

THE EFFECT OF DIFFERENT IMPLANT LOCATION IN MANDIBULAR IMPLANT ASSISTED PARTIAL OVERDENTURES RESTORING KENNEDY CLASS I CASES ON PERI-IMPLANT BONE LEVEL CHANGES AND PATIENT'S SATISFACTION

Mona M. Aboelnagga*^{ID} and Mahmoud El Moutassim-Bellah El Homossany*^{ID}

ABSTRACT

Purpose: The aim of this study was to evaluate and compare two different implant locations in premolar and molar regions in mandibular implant assisted partial overdentures restoring Kennedy class I cases. The parameters of evaluation were the peri-implant bone level changes, pocket depth around the last abutment and patient's satisfaction with the prosthesis.

Materials and method: Twenty-eight partially edentulous patients with lower bilateral free-end saddle, having first premolar the last standing tooth opposed to dentate maxillary arch, were selected. For all patients chromium cobalt partial denture was constructed following the conventional steps. Proper planning for implant placement bilaterally was made, where participants were randomly allocated into two groups. In group I; the implant was placed in the premolar area while in group II; the implant was placed in the second molar area. Implants were inserted using two-stage surgical technique following the conventional loading protocol. After 3 months, implants were exposed and the attachments were picked up to the denture base fitting surface using self-cure acrylic resin and implant assisted partial overdenture was delivered. Pocket depth around the last abutment and peri-implant marginal bone height were evaluated at loading time, after 6, 9, 12 and 18 months follow up visits. In addition participants answered patient's satisfaction questionnaire in the sixth month follow up visit. Data collected were statistically analyzed.

Results: Results showed statistically significant higher mean bone loss around the implants in group I compared to group II at measurements after 6m, 9m, 12m and 18m. In addition, group II showed statistically significantly higher mean pocket depth compared to group I at measurements after 6m and 18m. Visual analogue scale showed a statistically significant higher pain score in group II compared to group I regarding the mastication.

* Associate Professor, Removable Prosthodontics Department, Faculty of Dentistry, Ain Shams University, Egypt.

Conclusion: Within the limitations of this study, it was concluded that placing implant in premolar area near the abutment tooth caused more marginal bone loss at the implant site and less periodontal disease to the last abutment than being placed at the second molar site, and this difference was not clinically significance. Patient satisfaction was not affected by different implant locations, all participants were satisfied with the treatment modality except for mastication; where in patients with implant located in second molar region were more satisfied.

Keywords: Implant location, partial denture, free-end saddle, assisted overdenture, and patient satisfaction

INTRODUCTION

Prosthetic rehabilitation of free end saddle cases by means of a removable partial denture raises several biomechanical challenges. A rotational movement of the free-end saddle base is inevitable, which may induce excessive forces and bending moments are developed ⁽¹⁾. Patients with bilateral extension ridges can be treated by a removable partial denture, a cantilever type of fixed partial denture, an implant denture or no prosthesis ^(2, 3). Although a fixed prosthesis may be more demanded from a psychological point of view, In situations where economic, systemic, or local conditions preventing the use of a FPD, a well-constructed RPD can be an appropriate treatment alternative ⁽⁴⁻⁷⁾. Using dental implants provide a way for reducing the destructive forces in these prosthesis by combining them with implants in the free end saddle area, thus providing comfort and stability ⁽⁸⁾.

Fixed implant-supported prostheses were a treatment modality for these patients. Nevertheless, some patients are not good candidate for having enough implants because of severe bone resorption. In these cases, implant placement in the second molar is also very difficult. In certain dentitions with reduced bone volume, as in posterior edentulous areas where the posterior mandibular bone is lost at a rapid rate than the anterior region and the existence of the mandibular canal excludes the use of the available bone below this anatomical structure, only a single implant can be placed ^(8,9). To avoid these problems, the use of implants for the purpose of support and retention of distal extension

RPD was advocated. The name of this prosthesis is implant-assisted RPD (IARPD) ^(10,11).

An investigation suggested that an implant-retained partial overdenture utilizing resilient attachments, could implicates the placement of a limited number of implants, that can provide adequate retention for implant-tooth supported RPD, and offer a functional restoration without noticeable retentive elements ⁽¹²⁾. Furthermore, clinical trials advise the use of implant assisted partial denture over the use of conventional partial denture, because dental implants enhance chewing ability and patient satisfaction ⁽¹³⁻¹⁵⁾.

