Comparison between the effect of splinted and segmented full arch mandibular implant supported prosthesis on peri-implant bone level changes

Original Article

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ABSTRACT

Background: The mandible has a tendency to flex inwards around the mandibular symphysis which is accompanied with change in shape and decrease in mandibular arch width during opening and protrusion of the mandible.Therefore, the effect of stresses due to mandibular flexure on both bone and restoration in edentulous implant-fixed restoration needs to be evaluated.
Aim: The aim of this study is to compare the effect of splinted and segmented mandibular full arch implant-supported prosthesis on peri-implant bone level changes due to mandibular flexure.
Materials & methods: For this clinical study, fourteen patients with edentulous mandible and dentate maxilla were selected following certain criteria to receive mandibular fixed hybrid prostheses. Patient's lower denture was duplicated to clear acrylic stent and used as a surgical guide to mark the entry point of each implant. After three months of placing the implants, the patients were randomly divided into two groups.
Group I: patients received segmented mandibular implant supported full arch prosthesis.
Group II: patients received splinted mandibular implant supported full arch prosthesis.Crestal bone loss around distal implants was evaluated using CBCT at zero, six months and twelve months.
Results: Results showed that for the 6 to 12 months time interval, there was a significant difference between the two groups around implant number one where the bone loss for group II was 0.170.04± and for group I was 0.140.02± for implant number one. Moreover, there was a significant difference between two groups around implant number three where the bone loss for group II was 0.770.05± and for group I was 0.280.06±.Results also showed that for the 0 to 12 months interval. There was a significant difference between the two groups around implant number one where the bone loss for group II was o.490.04± and for group I was o.380.03± for implant number one. Moreover, there was a significant difference between two groups around implant number three where the bone loss for group II was 1.240.06± and for group I was 0.550.10±.
Conclusion: Within the limitations of this study, it is recommended to construct a full arch segmented mandibular fixed prosthesis rather than splinted.

Key Words: mandibular flexure, deformation, mandibular symphysis

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INTRODUCTION

Mandibular flexure occurs due to contraction of lateral pterygoid muscles and this property results in a mandibular deformation process that decreases the width of the mandibular arch during opening and protrusion. Four recognized deformation patterns [1] have been found: symphyseal bending associated with medial convergence, dorsoventral shear, corporal rotation, and anteroposterior shear. Any of these deformation patterns can results in compressive, tensile, or shear stresses on the mandibular bone tissue.The amount and distribution of these stresses depends on the type and amount of force exerted by masticatory muscles, mandibular geometry, and bone quantity and quality [2].

The bilateral contraction of the lateral or external pterygoid muscles (LPMs) is the primary cause of this phenomenon: when the lower heads contract, they pull the condyles and condylar necks medially, forward and down, resulting in a buccolingual rotation of the mandibular arch [3]. However, measuring the force generated by the contraction of LPMs to ascertain this is quite difficult due to their size and position. In addition to the lateral pterygoid muscles, the mylohyoid, platysma, superior pharyngeal constrictor, and other jaw depressor muscles provide supplemental aid for its generation [4].

In the frontal plane, the distance between the right and left mandibular ramus decreases due to elastic flexion of the mandible, resulting in a reduction in the width of the mandibular arch. For increasing degrees of jaw opening, mandibular arch static amplitude analyses reveal a gradual decrease in its medial–lateral diameter. Furthermore, dynamic investigations have displayed an increase during mandibular retraction and a decrease during protrusion movements, due to muscular contraction without tooth contact [5,6].

According to Frost's mechanostat theory [7,8] , individuals

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with natural teeth and without prosthetic restorations have stresses/strain values in the physiological adapted window or within the mild overload value (1,500–3,000 microstrains). The presence of periodontal ligament, that allows physiological tooth mobility, is considered the primary factor that prevents an increase of stress/strain and bone loss around teeth due to mandibular flexure during opening and protrusion of the mandible.

Dental implants have been considered the typical treatment modality for prosthodontic restoration of edentulous jaws but the long-term success of this treatment modality is highly affected by the biomechanical environment. Flexure of the mandible is considered one of the main causes of posterior implant failure in fixed implant prostheses [9] .

