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RESEARCH ARTICLE

The Effect of Implant Position, Thread Design and Tilting on Marginal Bone Resorption in Tilted Implant System

Açılı İmplant Uygulama Sistemlerinde İmplant Pozisyonu, Diş Tasarımı ve Açının Marjinal Kemik Rezorpsiyonu Üzerine Etkisi

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ABSTRACT

The all-on-four system utilizes 2 parallel anterior implants and 2 distally tilted posterior implants between mental foramina on mandible, between maxillar sinuses on maxilla with an immediately loaded temporary fixed prosthesis. Purpose of this study is evaluating the effect of implant position, thread design and tilting on marginal bone resorption after tilted implant surgery similar to the all-on-four system.

17 patient recieved 92 implants with 2 different forms (level, rapid). Radiographic assessment of marginal bone level change was performed at 1 year follow-up period. The differences between marginal bone resorption for implant position, thread design and tilting degree were analyzed with the Mann Whitney U test. The value p = 0.05 was considered as the level of significance.

Total marginal bone level was, on average, 0.2994mm (SD=0.80026) for mandible, 0.3992mm (SD=0.43636) for maxilla, 0.4377mm (SD=0.82100) for tilted implants, 0.2682mm (SD=0.41187) for axial implants, 0.3785mm (SD=0.70581) for level form implants, 0.2789mm (SD=0.46179) for rapid form implants. Mean bone loss was significantly higher in the tilted implants. There is no significant difference found in marginal bone loss between the maxilla-mandible and different threaded implant forms.

Keywords: All on four, thread design, tilted implants, marginal bone loss, bone resorption

ÖZET

All on four sistemi ile; mandibulada mental formenler arası bölgeye, maksillada maksiller sinüsler arası bölgeye anteriorda iki vertikal, sağ ve sol posteriorda açılı birer implant uygulamasını takiben aynı seansta sabit geçici protez uygulanır. Bu çalışmanın amacı All on four cerrahisi sonrasi implant konumu, yiv yapısı ve açılandırmanın marjinal kemik rezorpsiyonuna etkisini tespit etmektir.

17 hastaya, iki farklı formda(level, rapid), 92 adet implant uygulanmıştır. 1 yıllık takiplerinde panoramik radyografiler üzerinden marjinal kemik kayıpları karşılaştırılmıştır. İmplantların tipi, implantların konumu ve çeneler arasındaki marjinal kemik kaybı farkları Mann Whitney U testi ile analiz edilmiş, istatistik anlamlılık düzeyi 0,05 olarak kabul edilmiştir.

Total kemik kaybı mandibulada ortalama 0,2994mm(SS=0,80026); maksillada ortalama 0,3992mm(SS=0,43636), açılı implantlarda ortalama 0,4377mm (SS=0,82100); aksiyal implantlarda ortalama 0,2682mm(SS=0,41187), level form implantlarda ortalama 0,3785mm(SS=0,70581); rapid form implantlarda ortalama 0,2789mm(SS=0,46179) olarak ölçülmüştür. Total marjinal kemik kayıpları yönünden açılı implantlar yönünde anlamlı fark bulunmuş; maksilla-mandibula, implant yiv formları açısından değerlendirildiğinde anlamlı fark bulunamamıştır.

Anahtar Kelimeler: All on four, yiv şekli, açılı implantlar, marjinal kemik kaybı, kemik rezorpsiyonu

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INTRODUCTION

Edentulism can lead to significant bone resorption in the maxilla and mandible. Along with the bone resorption, retention and functional challenges arise with the use of removable prostheses.[1]

The complete loss of dentition is typically managed through three prosthetic options: removable partial or complete dentures, implant-supported fixed prostheses, and implant-supported removable prostheses. In edentulous arches, implant-supported fixed prostheses are often perceived by patients as an integral part of their own body, addressing both physiological and psychological needs more effectively than removable dentures.[2]

