Maxillary Bone Resorption with Conventional Dentures and Four-Implant–Supported Fixed Prosthesis Opposed by Distal-Extension Partial Dentures: A Preliminary 5-year Retrospective Study

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Purpose: The aim of this preliminary study was to evaluate maxillary bone resorption with conventional dentures and implant-supported prostheses opposed by distal-extension removable partial dentures (RPDs). ***Materials and Methods:*** Fifteen patients (seven women and eight men) with totally edentulous maxillary ridges and partially edentulous mandibular ridges (Class I Kennedy classification) received maxillary fixed prostheses on four implants and mandibular distal-extension RPDs (study group). The control group consisted of 15 patients who received conventional maxillary dentures and distal-extension mandibular RPDs without any implant treatment but were matched to the study group and acted as a historical group. Evaluation of vertical maxillary bone resorption for both groups was made at the time of prosthesis insertion (T0) and 5 years later (T2) using the proportional area measurements made on digital panoramic radiographs for anterior and posterior areas. ***Results:*** The control group showed significantly higher vertical bone loss than the test group ($P < .001$). The control group had 0.270 higher maxillary bone loss than the test group. For both groups, anterior maxillary areas showed significantly higher bone loss than posterior areas ($P < .003$). Anterior maxillary areas had 0.122 higher bone loss compared with posterior areas. Women had 0.035 higher maxillary bone loss compared with men. ***Conclusion:*** Within the limitations of this study, implant-supported fixed prostheses for the edentulous maxilla opposed by remaining mandibular anterior teeth reduce maxillary anterior and posterior alveolar bone loss compared with conventional dentures. However, they do not prevent maxillary bone loss. *Int J Oral Maxillofac Implants 2020;35:816–823. doi: 10.11607/jomi.8075*

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One of the most common clinical conditions is the presence of the edentulous maxillary arch opposed by mandibular front teeth with loss of posterior dentition. Rehabilitation of this condition with conventional maxillary dentures opposed by a bilateral distal-extension mandibular partial denture often results in a degenerative change known as "combination syndrome."[1] The continuous occlusal forces from the mandibular anterior teeth to the maxillary tissues usually result in loss of the anterior maxillary bone, which is replaced with the flappy tissue. Other features of the syndrome include development of fibrous tuberosities, palatal papillary hyperplasia, mandibular teeth extrusion, posterior mandibular bone loss, occlusal plane discrepancy, and decreased satisfaction with the maxillary denture regarding stability and retention.[1–4] Prevention of posterior teeth extraction, elimination of anterior hyperfunction, and stabilization of the maxillary arch with immediate or delayed implants are essential in prevention of this complex condition.[5]

The compromised maxillary bone may be managed with distraction osteogenesis, bone graft, sinus elevation, and ridge-splitting techniques.[5] However, these techniques can significantly increase patient morbidity, costs, and treatment time.[6,7] Another option for improving support of maxillary prostheses is the All-on-4 treatment concept (Nobel Biocare). Krekmanov and colleagues[8] suggested tilting of posterior implants to avoid vital structures such as the maxillary sinuses or the mandibular canal and shortening the distal cantilevers. Later, the use of distal inclined and vertical immediately loaded implants was proposed for the edentulous maxilla.[9] This concept provides several merits, such as *(1)* avoidance of additional surgical procedures and complications of bone grafting, *(2)* insertion of an acrylic provisional restoration immediately

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after surgery to restore oral functions, and *(3)* reduction of financial costs.[9–11]

The major radiographic evaluation method of residual ridge resorption is panoramic radiographs, as they are routinely used in clinical examinations as a part of many recall programs, thus providing enough data for retrospective studies.[12] Disadvantages of such radiographs include image distortion, magnification, and the production of radiographs with unclear anatomical landmarks.[13] Several authors[13–15] reported that rotational tomographic images are adequate for performing effective evaluation of maxillary and mandibular bone loss. They suggested tracing of two areas in the ridge: the first is detected by the topography of the residual ridge and the second from landmarks not subjected to change from bone loss. The proportion between these areas was known as the "area index." Kreisler et al[15] concluded that the proportion between experimental and reference areas on rotational tomography showed reliable results in evaluation of maxillary bone resorption.