On restoring a completely edentulous mandible with a conventional fixed prosthesis or an implant-supported prosthesis, a rigid structure is used, which splints two or more implants in one single unit. In implant prostheses, due to absence of the periodontal ligament, the stresses act directly on the bone, resulting in bone resorption. In a completely edentulous mandible restored with an implant- supported fixed prosthesis, stress concentration affects the bone around the implants carrying the rigid framework, which splints the implants together [10]. So, the effect of stresses due to mandibular flexure on both bone and prostheses in edentulous implant-supported prostheses needs to be further studied.

There is another important consideration in the mandibular arch, during restoring it with a rigid splint of natural teeth or osseointegrated implants by means of a fixed cross-arch bridge that could generate torsional stresses which, in natural dentition, can be compensated by the adaptive potential of the periodontal ligament. It has been suggested that such stresses can also have a profound effect on the prosthetic superstructure, with possible fractures of ceramic and luting cement failures. The reported biomechanical problems resulting from mandibular deformation are more important in patients with parafunctional habits, such as bruxism [11].

The null hypothesis was adopted that there is no difference between a splinted full-arch mandibular implant supported prosthesis when compared to 2-piece frameworks. The objective of this paper was to compare bone stress distribution around implants of fixed full-arch mandibular restorations with one piece frameworks versus two piece frameworks.

SUBJECTS AND METHODS

Patient selection and study design

Fourteen patients with edentulous mandible and dentate maxilla were selected. Their age ranged between 45 and 55 years. They were selected from outpatient clinic of the Prosthodontic Department, Faculty of Dentistry, Ain shams University.The inclusion criteria were patients with angle's class I maxillomandibular relationship, the mandibular ridge covered with firm, healthy mucosa with no signs of inflammation or bony undercuts and patient's free from any systemic disease that may affect the oral tissues or the bone metabolic rate. The patients had adequate restorative space (at least 15 mm from bone level to occlusal plane). Patients with parafunctional habits and heavy smokers were excluded in this study. Also patients who had diseases that may complicate surgical procedures as liver diseases were also excluded.

All patients were informed about the surgical and prosthetic steps for this treatment modality. They were also informed about the importance of properly following the instructions and signed an informed consent.

The patients signed written consents. The study proposal was approved by the ethical committee of the faculty of Dentistry, Ain Shams University (Local ethical committee, No: FDASU-RecIR112216). CONSORT guidelines for clinical trials were followed. A single operator performed all the surgical and prosthetic steps.

Bone loss measurements were recorded by another operator who was blinded to the group distribution. The statistical analysis was also performed by a blinded personal to avoid bias.

Surgical procedures:

All selected patients received new mandibular single dentures. Primary and secondary impression was done. Face bow record was taken to mount the upper cast on semi-adjustable articulator. Centric relation was taken to mount the lower cast. Occlusal adjustment of the maxillary arch was done using clear acrylic stent guided by proper setting of denture teeth.

The new mandibular denture was duplicated to create a radiographic stent (with gutta-percha radiopaque markers fitted to the polished surface).

Cone beam computed topography (CBCT) scan was taken for the mandibular arch while the patient was wearing the radiographic stent to determine the exact positions of the implants. Implants were evenly distributed over the entire arch. Implant size was selected according to the available bone volume. Then the radiographic stent was converted to surgical stent by drilling channels through the stent in the planned implant positions. Six implants were inserted and evenly distributed over the entire arch (Figure 1).

Implants that were installed in the position of lower lateral incisor was given code number one, implants in the position of lower first premolar was given code number two and implants in position of first molar was given code number three.

Figure 1 (six implants were placed evenly distributed)

Prosthetic procedure:

After the period of osseointegration, healing abutments were attached to implants for two weeks. Closed tray impression technique was first made by attaching closed-tray impression copings to implants. This was done in a stock tray loaded with an elastomeric impression material. After the impression material was set, the impression was removed and impression copings were unscrewed from the implants. These unscrewed impression copings were then screwed to implant analogues and together re-inserted into the impression. After pouring the impression to obtain a stone cast, open tray impression copings were then screwed to the implant analogues in the stone cast and splinted together by using dental floss and auto-polymerizing resin material. Next, the copings were splinted together, and relief wax was added to cover undercuts on impression copings exposing just the screw head.