The application of dental implants in their contemporary form was first introduced by Branemark in 1965, and has since evolved and been successfully implemented through to the present day.[3] In cases where dental implant placement is required in edentulous and severely resorbed arches, various anatomical limitations (such as the mandibular canal, mental foramen, and maxillary sinus), as well as insufficient bone height and width, may render the standard approach of placing six to eight axially placed implants with a fixed prosthesis unfeasible. In such cases, advanced surgical procedures, including sinus lift, ridge splitting, and bone augmentation, may be required. However, the applicability of these advanced surgical techniques has decreased due to factors such as increased morbidity risk, longer operative time, higher costs, and extended edentulous periods.[4-6] As a consequence of these considerations, the region between the mental foramina in the mandible and the area between the maxillary sinuses in the maxilla have become established as preferred sites for implant placement in clinical practice.[2,7]

The all-on-four system is a treatment concept first developed by Malo and colleagues in 1998. It involves the placement of four implants in edentulous arches: two vertical implants in the anterior region between the mental foramina in the mandible and between the maxillary sinuses in the maxilla, and two angled implants in the posterior regions on both sides.[8,9] With the all-on-four system, a fixed temporary prosthesis is placed during the same surgical session as the implant placement.[10] Depending on the clinical situation, the procedure may involve the use of 4 to 6 implants in the maxilla.[5,8]

When dental implants begin to function, they are subjected to various forces. If the distribution of these forces is not appropriately designed from both a prosthetic and surgical perspective, undesirable outcomes such as bone resorption and implant failure may occur.[11] To consider implant placement successful, some researchers suggest that the marginal bone loss should be less than 0.2 mm by the end of the first year of implant function.[12] In contrast, other researchers consider a radiographic bone loss of 2 mm or less after the surgical procedure as an indicator of success.[13] Marginal bone loss is considered a crucial factor in determining the success of dental implants. As a result, numerous studies have been conducted to evaluate marginal bone loss in various implant applications.[14,15]

In studies investigating marginal bone loss within the all-on-four concept, axial and angled implants have been evaluated separately, with distinct categorizations for implants placed in the maxilla and mandible.[16,17]

The aim of this study is to evaluate the relationship between marginal bone loss in implants placed in the maxilla and mandible within the tilted implant concept, with regard to variables such as implant positioning, thread design, and angulation.

MATERIAL METHOD

This study has been approved by the Non-Interventional Research Ethics Committee of Istanbul Yeni Yüzyıl University, under decision number 2022/05-860, in accordance with the principles outlined in the Declaration of Helsinki of the World Medical Association. The study included 17 patients (7 females, 10 males) who presented to our clinic due to total edentulism, classified as healthy according to the ASA scale (ASA-1/ASA-2). A total of 65 Mode Level implants (Mode Level Implant; Mode Medikal, Istanbul, Türkiye) and 27 Mode Rapid implants (Mode Rapid Implant; Mode Medikal, Istanbul, Türkiye) were placed in the participants. A total of 48 implants were placed in the maxilla, and 44 implants were placed in the mandible. The surgical placement of the implants was performed by an experienced oral and maxillofacial surgeon, while the prosthetic restorations were carried out by a skilled prosthodontist. In the maxilla, some patients received 6 implants, with the posterior implants angulated distally. Following implant placement, all patients were rehabilitated with immediate acrylic fixed prostheses. After 3 months, permanent fixed restorations

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were applied using hybrid prostheses. A panoramic radiograph was obtained from all patients following the loading of the temporary prosthetic restorations. Panoramic radiographs were obtained digitally using a CCD sensor-based orthopantomograph (PAX-I, Vatech, South Korea). Patient follow-up was conducted radiographically and clinically at 3, 6, and 12-month intervals (Figure 1). During the 12-month follow-up, radiographic images taken with the same device were compared to the initial radiographs, and marginal bone loss at the mesial and distal aspects of the implants was measured using Image J software (US National Institutes of Health, USA) (Figure 2). Radiographic measurements were performed twice by a researcher who was not involved in the treatment process, and the arithmetic mean of the repeated measurements was used for analysis. The arithmetic mean of the mesial and distal marginal bone resorption values was considered the total marginal bone resorption for each implant. The distance from the implant-abutment connection to the first visible bone level in contact with the implant at the closest point was measured and compared with the values on the follow-up radiograph. Axial and tilted implants, as well as their distribution in the maxilla and mandible, were evaluated separately according to the implant thread designs (level, rapid).