The fixed hybrid prosthesis supported by four implants is a successful treatment option for edentulous patients. However, long-term studies with a period of at least 5 years are scarce.[16] Reviewing the literature, several studies evaluated maxillary bone resorption in patients wearing maxillary conventional dentures and different types of mandibular prostheses, such as two-implant overdentures, fixed prostheses on four or six implants, and conventional dentures.[14,17–23] Nevertheless, the evaluation of maxillary bone resorption with four-implant fixed prostheses in the maxilla was not a concern. A beneficial result of providing implant support for the prosthesis is the preservation of the existing residual bony ridge.[24] Although the use of implant-supported fixed screw-retained prostheses in the rehabilitation of the edentulous maxilla has been proven to be a successful long-term prosthetic solution, there is evidence that this kind of rehabilitation was associated with ongoing bone loss that may need clinical attention.[25] Therefore, the aim of this retrospective study was to evaluate maxillary bone resorption with conventional dentures and four-implant–supported fixed prostheses opposed by distal-extension partial dentures.

MATERIALS AND METHODS

The study group consisted of 15 participants with totally edentulous maxillary ridges and partially edentulous mandibular ridges (Class I Kennedy classification) who were recruited from patients regularly attending the outpatient clinic of the faculty of dentistry, with the following inclusion criteria:

- All patients wearing maxillary conventional dentures and distal-extension mandibular partial dentures.
- All patients were unsatisfied with the retention and stability of maxillary conventional dentures and presented a clear preference for a stable prosthesis.
- Sufficient bone quantity and quality in the area anterior to the maxillary sinuses (as verified by preoperative CBCT) to receive dental implants of at least 3.75-mm diameter and 11-mm length.
- A minimum of 1 year passed after the last extraction.

Patients with systemic diseases relating to bone resorption, such as uncontrolled diabetes mellitus or osteoporosis, and subjects with abnormal habits, such as clenching and bruxism, were excluded. The study group received four implants in the edentulous maxillary arch, and the implants were immediately loaded with maxillary dentures. Six months later, the participants received screw-retained fixed full-arch restorations. The control group consisted of 15 patients with edentulous maxillary ridges and Class I Kennedy mandibular ridges who received conventional maxillary dentures and distal-extension mandibular RPDs without any implants but were matched to the study group with respect to age, sex, maxillary bone height, and period of edentulism and acted as a historical group. For both groups, only patients with available records at baseline and 5 years later were included. Sample-size calculation and randomization were not possible due to the retrospective study design. After the participants were instructed on the objectives of the research and the need for regular recalls, they all signed a written consent. The study was conducted according to the ethical principles stated by the ethical committee of the faculty (No. 01020418).

Surgical and Prosthetic Procedures

For the test group, radiopaque gutta-percha markers were added to the polished surface of the maxillary dentures, and a dual-scan protocol using CBCT (i-CAT) was followed. The first scan was made with the maxillary denture alone, while the second scan was done with the patient occluding on the dentures.[25] The two data sets of the double scans were overlapped, and then the acquired images were used to virtually plan the implant position and orientation for the maxillary arch using the OnDemand software (Cybermed). Two implants were designed to be at the canine/lateral incisor area, while the posterior implants were designed to be at the premolar area just anterior to the maxillary sinus, taking into consideration the safety margin. The posterior implants were tilted distally, forming a 30-degree angle from the vertical plane, and implants were emerged in the second premolar tooth or mesial

Fig 1 Planning of the implants using the CBCT software.

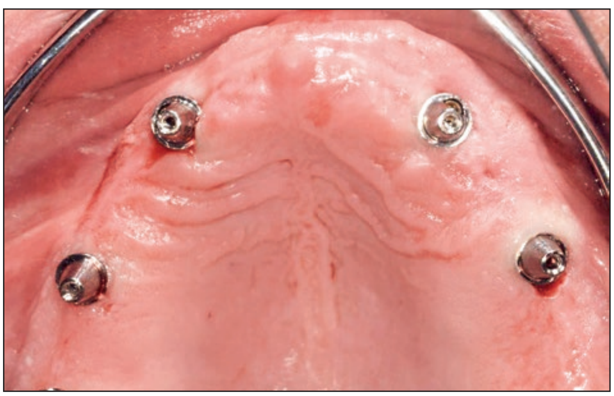

Fig 2 Multiunit abutments screwed to the implants.