Self cure acrylic resin special tray was constructed on the cast. The special tray was modified by creating holes exposing the screw head of the open tray impression analogues. The splinted impression analogues were then separated to be inserted and re-splinted in the patient's mouth. The perforated special tray was loaded by elastomeric impression material. After setting of the impression material, the open tray copings were unscrewed, the impression was removed then the implant analogues were screwed to the transfer copings. The impression was poured to obtain final stone cast.

Cold cured acrylic resin mandibular trial denture base was constructed on the final stone cast. It was connected to an implant abutment anteriorly and two implant abutments posteriorly to be totally implant supported .This screw retained lower acrylic record base provides stability for the record bases during taking jaw relation .Then wax rim was added to the trial denture base . Face bow record was made to mount the maxillary cast on a semi-adjustable articulator.

The lower cast was mounted by centric occluding relation recorded following the interocclusal wax wafer technique and protrusive record was made to adjust the horizontal condylar guidance of the articulator.

The patients were divided randomly into two groups using a numbered excel sheet and closed envelope method to allocate them into the perspective group according to the design of the final prosthesis: Group I: patients received segmented (at the midline) mandibular full arch fixed hybrid prosthesis (Figure 2). Group II: patients received splinted mandibular full arch fixed hybrid prosthesis (Figure 3).

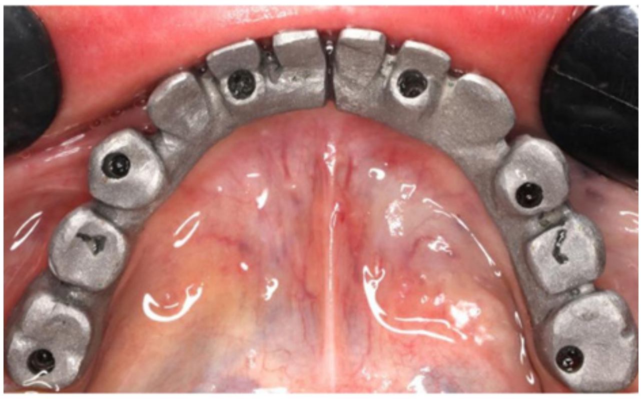

Figure 2 (segmented framework)

Figure 3 (splinted framework)

For both two groups, metal try in was performed to ensure seating and passivity of the framework. Porcelain build up was done to achieve group function occlusion. Then, it was fired and glazed. The final prosthesis was inserted in the patient's mouth (fig 4). Occlusion was adjusted and the screws were tightened according to manufacturer instructions. Screw access holes were sealed with flowable composite.

Figure 4 (final segmented prosthesis)

Crestal bone loss around distal implants was evaluated using CBCT at zero, six months and twelve months.

Statistical analysis:

Numerical data were represented as mean and standard deviation. Normality and variance homogeneity were verified using Shapiro-Wilk's and Levene's tests respectively. Data were analyzed using mixed model ANOVA. Comparison of simple effects were done utilizing the error term from the ANOVA model. P-values were adjusted for multiple comparisons utilizing Bonferroni correction. Differences in bone loss between right and left sides were analyzed using paired t-test. The significance level was set at p<0.05 within all tests. Statistical analysis was performed with R statistical analysis software version 4.3.2 for Windows [1] .

RESULTS

Results of mixed model ANOVA showed that there was a significant interaction between group and time (p<0.001). Results of intergroup comparisons are presented in table (1) and in figure (1). Results showed that for the change from 0 to 6 months, group (II) showed significantly higher bone loss around all implants (p<0.05). For the changes from 6 to 12 months and from 0 to 12 months, group (II) showed also significantly higher bone loss but around implants (1) and (3) only (p<0.05). Results of intragroup comparisons are presented in tables (2) and (3) and in figures (2) and (3). For both groups and implants, there was a significant difference between bone loss values measured at different intervals (p<0.001). For implants (1) and (2) in both groups (I), post hoc pairwise comparisons were all statistically significant (p<0.0001), with the highest value measured at (012-), followed by (06-) and the lowest value measured at (612-) months. For group (II) implant (3), there were also all statistically significant (p<0.001), but with the highest value measured at (012-), followed by (612-) and the lowest value measured at (06-) months. However, for implant (3) in group (I), change measured at (012-) was significantly higher than other intervals (p<0.001). Results of the comparisons between the right and left sides are presented in table (4) and in figure (4), showed that for both groups and at different intervals, there was no significant difference between bone loss measured at both sides (p>0.05).