Statistical analyses were performed using IBM SPSS Statistics 20.0 software (IBM Corp. Released 2011. IBM SPSS Statistics for Windows, Version 20.0. Armonk, NY: IBM Corp., USA). Descriptive statistical methods (mean, standard deviation, frequency) were applied in evaluating the data. The normality of the data distribution and the homogeneity of variances were assessed using the Kolmogorov-Smirnov and Levene tests. It was found that the data did not follow a normal distribution. Differences in distal, mesial, and total marginal bone loss between implant types, implant positions, and arches were analyzed using the Mann-Whitney U test. A significance level of 0.05 was considered for all analyses.

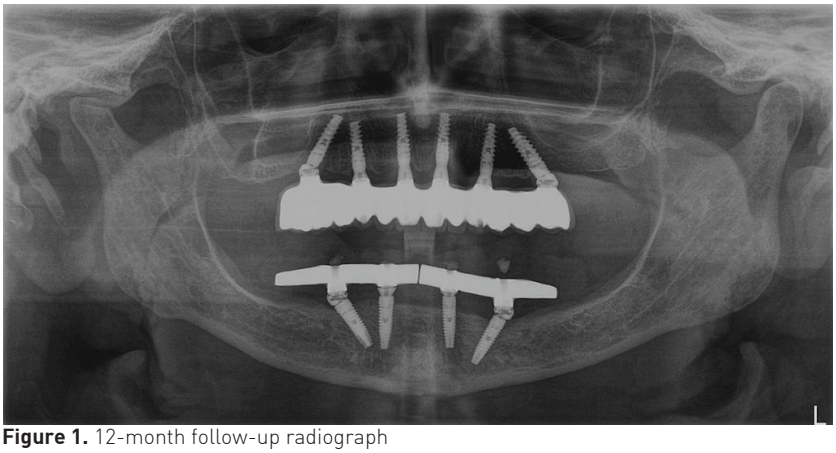

Figure 1. 12-month follow-up radiograph

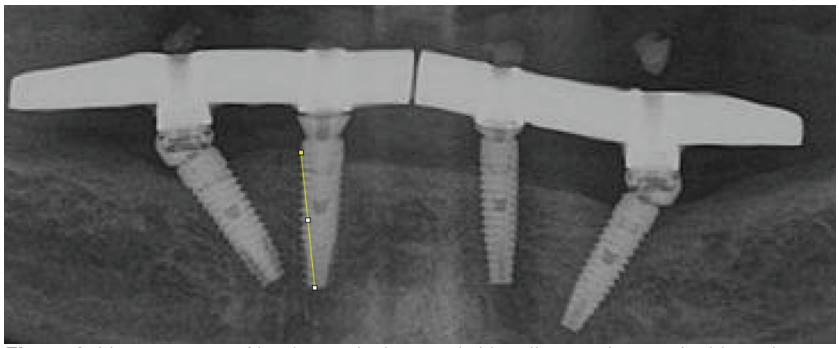

Figure 2. Measurement of implant apical-crestal ridge distance in marginal bone loss assessment

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RESULTS

None of the 92 implants placed in the 17 patients participating in this study experienced failure. The follow-up results for all patients were compared over a 1-year period.

