46	Maxilla	4.3	13	68	0.3	0	4.3	10	94	0.4	0.1	4.3	11.5	89	0.5	0.1	4.3	16	69	0.2	0.5
Male	67	12	Maxilla	4.3	15	59.46	1.41	0.45	4.3	10	77.13	0.2	0	4.3	10	78.02	0	0	4.3	15	64.9	0.3	0
Female	60	47	Maxilla	4.3	13	73	0.4	0.45	4.3	13	90	0.3	0.8	4.3	13	83	0.2	0.8	4.3	13	67	0.8	0.2

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Table 2. The Pearson correlation coefficient test between implant angulation and distal marginal bone loss of implants.

		Distal MBL /mm/	Implant angulation
Distal MBL /mm/	**Pearson Correlation**	1	-.019
	Sig. (2-tailed)		.901
Implant angulation	**Pearson Correlation**	-.019	1
	Sig. (2-tailed)	.901	

Table 3. Partial correlation test between implant angulation and distal marginal bone loss of implant when gender, age, and follow-up are controlled separately.

Control Variables			Distal MBL /mm/	Implant angulation
Gender, Age, Follow-up	**Distal MBL /mm/**	**Correlation**	1.000	-.007
		Sig. (2-tailed)	.	.966
		df	0	39
	Implant angulation	**Correlation**	-.007	1.000
		Sig. (2-tailed)	.966	.
		df	39	0

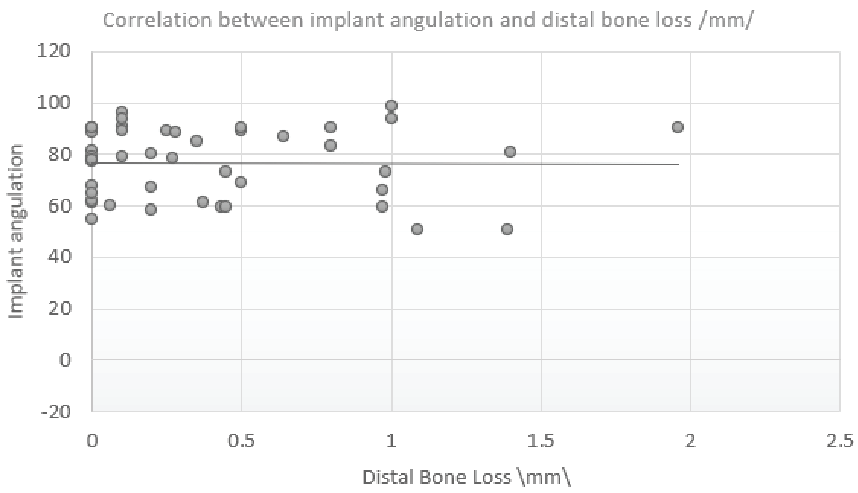

Figure 5. Correlation between implant angulation and distal bone loss.

There was a very weak negative correlation between angulation and mesial marginal bone loss (r=-0.243) (Table 4) (Figure 6) with no significant correlation (P →0.129) in the partial correlation test when gender, age, and follow-up were controlled (Table 5).

The statistical analysis showed a very weak negative correlation between the angulation and the mean marginal bone loss (r=-0.148) (Table 6) (Figure 7) meaning the mean marginal bone loss decreases very slightly when the implant angulation increases or becomes closer to 900 to the alveolar bone ridge. In the partial correlation test, these results were not significant (P →0.386) when gender, age, and follow-up were considered (Table 7).

In the Paired Sample t-test mean-marginal bone loss in axial implants was 0.42+0.42 mm and in tilted implants it was 0.60+0.47 mm. The difference between axial and tilted implants in mean marginal bone loss was not statistically significant (P →0.086) (Table 8) (Figure 8).

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Table 4. The Pearson correlation coefficient test between implant angulation and mesial marginal bone loss of the implants.

		Mesial MBL /mm/	Implant angulation
Mesial MBL /mm/	Pearson Correlation	1	-.243
	Sig. (2-tailed)		.112
Implant angulation	Pearson Correlation	-.243	1
	Sig. (2-tailed)	.112	