The frequent site of implants is just posterior to the abutment tooth for the purpose of restoring functions of key teeth. The first molar is a key implant site. Since the biting force doubles in the molar area than at the premolar area and reaches up to five times higher than the anterior teeth, the natural teeth has increased diameter in the molar and increased root number, which results in more than twice the surface area of the rest of the dentition ⁽¹⁶⁻¹⁸⁾. The utilization of implants to support or assist distal extension RPD has been well recorded ^(14,19,20).

Many clinical advantages of implant assisted RPD are declared as the increased retention and consequently minimizing the lateral and vertical displacement of the RPD, effective distribution of the masticatory forces between the denture and the remaining natural teeth, and minimizing bone resorption that takes place beneath the distal extension base ^(21,22).

Where to place the implants in free end saddle cases has been a question both in clinical and in vitro studies, since it plays a critical role in the load distribution of the IARPD thus impact the clinical outcome of such treatment modality. Distalized position, at the second molar location, or middle position, at the first molar and second premolar area, for ideal implant position have been argued in in-vitro studies to increase stability of the IARPD (22-24). Nevertheless, a preferred location has not been clarified. A number of in-vitro studies have analyzed RPDs combined with dental implants revealed that RPDs assisted by implants placed mesially in the edentulous span showed the highest stresses nearby the implants and least around the abutment teeth, in contrary to that occurring in distally placed (22-24).

This study was made because of its relative importance as a feasible alternative solution to resolve one of the major dilemmas in management with RPDs, to overcome the anatomical limitations in the posterior region of the mandibular arch. The possibility of positioning the implants in a region closer to the last abutment tooth and not in the posterior at molar region is most frequently observed. Thus, this research aimed to test the null hypothesis that there is no difference between different implant locations in Kennedy class I on the marginal bone loss around the implants and the pocket depth related to the last abutment, besides patient's satisfaction about this line of treatment.

MATERIALS AND METHOD

The sample size was calculated according to the results of Rostom D. and Faroukabdulla M (25). Standard deviation in group I is 2.6 while Standard deviation in group II is 2.9. The estimated difference between means was 2.01. The power was 80 % and the confidence interval was 95%. The effect size is 0.9 and the critical T is 1.67. The required sample size was 14.

Twenty-eight patients were selected from the outpatient clinic, Prosthodontic Department,

Faculty of Dentistry, Ain shams University to participate in this study according to the following criteria: age ranged between 35-55 years, the mandibular arch exhibited bilateral distal extension edentulous areas, with the first premolars are the last standing abutments teeth while the opposing maxillary arch was dentulous or partially edentulous that was restored and the remaining mandibular teeth had good bony support, free from periodontal diseases according to the clinical and radiographic evaluations.

The alveolar ridges at the prospective implants sites were palpated to ensure that is covered by healthy firm mucosa with no signs of inflammation or flabby tissues covering the edentulous areas, besides the absence of any bony undercuts, sharp bony edge and thin ridge or any abnormalities. The distal edentulous ridge exhibits U shape form with at least 11 mm bone height and 6 mm width. Patients should have sufficient inter-ridge space.

In order to ensure implants success, it was necessary to select patients who were free from any local or systemic contraindications to this treatment modality. Medical and dental histories were taken from all patients to ensure absence of cardiovascular diseases, diabetes, metabolic disorders, and osteoporosis, as indicated by a medical questionnaire distributed to them. In addition, patients included in the study had Angle class I jaw relationship with sufficient interarch distance, free from temporomandibular joint disorders and had no abnormal habits such as bruxism or clenching and were non-smokers. Patients were asked about the cause of their teeth extraction and their expectations of the implant-retained prosthesis.

For all patients, detailed intraoral examination of the remaining teeth; carious teeth were restored, and any present restorations were evaluated. In addition, radiographic examination of the abutment teeth was done to evaluate the crown/ root ratio, periapical condition, periodontal membrane space and the alveolar bony support of the abutment teeth.

A thorough periodontal therapy including supra and sub-gingival scaling was performed to establish a good experimental baseline. Patients were instructed on proper oral hygiene measures and their importance for both the health of oral tissues and the life expectancy of their dentures.

The selected patients were informed about the advantages of the implant-assisted RPD, the steps needed for its construction and the importance of its maintenance and care. Each patient signed consent of approval to share in the research including the surgical procedure and the follow-up steps.

Evaluation of the diagnostic casts

Preliminary impressions were made for upper and lower arches using irreversible hydrocolloid impression material (Alginate- Cavex Holland BV). Study casts were mounted on a semi-adjustable articulator (Non Arcon dental articulator –ARH-Dentatus AB) using a face bow (Dental facebow –AEB- Dentatus AB) and provisional interocclusal wax record (Modeling wax, Cavex, Holland). A protrusive interocclusal wax record was made to adjust the articulator condylar guidance. The occlusal plane was evaluated and any over-erupted or tilted teeth were identified.