Table 1. Distribution of marginal bone loss in the mandible and maxilla

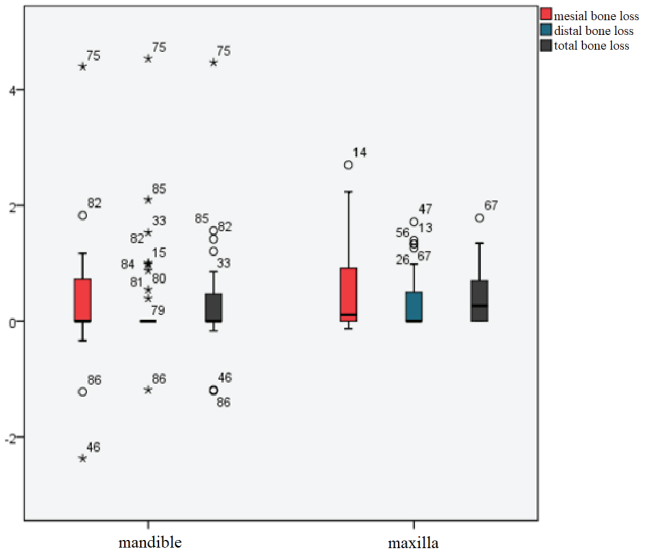
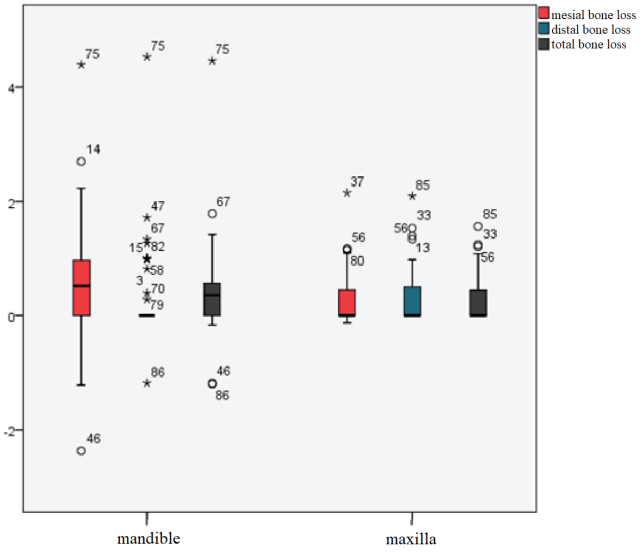


Table 2. Statistical results of marginal bone resorption in the mandible and maxilla, the Mann-Whitney U test (p<0.05)

	jaw	N	Mean	Std. Deviation	Std. Error Mean
Mesial bone loss	mandible	44	0.3433	0.88996	0.13122
	maxilla	48	0.5167	0.71808	0.10588
P*			0.36		
Distal bone loss	mandible	44	0.2555	0.81440	0.12008
	maxilla	48	0.2816	0.47757	0.07041
P*			0,18		
Total bone loss	mandible	44	0.2994	0.80026	0.11799
	maxilla	48	0.3992	0.43636	0.06434
P*			0.08		

When marginal bone resorption was examined, the following measurements were obtained: in the mandible, the average mesial bone resorption was 0.3433mm (SD = 0.88996) and the distal bone resorption was 0.2555mm (SD = 0.81440); in the maxilla, the average mesial bone resorption was 0.5167mm (SD = 0.71808) and the distal bone resorption was 0.2816mm (SD = 0.47757). The total marginal bone loss was measured as 0.2994mm (SD = 0.80026) in the mandible and 0.3992 mm (SD = 0.43636) in the maxilla (Table 1). According to statistical results, no significant difference was found in marginal bone loss between the mandible and maxilla when the tilted implant concept was applied (Table 2).