Fig 3 Immediate loading of the implants with existing denture.

region of the first molar tooth[9,11] (Fig 1). This arrangement increases the anteroposterior spread, allows better implant anchorage, shortens cantilever length, and increases interimplant distance.[8] For each subject, a mucosal-borne surgical guide with four metal rings opposed to the implant positions was manufactured by rapid prototyping technology (In2Guide, Cybermed).

Patients were premedicated with antibiotics (amoxicillin 875 mg and clavulanic acid 125 mg) twice daily and chlorhexidine mouthwash 0.12% three times/day. Both medications were started 1 day before surgery and continued 6 days after surgery. Four TioLogic implants (Dentaurum) were placed between the maxillary sinuses using a flapless surgical protocol. The surgical guide was attached to the maxillary bone using fixation pins, and the implant osteotomy was made using a universal surgical kit (In2Guide). The minimum implant insertion was 35 Ncm to allow immediate loading. Seventeen-degree multiunit abutments (Dentaurum) were attached to the anterior implants, and 30-degree abutments were attached to the posterior implants (Fig 2). Implant insertion and abutment seating were evaluated by postoperative panoramic radiographs. Implants were immediately loaded by maxillary dentures. The titanium caps were attached to the abutments, and the denture was hollowed over the caps. The denture was picked up to the caps using autopolymerized acrylic resin (Fig 3). The caps were shortened, and the palatal portion of the denture, denture flanges, and second molar acrylic teeth were removed. The occlusion was relieved over the first molar teeth to avoid overloading of the inclined implants. An anti-inflammatory drug (ibuprofen, 600 mg) was prescribed twice daily for 7 days after surgery. Patients were encouraged to chew soft food, perform adequate cleaning, and attend regular visits to perform necessary denture modifications and relining.

After 6 months of osseointegration, the provisional denture was removed, and an abutment-level impression was made. The long impression posts were splinted with an autopolymerized resin pattern (Duralay, Reliance Dental). Light-body rubber-base impression material (Lascod) was injected into the posts, and an overall impression was made using the putty material. The plastic caps were screwed into multiunit abutments on the model. A porcelain-fused-to-metal (PFM) hybrid fixed restoration that restored the gingiva and teeth was constructed (Fig 1). The model was scanned

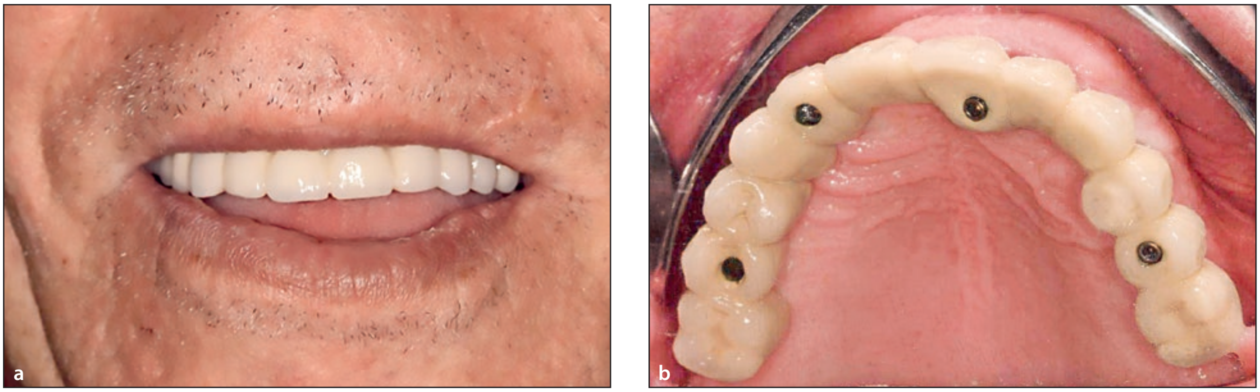

Fig 4 The fixed screw-retained prosthesis in the patient's mouth. *(a)* Frontal view. *(b)* Occlusal view.

using a CAD/CAM machine (Dentsply Sirona), and the prosthesis was designed using the accompanying software. The designed prosthesis had 12 teeth and was printed in castable resin (GC Pattern Resin, GC Corp) and then tried in the patient's mouth for passivity. The resin was cast in cobalt-chromium alloy (Heraeus-Kulzer). The opaque layer was added to the metal, and porcelain was fired, finished, and glazed. The prostheses were delivered to the patients (Fig 4).