Table (1): Intergroup comparisons for bone loss.

Interval	Implant	Bone loss (mm) (Mean±SD)		Test statistic	p-value
		Group (I)	Group (II)		
0-6 months	(1)	0.24±0.02	0.32±0.02	10.25	<0.001*
	(2)	0.24±0.02	0.26±0.02	2.37	0.025*
	(3)	0.27±0.04	0.47±0.02	16.61	<0.001*
6-12 months	(1)	0.14±0.02	0.17±0.04	2.49	0.020*
	(2)	0.13±0.02	0.13±0.03	0.00	1
	(3)	0.28±0.06	0.77±0.05	23.03	<0.001*
0-12 months	(1)	0.38±0.03	0.49±0.04	8.48	<0.001*
	(2)	0.37±0.04	0.39±0.04	1.24	0.227
	(3)	0.55±0.10	1.24±0.06	21.77	<0.001*

*Significant (p<0.05)

[1] R Core Team (2023). R: A language and environment for statistical computing. R Foundation for Statistical Computing, Vienna, Austria. URL https://www.R-project.org/.

Table (2): Intragroup comparisons for bone loss in group (I).

Group	Implant	Bone loss (mm) (Mean±SD)			Test statistic	p-value
		0-6 months	6-12 months	0-12 months		
Group (I)	(1)	0.24±0.02B	0.14±0.02C	0.38±0.03A	457.70	<0.001*
	(2)	0.24±0.02B	0.13±0.02C	0.37±0.04A	963.85	<0.001*
	(3)	0.27±0.04B	0.28±0.06B	0.55±0.10A	308.14	<0.001*

Values with different superscript letters within the same horizontal row are significantly different *Significant (p<0.05)

Table (3): Intragroup comparisons for bone loss in group (II).

Group	Implant	Bone loss (mm) (Mean±SD)			Test statistic	p-value
		0-6 months	6-12 months	0-12 months		
Group (II)	(1)	0.32±0.02B	0.17±0.04C	0.49±0.04A	510.74	<0.001*
	(2)	0.26±0.02B	0.13±0.03C	0.39±0.04A	573.68	<0.001*
	(3)	0.47±0.02C	0.77±0.05B	1.24±0.06A	3104.87	<0.001*

Values with different superscript letters within the same horizontal row are significantly different *Significant (p<0.05)

Table (4): Comparison between sides.

Interval	Implant	Bone loss (mm) (Mean±SD)		Test statistic	p-value
		Right	Left		
Group (I)	0-6 months	0.26±0.04	0.24±0.02	1.01	0.325
	6-12 months	0.19±0.11	0.17±0.04	0.86	0.340
	0-12 months	0.45±0.14	0.41±0.04	1.27	0.219
Group (II)	0-6 months	0.34±0.10	0.36±0.09	0.67	0.511
	6-12 months	0.35±0.18	0.36±0.23	0.15	0.882
	0-12 months	0.69±0.27	0.72±0.31	0.27	0.790

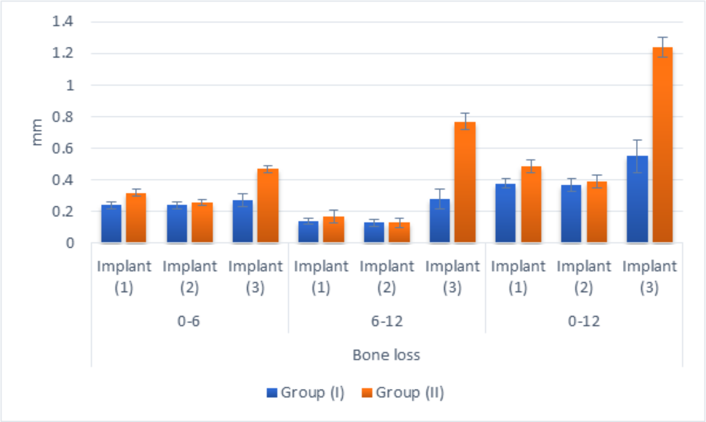

Figure (1): Bar chart showing mean and standard deviation values of bone loss in different groups.