Table 3. Distribution of marginal bone loss according to implant angulations



When evaluated based on implant angulation, the following bone resorption measurements were observed: for the angulated implants, the average mesial bone loss was 0.6000mm (SD = 1.03537) and the distal bone loss was 0.2755mm (SD = 0.81820). For the axial implants, the average mesial bone loss was 0.2743mm (SD = 0.48391) and the distal bone loss was 0.2622mm (SD = 0.49109). The total bone loss was measured as 0.4377mm (SD = 0.82100) for angulated implants and 0.2682mm (SD = 0.41187) for axial implants (Table 3). In the application of the all-on-four concept, a significant difference in marginal bone loss was observed at the mesial site between angulated and axial implants, with angulated implants exhibiting greater bone loss. However, no significant difference in marginal bone loss was found at the distal site.

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Additionally, a significant difference in total marginal bone loss was noted, with angulated implants showing greater resorption (Table 4).

Table 4. Statistical results of marginal bone resorption in implants with angled and axial placements, the Mann-Whitney U test (p<0.05).

	Angulation	N	Mean	Std. Deviation	Std. Error Mean
Distal bone loss	Angled	44	0.2755	0.81820	0.12335
	Axial	48	0.2622	0.49109	0.07088
P*			0.92		
Mesial bone loss	Angled	44	0.6000	1.03537	0.15609
	Axial	48	0.2743	0.48391	0.06985
P*			0.01		
Total bone loss	Angled	44	0.4377	0.82100	0.12377
	Axial	48	0.2682	0.41187	0.05945
P*			0.05		

Table 5. Distribution of marginal bone loss according to implant thread shape

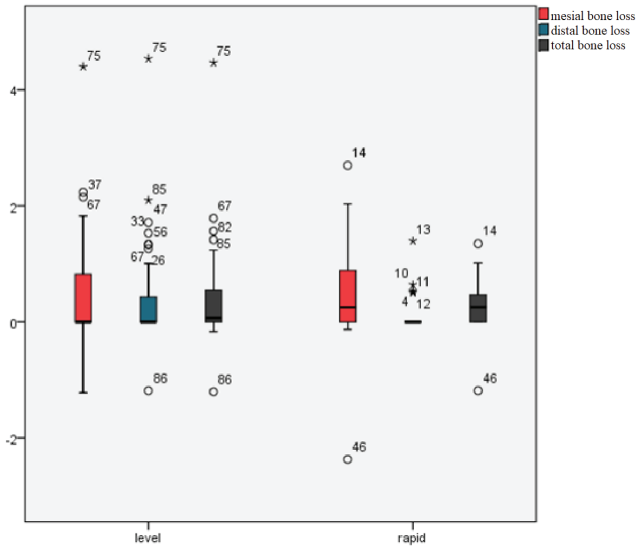

Table 6. Statistical results of marginal bone resorption according to implant thread shapes, the Mann-Whitney U test (p<0.05).

	implant	N	Mean	SS.	Std. Error Ort.
Mesial bone loss	level	65	0.4321	0.77850	0.09656
	rapid	27	0.4250	0.89332	0.17192
P*			0.97		
Distal bone loss	level	65	0.3249	0.75764	0.09397
	rapid	27	0.1329	0.32136	0.06185
P*			0.91		
Total bone loss	level	65	0.3785	0.70581	0.08754
	rapid	27	0.2789	0.46179	0.08887
P*			0.42		

When evaluated according to thread design, the following bone resorption measurements were obtained: for the level-threaded implants, the average mesial bone loss was 0.4321mm (SD = 0.77850) and distal bone loss was 0.3249mm (SD = 0.75764). For the rapid-threaded implants, the average mesial bone loss was 0.4250mm (SD = 0.89332) and distal bone loss was 0.1329mm (SD = 0.32136). The total bone loss was measured as 0.3785mm (SD = 0.70581) for level-threaded implants and 0.2789mm (SD = 0.46179) for rapid-threaded implants (Table 5). The thread design of the implants did not result in a significant difference in marginal bone loss when the all-on-four concept was applied (Table 6).