-Occlusal equilibration was performed to harmonize centric occlusion with centric relation and to establish simultaneous occlusal contact in centric thus reducing any occlusal discrepancies and being controlled. The reduced cusps were marked. The marked diagnostic cast was used as a guide for performing the needed occlusal adjustments intra-orally with the guidance of T scan (Tekscan®, South Boston, U.S).

-Preliminary surveying of the lower study cast was carried out and the needed mouth preparations were registered.

-On a duplicate of the lower study cast, artificial teeth were set on waxed denture base. Heat cured transparent acrylic resin was made with wrought

wire clasps on the first premolars to be used as a radiographic stent. Holes were made in the position of the second molar and filled with a metal ball of known dimension as a reference and kept in place by pink wax.

-Afterwards, modification of the patient's radiographic stent was done to be used as a surgical stent; by removing the metallic ball and vertical channels (in the center of the second premolar and second molar) were made to guide the drilling of the pilot drill.

Radiographic evaluation

- Pre-operative radiographic examination for all patients was done, while wearing their radiographic stents, using digital panoramic radiograph (Planmeca Promodel, Helsinki-Finland. Serafi scan) to examine the condition of the edentulous ridges in the area where the proposed position of the implant. Fig.(1)



Fig. (1): OPG with ball metal in the stent at the proposed implant site.

- The bone height, width and quality were calculated radiographically, and the mandibular canal was traced, to ensure at least 6 mm bone width and 11 mm bone height at the proposed implants site (at second premolar and second molar areas).

Patients grouping:

The selected patients were randomly divided into two equal groups using the function of random

numbers presented in the Microsoft Excel sheet. Patients in this study were rehabilitated with an implant-assisted partial overdenture restoring mandibular Kennedy Class I.

Where in group I: the two implants were placed in the second premolar position bilaterally, while in Group II: the two implants were placed in the second molar position bilaterally.

For allocation of the participants, a randomization sequence with 1:1 allocation ratio using twenty-eight small papers written in half of them 5 and the other half 7 and put in sealed similar envelopes. Where at the morning of the surgical visit, blindly one of these papers was drawn to enroll this participant in the selected group.

Surgical procedure

A day before the first stage surgery, all participants were given prophylactic premedication including anti-inflammatory and analgesic, antibiotic and mouthwash.

- At the surgical visit, an incision was placed in mid-crestal position to elevate full-thickness flap, the implants position was verified with the surgical stent.
- An insertion marking for the implant position, either at the second premolar or second molar site (depending on the group the patient belongs to), taking into consideration the drill was inserted into the center of the alveolar crest with a direction parallel to the distal surface

of the last standing abutment (according to the selected path of insertion). Fig (2 A,B)

- Then the steps were performed in sequence till implant insertion (Dental implants 3.75 mm in diameter and 10 mm in length) (Superline® Dentium Co., Seoul, Korea) nearly flushed with the crestal bone and initial stability was obtained. Fig (2 C,D) The cover screw was placed then simple interrupted sutures were performed. Afterward, the same steps were followed for the other side at the same visit.
- The patient was instructed to continue his medication and to follow the oral hygiene measures. The implants were left in a submerged position for 3 months for healing period that the patients were recalled for the second stage surgery and prosthetic phase. The implants were relocated guided by the surgical stent, the implant cover screws were exposed and were loosened and the final abutments were placed using the hex driver.

Prosthetic rehabilitation; Partial denture construction

-For both groups, metallic partial denture Co-Cr alloy, (Vitallium alloy, Vitallium System, USA) was constructed following the conventional procedures; the design contained RPI direct retainer with cingulum rests indirect retainer, lingual bar major connector and combined denture base. During wax-up of the partial denture framework, space on each

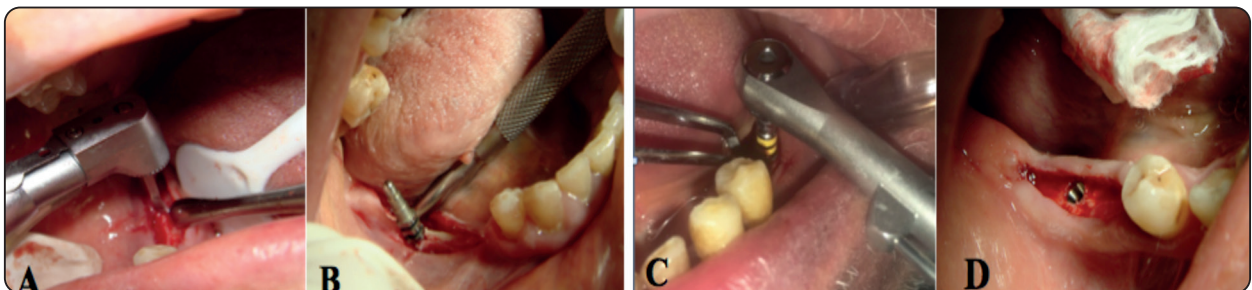


Fig. (2): A) The drill was inserted into the center of the alveolar crest. B) The direction indicator was used to check the parallelism of the osteotomy. C, D) Implant insertion till the implant cervical portion flushed with the crestal bone.