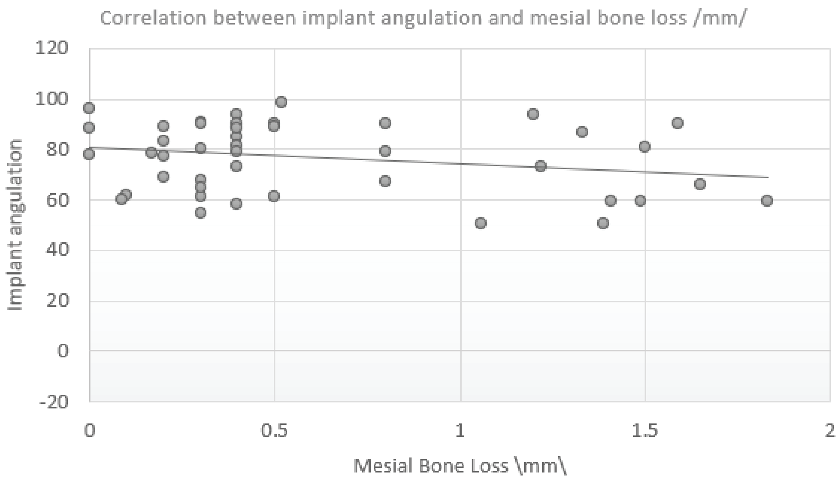

Figure 6. Correlation between implant angulation and mesial bone loss.

Table 5. Partial correlation test between implant angulation and mesial marginal bone loss of implant when gender, age, and follow-up are controlled separately.

Control Variables			**Mesial MBL /mm/**	**Implant angulation**
Gender, Age, Follow-up	**Mesial MBL /mm/**	Correlation	1.000	-.241
		Sig. (2-tailed)	.	.129
		df	0	39
	Implant angulation	Correlation	-.241	1.000
		Sig. (2-tailed)	.129	.
		df	39	0

Table 6. The Pearson correlation coefficient test between implant angulation and mean marginal bone loss of the implants.

		Mean MBL /mm/	**Implant angulation**
Mean MBL /mm/	**Pearson Correlation**	1	-.148
	Sig. (2-tailed)		.337
Implant angulation	**Pearson Correlation**	-.148	1
	Sig. (2-tailed)	.337	

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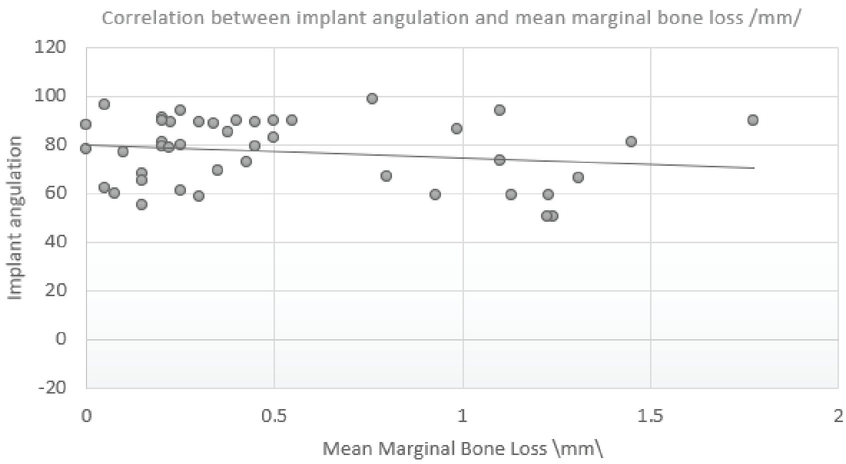

Figure 7. Correlation between implant angulation and mean marginal bone loss.

Table 7. Partial correlation test between implant angulation and the mean marginal bone loss of implant when gender, age, and follow-up are controlled separately.

Control Variables			Mean MBL /mm/	Implant angulation
Gender, Age, Follow-up	Mean MBL /mm/	Correlation	1.000	-.139
		Sig. (2-tailed)	.	.386
		df	0	39
	Implant angulation	Correlation	-.139	1.000
		Sig. (2-tailed)	.386	.
		df	39	0

Table 8. Paired Sample t-test between axial and tilted implants in mean marginal bone loss.

		Paired Differences							Significance	
					95% Confidence Interval of the Difference					
		Mean	Std. Deviation	Std. Error Mean	Lower	Upper	t	df	One-Sided p	Two-sided p
Pair 1	Axial implant – Tilted implant	-.177727	.462747	.098658	-.382898	.027443	-1.801	21	.043	.086

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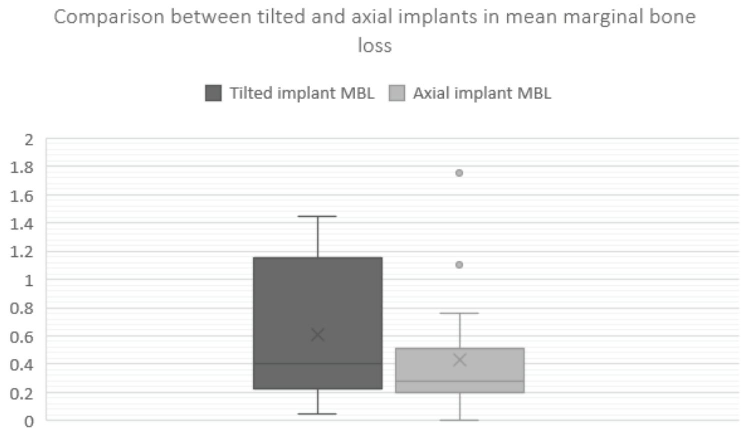

Figure 8. Comparison between tilted and axial implants in mean marginal bone loss.