DISCUSSION

Studies have demonstrated the success of placing fixed prostheses on 4-6 standard axial implants in the region between the mental foramina.[7,18,19] However, the need to increase cantilever length can lead to long-term prosthetic failures.[2,10,13] Research has shown no significant difference in stress distribution between angulated and axial implant placements, with angulated implants being considered a viable option for placement.[14,20–22] In studies applying the all-on-four concept with 4 or 6 implants, high success rates have been observed and supported by clinical evidence.[5,8,17]

The successful outcomes of the immediate loading procedure have been demonstrated in numerous studies, and it has also been frequently applied with favorable results in the all-on-four system.[11,17,18,23,24] In a systematic review conducted by Gaonkar

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et al., it was noted that the placement of angulated or axial implants with immediate loading in the maxilla or mandible under the all-on-four concept did not affect the marginal bone levels.[24]

Fracture of acrylic prostheses is among the most frequently encountered prosthetic complications in immediate loading procedures, as observed in numerous studies. As a preventive measure, it has been recommended that permanent prostheses be reinforced with a metal framework.[17,24]

In this study, the total bone resorption was measured as an average of 0.2994mm (SD = 0.80026) in the mandible and 0.3992mm (SD = 0.43636) in the maxilla. In studies conducted by Malo et al., at the 1-year follow-up, marginal bone loss was measured as 0.9mm (SD = 1.0) in the maxilla and 0.6mm (SD = 0.6) in the mandible.[18,19] In a systematic review by Patzelt et al., no significant difference was found in the marginal bone resorption between the maxilla (1.0mm, SD = 0.5) and mandible (0.8mm, SD = 0.4) based on the 13 studies examined. [25] The results obtained in our study are consistent with those of previous research.

The total bone resorption was measured as an average of 0.4377mm (SD = 0.82100) for angulated implants and 0.2682mm (SD = 0.41187) for axial implants in this study. Agliardi et al. reported 0.8mm of bone loss for angulated implants and 0.9 mm for axial implants[2]; Francetti et al. found 0.7mm (SD = 0.5) for angulated implants and 0.7mm (SD = 0.4) for axial implants[11]; Hinze et al. reported 0.76mm (SD = 0.49) for angulated implants and 0.82mm (SD = 0.31) for axial implants[13]; and Tironi et al. found 1.2mm for angulated implants and 1.4mm for axial implants.[27] In all of these studies, no statistically significant difference was found in marginal bone resorption between angulated and axial implants.

The total bone loss was measured as an average of 0.3785mm (SD = 0.70581) for level-threaded implants and 0.2789mm (SD = 0.46179) for rapid-threaded implants. There are few studies examining the relationship between implant thread design and marginal bone resorption. Wu et al., in their study using finite element analysis and in vitro comparisons, compared two implant forms with different thread designs but the same size and diameter. They found no significant differences in the stresses occurring in the peri-implant bone between the two implant designs.[26] Our findings are consistent with these results.

It is well-established that marginal bone loss can lead to implant failures in the long term. In a 10-year follow-up study conducted by Pera et al., it was noted that marginal bone loss is most commonly observed within the first month following implant placement and loading.[27] In a longitudinal study by Malo et al., which involved surgical and prosthetic rehabilitation using the all-on-four system with follow-up periods ranging from 10 to 18 years, it was reported that the risk of implant failure increased when marginal bone loss exceeded 3mm.[17] Considering that the expertise and experience of the clinicians providing patient care can influence the outcomes of the studies, long-term follow-up in additional research is essential to confirm the accuracy of these evaluations.

CONCLUSION

The implant thread design, implant positioning, angulated or axial placement, and thread morphology in the tilted implant system have been shown to have no significant effect on marginal bone loss. This study presents only 1-year follow-up results. Further clinical studies with longer follow-up periods are needed to assess long-term outcomes.

CONFLICT OF INTEREST

The authors of the article declare that there are no personal or financial conflicts of interest related to the study.

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