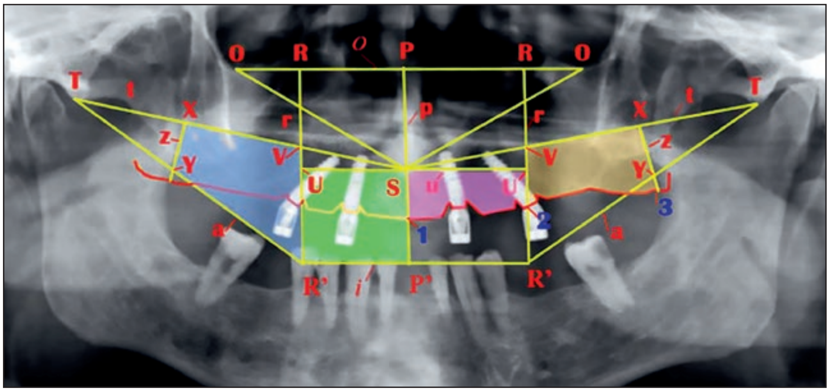

Fig 5 Traced panoramic radiographs with reference lines and points.

Evaluation of Maxillary Bone Resorption

Evaluation of vertical maxillary bone resorption for the study and control groups was done at baseline (T0) and 5 years later (T5). Baseline was considered the time of denture insertion for the control group and the time of implant loading for the study group. Evaluations were done using proportional area measurements introduced by Kreisler et al.[15] For each group, digital rotational tomography was performed at T0 and T5. To standardize all panoramic images, each participant occluded on an occlusal template attached to the chin stabilizer of the machine. Radiographs were only included if the reference landmarks were clear. The resolution and size of the images were standardized using Scanora software (Soredex, KaVo). The images were traced and measurements were made using the AutoCAD software program (Autodesk). The following landmarks were utilized for the measurements (Fig 3): The nasal spine (*S*) and the inferior borders of the orbit O_{right} and O_{left} were connected to give a "midline triangle"; the line *o* connects O_{right} and O_{left}; *p* is a line perpendicular to *o* through *S*; the intersection between *o* and *p* is point *P*; the point *R* divides the distance *PO* into two-thirds and one-third; *r* is a line perpendicular to *o* through *R*; *u* is a line parallel to *o* through *S*; lines *u* and *r* join at point *U*; *P'* point is located at the same distance *SP* beginning from *S*; *R'* is located at the same distance *UR* beginning from *U*; the line *i* connects R'_{right} and R'_{left}; *T* is the lower point of the articular tubercle; the line *t* connects *S* and *T*; the line *a* connects *T* and *R'*; *t* joins *r* at *V*; *VR'T* form the "lateral triangle"; *X* divides the distance *VT* into two equal halves; *z* is a line perpendicular to *t* through *X*; *z* joins *a* at point *Y*; and 1 is the intersection of the ridge crest with *p*, 2 is the intersection of ridge crest with *r*, and 3 is the intersection of ridge crest with *z*. This tracing divides the maxilla into two anterior and two posterior areas. In the anterior portion, the experimental area is *S12U* and the reference area is *SP'R'U*. In the posterior portion, the experimental area is *V23X* and the reference area is *VR'YX*. This method was modified to include the bone crater defect around the implants and to subtract peri-implant marginal bone loss from these areas[26] (Fig 5). Experimental and reference areas on both sides were combined, and the average was used. The ratio (*R*) = average experimental area/average reference area for the anterior and posterior areas. The bone resorption (change in *R*) was

Table 1 Baseline Characteristics of Groups

	Control group	Study group	*P* value
Mean age (y)	58.66 ± 3.03	59.26 ± 3.41	.73
Sex (female/male)	(7/8)	(7/8)	1.00
Mean maxillary bone height (mm) at canine regions	18.0 ± 3.1	17.9 ± 2.2	.88
Mean period of edentulism (y)	2.8 ± 1.01	3.1 ± .99	.37

Table 2 Mean Change in *R* for Both Groups

	Anterior area	Posterior area	*P* value
Control group			
Mean	−0.506	−0.301	.001*
SD	0.042	0.030	
Median	−0.530	−0.300	
Min	−0.56	−0.34	
Max	−0.45	−0.23	
Study group			
Mean	−0.153	−0.114	.002*
SD	0.024	0.022	
Median	−0.1500	−0.1200	
Min	−0.19	−0.15	
Max	−0.12	−0.08	
***P* value**	< .001*	< .001*	

*P is significant at .05.