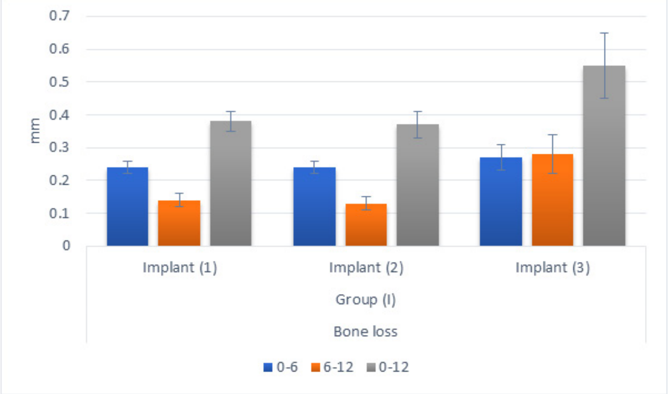

Figure (2): Bar chart showing mean and standard deviation values of bone loss in group (I).

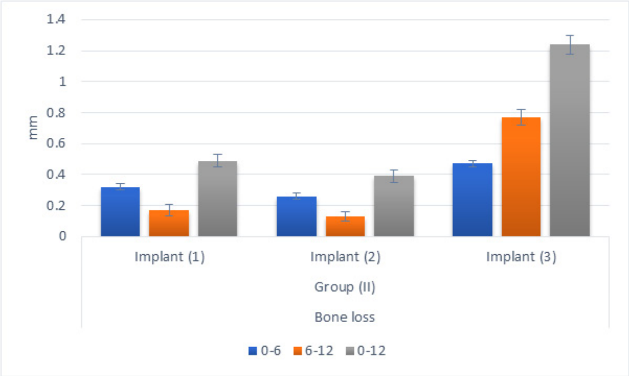

Figure (3): Bar chart showing mean and standard deviation values of bone loss in group (II).

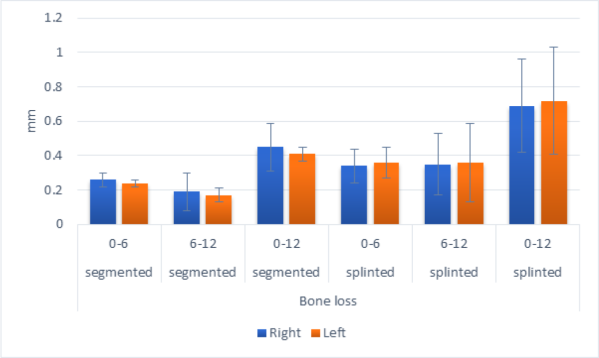

Figure (4): Bar chart showing mean and standard deviation values of bone loss for different sides.

DISCUSSION

The amount of inter-arch space is considered the primary factor that determines the restoration type. Implant supported hybrid prosthesis is the best choice in cases with crown height space more than 15 mm. Plus, other patient-related factors such as lip support, a low mandibular lip line or the patient's greater esthetic demands should be evaluated. [12] Cement retained implant prostheses provide several advantages such as reduced costs, reduced complexity of components and laboratory procedures, reduced chair-side time and better esthetics, which is important from the patient's perspective [13]

There are different clinical assessment techniques that were used to evaluate implant framework misfit. The alternate finger pressure was used to evaluate the rocking of the prosthesis and observe any saliva bubbling around the misfit gap as well as direct vision and tactile sensation by using the tip of an explorer to verify the marginal fit. Periapical Radiographs also can be used but it can be superimposed or overlapped and depends on the angulations [14] .However, there are acceptable levels of misfit. Jemt defined passive fit as a level that didn't result in any long-term clinical complications and suggested misfits smaller than 150 µm were acceptable [15] .