DISCUSSION

Bone augmentation operations are one of the best options for implant-supported prosthesis of the atrophic jaws. However, the augmentation procedure may not be convenient for many patients due to medical or socioeconomic conditions as well as a patient who avoids multiple surgical procedures. The all-on-four concept provides surgical and prosthetic advantages such as increasing the contact area between the bone and implant by using longer implants and reducing cantilever length. In the literature, it is still a controversial topic whether tilted implants cause more marginal bone loss compared to axial implants.

In this study, there was no statistically significant difference in marginal bone loss between tilted and axial implants which is consistent with the literature.[7,14,15,13,8,9] Malo et al.[12] evaluated the average marginal bone loss with periapical radiographs, the bone loss of 5- and 10-year evaluations were stable with an average annual bone loss under 0.1 mm. However, the present study used CBCT images to measure the bone level, for more accurate data on mean marginal bone loss, which was 0.6 mm and 0.4 mm for tilted and axial implants respectively.

A recent systematic review and meta-analysis evaluated 8 papers consisting of a total of the 2036 axial implants and 1951 tilted implants with ranged follow-up periods from 5-17 years[13]. They found that there was no significant difference in marginal bone loss between tilted and axial implants. However, the paper was not conclusive about the effect of angulation degree, and all the studies measured bone loss using periapical radiographs.

Studies evaluating the inclination degree of tilted implants' effect on marginal bone loss are very limited and mostly designed to divide the study groups according to a specific reference angulation degree. Luciano et al[16], studied the placement of posterior implants at an angle greater than 450. The study showed that tilting angulation of posterior implants did not significantly influenced peri-implant bone loss, while the peri-implant bone loss was greater for those distally tilted implants consistent with our results. When the analysis was performed independently for the maxilla and mandible, no significant differences in the marginal bone loss were found between tilted and straight implants.

In literature, studies described a wide variety of prosthetic restorations. Paolo Malo et al. reported a 98.8% prosthetic success rate in the mandible with 10-18 years follow-up[11] and a 99.2% in the maxilla with 5-13 years follow-up[12]. There is a very limited number of studies that reported the correlation between marginal bone loss and prosthetic complications. It was suggested that the condition of the alveolar ridge, the antagonist dentition type, the implant brand/model, and using a temporary prosthesis during the osseointegration period significantly affect the MBL of axial and tilted implants as they were considered parts of the same supporting compound for a

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fixed dental prosthesis.[17] In the present study, all the patients used provisional prosthesis, and fixed prosthesis as a final restoration and all the implants were the same brand. Hence the effect of the prosthetic rehabilitation can be eliminated, however, the antagonist dentition was different for all the patients and statistical analysis was not performed due to the small sample size. The limitations of this study are the difference of the antagonist prosthetic restoration sand not standardizing the macroscopic structures like diameter and length due to the retrospective nature of the study along with small sample size.

Hopp et al.[3] evaluated the effect of gender on marginal bone loss in 891 (364 male, 527 female) patients in their study. They revealed that the female gender was associated with marginal bone loss →2.8 mm at 5 years of controls showing a 2-fold increased risk compared to males. Another study evaluated the influence of patient-dependent variables like age and gender on the MBL of axial and tilted implants. The results showed that the patient-dependent variables assessed did not significantly affect the MBL for the tilted implant group[17] similar to our results.

CONCLUSION

It is important to evaluate the prospect of marginal bone loss and survival of the tilted implants as these implants are exposed to higher lateral forces compared to axial implants. CBCT evaluation and correlation of the angle and the bone loss of the All-on-four concepts were not studied previously as far as our knowledge. Regarding the result of this study, there is a slight correlation between the inclination degree of the implants and marginal bone loss which suggests that a variety of different implant angulations can be well tolerated within physiologic limits. However, this finding was not significant, which may be due to the small sample size. In conclusion, it is safe to use tilted implants in the All-on-four concept for successful results, but studies with larger sample sizes and evaluating the superimposition of the pre-and post-operative CBCT images of the marginal bone would also be beneficial.

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