Table 3 Linear Regression Model to Test the Relation Between *R* and Confounding Factors

	Unstandardized coefficients		Standardized coefficients			95.0% confidence interval for B	
	B	SE	Beta	*t*	*P*	Lower bound	Upper bound
(Constant)	−0.429	0.291		−1.470	.147	−1.013	0.156
Age	0.000	0.005	−0.004	−0.037	.971	−0.011	0.010
Sex	0.310	0.014	0.970	9.07	.049*	0.280	0.37
Ridge height	−0.001	0.006	−0.008	−0.167	.868	−0.013	0.011
Years of edentulism	0.003	0.012	0.018	0.254	.800	−0.020	0.026
Prosthesis	0.269	0.014	0.858	19.132	.000*	0.241	0.297
Position	0.122	0.013	0.389	9.217	.000*	0.095	0.149

*P is significant at .05.

calculated by subtracting *R* at T0 from *R* at T5 (negative sign indicates bone loss, and positive sign indicates bone apposition).[21] Radiographic measurements were done by one operator (P.S.W.) blinded to the treatment groups.

Statistical Analysis

Differences in maxillary bone resorption between prostheses and areas were analyzed with an independent samples *t* test. A multiple linear regression model (stepwise method) was made to analyze the correlation between maxillary bone resorption and potential confounders that may be involved in ridge resorption, such as: age, sex, ridge height, years of edentulousness, group, and position of maxillary areas. The level of significance was adjusted at .05.

RESULTS

Fifteen participants for each group (seven women and eight men) with ages ranging from 55 to 64 years were included in the study. One subject in each group was excluded from the study due to unidentified landmarks on their panoramic radiographs. Subjects with increased peri-implant bone loss were included. Therefore, 28 patients (56 panoramic radiographs) were available for the study (14 subjects in each group).

Baseline characteristics of participants at the beginning of the study are demonstrated in Table 1. No difference in baseline criteria between groups was noted. Comparison of *R* between maxillary areas (anterior and posterior) and between groups (control and test) was shown in Table 2. For anterior and posterior maxillary areas, the control group showed significantly higher *R* values than the study group. For both groups, anterior maxillary areas showed significantly higher *R* values than the posterior maxillary areas.

A multiple linear regression model was adopted using the stepwise method to study the relation between *R* and potential confounding factors (age, sex, ridge height, years of edentulism, type of prosthesis/group, and position of maxillary areas [anterior/posterior]). Dummy variables were generated for binary variables (group, maxillary areas, and sex) for inclusion in the model. The initial model included all confounding factors (age, sex, ridge height, years of edentulism, type of prosthesis, and position of maxillary areas [Table 3]). Only sex, prosthesis type, and position of maxillary areas were significantly correlated with change in *R*. All other factors (age, ridge height, and years of edentulism) were excluded from the model.

Table 4 Final Model to Test the Relation Between *R* and Prothesis, Position, and Sex

	Unstandardized coefficients		Standardized coefficients			95.0% confidence interval for B	
	B	Standard error	Beta	*t*	*P*	Lower bound	Upper bound
(Constant)	−0.447	0.013		−34.037	.000	−0.473	−0.420
Prosthesis	0.270	0.013	0.861	20.958	.000	0.244	0.296
Position	0.122	0.013	0.389	9.465	.000	0.096	0.148
Sex	−0.035	0.013	−0.110	−2.687	.009	−0.061	−0.009

**P* is significant at 5%.

The final model contained sex, prosthesis type, and position of maxillary areas (Table 4). The effect of the prosthesis was that the conventional denture (control group) had 0.270 more bone loss compared with the fixed prosthesis (study group). The effect of position of maxillary areas revealed that the anterior maxillary area had 0.122 more bone loss than the posterior maxillary area. The effect of sex was that women had 0.035 higher bone loss compared with men.