Median mandibular flexure may cause problems for implant supported prostheses. There are a lot of complications that may occur due to mandibular flexure such as increased stress in dental implant-related prosthesis and abutments, poor fit of fixed prostheses, fracture of screws of implants , loosening of cemented prostheses and resorption around implant. Therefore, for better longevity and outcomes of implant supported prosthesis, it is important to reduce median mandibular flexure.

Results showed that for the 0 to 6 months time interval, there was a significant bone loss around all implants. This result agreed with Albrektsson et al.[16] that proposed criteria for assessing and evaluating the success of implant survival; these criteria included marginal bone remodeling of less than 2.0 mm in the first year after implant placement and less than 0.2 mm each year thereafter. This study showed that for the 6 to 12 months time interval .There was a significant difference between the two groups around implant number one. There was also a significant difference between two groups around implant number three.

It was also found that for the 0 to 12 months time interval. There was a significant difference between the two groups around implant number. There was also a significant difference between two groups around implant number three. These findings are in line with, some authors [17,18] who suggested that an implant supported prosthesis in the mandible restored in a single, continuous and rigid bar can result in severe stresses both at the bone/implant interface and at the prosthetic superstructure, as a result of the linear and torsional deformations of the mandible subsequent to functional and parafunctional loads. According to Fischman (1990), mandibular elastic flexure could illustrate the higher bone loss around anterior implants that is often seen in full-arch implant supported prosthesis with distal cantilevers.

In the anterior symphyseal region, the flexure has a more profound effect than in the posterior region and a cross-arch implant-supported fixed restoration, which is more rigid than the bony tissue, does not follow the flexure of the mandibular bone, thus producing high stress concentrations. High stress concentrations can affect the structural integrity of the mechanical components, increasing the rate of screw loosening and fractures, enhanced by the intrinsic rigidity of the system. According to the previously reported theories, rather than one cross-arch rigid bar, it is better to section, when possible, the prosthesis in two or three unit bridges, which do not rigidly connect the implants that are located distally to the mandibular foramina to the anterior implants [17,18].

Division of the prosthesis superstructure at the level of symphysis is recommended by some authors to decrease the dangerous stresses occurring at that level due to using single rigid structure which can lead to increasing the rate of screw loosening and fracture [19-21] .Other studies favour the splinted superstructure as it can evenly distribute stresses between the splinted implants which can provide additional resistance to mandibular bending [22,23] . In any case, all studies conclude that it is preferable to segment the superstructure at the midline rather than three or more segments [24]

It was reported that there is no significant difference in medial mandibular flexure in the maximum opening between men and women, age ranges and different configurations of the mandibular arch [25] . In implant-supported fixed prostheses, an ideal biomechanical distribution of stresses at the prosthetic superstructure and bone\implant interface is very important, being affected by many factors such as correct prosthetic design and occlusal scheme. One of the primary concerns of implant treatment is decreasing stress in an implant-supported restorative prosthesis. The mandibular flexure should be considered one of most important factor because it could result in discomfort related to the patients' rehabilitation with a mandibular fixed implant-supported prosthesis during function [26].

One of the most common protocols in restoring edentulous mandible is placing implants in the interforaminal region for anatomic reason with a prosthethic superstructure designed with cantilever distal extension [27]. Different clinical studies have suggested that fixed implant supported prostheses with cantilevers can result in severe stresses which can be harmful both to the implants and to the surrounding bone. In the current study, placement of posterior implants was used to decrease the lever arm, allowing a better distribution of occlusal forces and increased the prosthesis stability. allowing a better distribution of occlusal forces and increased the prosthesis stability.

Several studies have shown that frameworks constructed with a precise and passive fit result in smaller amounts of stress on the implant [28] and this could be achieved by sectioning the framework. Thus, the section of the framework could decrease the stress on the implant during functional movement of the mandible increasing their longevity. Sectioning the prostheses into two pieces [29,30] has been recommended to permit mandibular flexure of the restored mandible to come close to its natural state [31]. It has been concluded that these designs will decrease stress concentration in posterior and anterior implants [32]. However, aesthetic can be affected by sectioning the prosthesis and these sections could lead food impaction on the sectioned areas, compromising the patient's hygiene.

CONFLICTS OF INTEREST

The authors declare that there are no conflicts of interest.

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