DISCUSSION

Rotational radiographs were utilized to evaluate ridge resorption, as these radiographs are routinely used to evaluate implant and prosthetic restorations in clinical examination and follow-up sessions. Also, these radiographs are suitable for retrospective studies due to their availability in patients' records. The proportion evaluation of maxillary bone loss is a more appropriate and reliable method than absolute calculations,[15] as it minimizes the pitfalls of magnification and distortion associated with panoramic radiographs[13,14] and compensates for head position errors.[20] One of the important objectives of any prosthetic treatment for edentulous patients is the preservation of remaining tissues. It is interesting to observe that anterior bone loss and subjective loss of fit of maxillary dentures opposed by distal-extension partial dentures was the stimulus for managing these patients with implant-supported prostheses to provide increased support and stability of the maxillary prosthesis to prevent exacerbation of maxillary bone resorption and development of combination syndrome.

In this study, the control group showed significantly higher bone loss than the test group and was associated with 0.27 more bone loss compared with the test group. The increased bone loss with conventional dentures may be attributed to increased occlusal forces from mandibular anterior teeth, which increase maxillary bone loading and resorption.[27] The excessive occlusal force occurred because patients usually chew using anterior teeth.[5] This finding was not surprising since Kelly[1] found a loss of 1 to 3 mm of anterior maxillary bone when a complete maxillary denture opposed mandibular anterior teeth and a distal-extension RPD after 3 years using cephalometric radiographs and defined this bone loss as an important sign of combination syndrome. He attributed the severe resorption to the fulcrum line formed in the maxillary denture at the first premolar region, which creates increased occlusal pressure on the maxillary anterior bone and negative pressure on the posterior part.[27] This increased bone loss may also be attributed to the lack of regular prosthetic follow-up that is necessary to monitor the premature occlusal relation in the anterior teeth that occurs due to teeth wear or posterior mandibular bone resorption. The lack of relining to obtain favorable load distribution is also responsible for increased bone loss. From a clinical point of view, these results signify the importance of providing adequate implant support for edentulous maxillary prostheses opposed by natural mandibular teeth to preserve maxillary bone even if signs and symptoms of combination syndrome did not appear.

The studies evaluating the maxillary bone resorption opposing the remaining mandibular anterior teeth are scarce. However, it is widely accepted that inter-foraminal implants supporting mandibular overdentures create a biomechanical situation similar to that of natural anterior teeth complicated with combination syndrome.[2,3] Therefore, maxillary bone loss with conventional dentures opposing mandibular anterior teeth could be compared with bone loss values of conventional dentures opposing interforaminal implants and supporting either fixed prostheses or overdentures. In agreement with the results of this study, several investigators demonstrated significant resorption of bone in the maxillary anterior area in subjects with mandibular implant-assisted overdentures.[4,19,20,28] Jacobs et al[14] attributed the increased bone loss to the increased occlusal loads of tissue-implant–borne mandibular overdentures. Similarly, Barber et al[19] reported 0.43 ± 1.36 mm bone resorption in the anterior maxillary region per year when maxillary conventional dentures opposed transmandibular implants and concluded that these implants caused a similar maxillary bone resorption to natural mandibular anterior teeth.

In the study group, the effective support of the prosthesis by the implants provides all the masticatory loads that are transferred directly to the implants with maxillary ridge protection from excessive loading. The lack of bone loading could be responsible for decreasing maxillary ridge resorption. This finding agreed with a systematic review in which the authors reported that implant prostheses preserve the remaining alveolar ridge by reduction of the resorption rate and formation of new bone.[29] However, the lack of studies evaluating maxillary bone under implant-supported prostheses preclude direct comparison of the findings of this report with other authors. It could be expected that implant-supported prostheses would prevent bone loss or cause maxillary bone deposition since Wright et al[24] and Nakai et al[30] noted that patients rehabilitated with implant-stabilized mandibular fixed cantilever prostheses demonstrated bone apposition in posterior mandibular areas. Surprisingly, bone loss also occurred in the study group, but it was significantly lower than the control group. This could be attributed to several reasons. First, the decreased density and increased susceptibility of maxillary bone to osteoporosis compared with mandibular bone may be responsible for increased bone loss.[31] The second, and most important, reason is the subtraction of peri-implant alveolar bone loss from the area index and inclusion of this crestal bone loss in the final bone resorption of the residual ridge. The peri-implant bone loss occurred as a result of immediate loading of the implants by provisional prostheses. It is not possible to separate bone loss that occurred due to physiologic bone remodeling from bone loss that occurred due to implant loading since the immediate loading protocol was used. Third, the bone deposition under mandibular implant-supported fixed prostheses was attributed to mandibular bone flexure under masticatory load, which is induced by the load transmission anterior to the mental foramina.[24] This dynamic loading of bone has a marked role in new bone formation.[32] However, such flexion does not occur in maxillary bone. Therefore, in a clinical setting, providing the edentulous maxilla with an implant-supported fixed prosthesis reduced but did not eliminate bone resorption of the maxillary ridge opposed by natural mandibular teeth.

For both groups, anterior maxillary areas showed significantly higher bone loss than posterior maxillary areas. The anterior maxillary area had 0.122 more bone loss than the posterior area. A similar result was observed in other studies. Kreisler et al,[20] in a retrospective investigation, found increased resorption in the anterior (5% to 12%) compared with the posterior (2% to 7%) area of the edentulous maxilla opposed by mandibular two-implant overdentures after 8 years.[20] Other authors found increased maxillary bone resorption in anterior areas compared with posterior areas of the maxillary arch.[18] The increased bone loss in the anterior maxilla could be attributed to progressive tilting and settling of the mandibular distal-extension partial denture under masticatory forces, which transmit forces to the mandibular residual ridge via the tissue-supported posterior section of the RPD. This causes unfavorable loading of the maxillary anterior region[33] with enhanced bone resorption.[3,14,28] Another explanation could be attributed to the transmission of increased occlusal loads to the anterior maxillary regions with maxillary bone loss and mucosal inflammation.[18] Furthermore, the increased bone loss in the anterior maxilla could be attributed to the reduced initial bone width in this area, as noted in preoperative CBCT radiographs. Khuder et al[34] investigated residual ridge resorption of anterior and posterior maxillary ridges, in subjects wearing mandibular implant overdentures and conventional dentures. They found a significant association between ridge resorption and occlusal load at the anterior maxilla. The reduced posterior ridge resorption may be attributed to the favorable load distribution and avoidance of excessive occlusal load on the posterior ridge by the mandibular anterior teeth (control group) or implants (study group).[34] From these results, it is more relevant clinically to place implants in the anterior area of the maxilla rather than posterior areas, as the most significant amount of bone loss usually occurs in the anterior maxillary region.

In this study, only sex, prosthesis type, and position of maxillary areas were significantly correlated with maxillary ridge resorption. In line with this observation, Elsyad et al[23] found that the type of prosthesis and ridge location were significantly correlated with maxillary bone resorption. Conversely, age, ridge height, and years of edentulism had no relation to ridge resorption. Similarly, Jacobs et al[14] found no relation between age and bone loss in a regression model. The effect of sex was that women had 0.035 higher maxillary bone loss compared with men. This finding was not surprising since women have a higher risk of bone loss due to the effect of hormonal change.[33] The limitations of this study include the small sample size and the short follow-up period. Furthermore, the use of panoramic radiographs with area measurements allows evaluation of proportions rather than actual measurements. Therefore, the results had limited generalizability and clinical relevance and can be used only for comparison between groups. Also, panoramic radiographs reveal bone height, only not bone width (buccolingual thickness), which can be measured accurately using CBCT. Therefore, CBCT is recommended for three-dimensional bone evaluation of the residual ridges in future studies. Moreover, the lack of randomization of patients to treatment groups should be considered. Therefore, future long-term randomized controlled trials with increased population number are required to ensure the findings of this preliminary report.

CONCLUSIONS

Within the limitations of this investigation, it could be concluded that four-implant–supported fixed prostheses for the edentulous maxilla opposed by remaining mandibular anterior teeth reduce maxillary anterior and posterior alveolar bone loss compared with conventional dentures. However, they do not prevent maxillary bone loss.

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