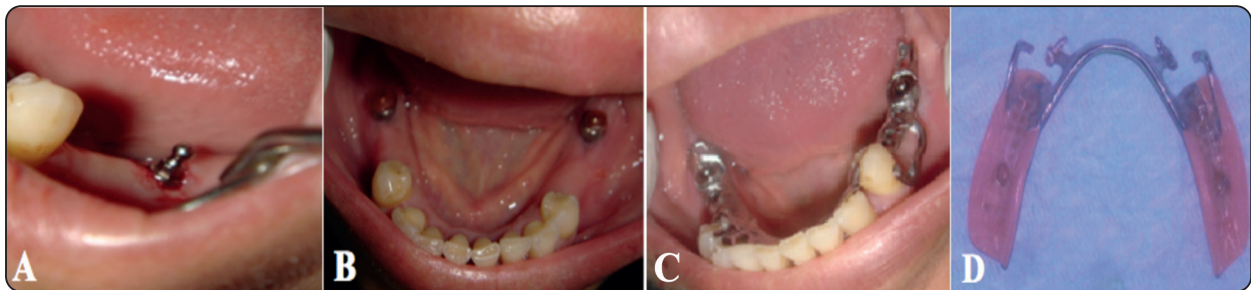


Fig. (3): A,B) Ball head abutment in place with metal housing. C) The framework was tried-in while the O-ring metal housing in place. D) Relief made in the fitting surface for the housing pickup.

side was made in the denture base minor connectors (mesh pattern) around the metal housing to ensure complete seating of all components in the patient's mouth without any interference. At the visit of denture insertion, the fitting surface of the combined denture base over the implant was relieved to ensure the fit of the partial denture while the metal housing was in its place. Fig. (3)

-Block-out shim was applied and pink self-cure acrylic resin was added in the relieved area in the fitting surface of the denture base. The partial denture with the attached O-ring housing was picked up. Then any excess material was checked, removed and polished leaving a smooth surface.

-The needed occlusal adjustments in the insertion and the follow-up visits were assessed and done.

Patients were instructed to proper oral hygiene measures and their importance for both the health of the oral tissues and the success of the prosthesis and the implants.

Post insertion evaluation:

Before dismissing the patient at the insertion appointment, the following data were obtained as baseline measurement:

1- Pocket depth measurements around the last abutment teeth; three registrations were made for each principle abutment tooth: in mid-buccal, mid-lingual, and mid-distal. In each record, the same operator used William's periodontal graduated

probe that was placed with light pressure, parallel to the long axis of the tooth. The values were added and the means were obtained for each patient.

2- Bone height changes around the implants; Standardized long cone digital periapical radiographs (Digora Optime, Orion Corp./Soredex) were done for each implant in all participants. A custom-made putty rubber base bite block was used to stabilize the plastic film holder Rinn- XCP (Rinn corp. Elgin, IL, USA) during all the follow-up exposures to standardize the cone-implant distance and the film-implant distance each time. The bone height was measured mesial and distal to the implants by measuring the distance from the alveolar crest to the implant apex (a line was drawn at the implant apex parallel to the implant collar for standardization each time).

Pocket depth around the last abutment and peri-implant marginal bone height changes were measured at loading time, after 6, 9, 12 and 18 months follow-up visits. The marginal bone loss at the determined intervals was obtained by calculating the difference in bone height measured at that interval from that of the baseline measurement.

In addition, a patient's satisfaction questionnaire, ⁽²⁰⁾ composed of five questions about the chewing ability improvement, speech, no pain from the prosthesis components, digestion and the psychological effect. It is provided with a visual analogue scale (VAS) from "0" for a negative

response to “100” for a positive response. It was translated into Arabic and distributed to all participants during the sixth month follow-up visit to fill it according to the visual analogue scale. Data collected were tabulated and statistically analyzed.

Statistical analysis

Recorded data were analyzed using the statistical package for social sciences (SPSS Inc., Chicago, Illinois, USA), version 20. Quantitative data were expressed as mean \pm standard deviation (SD). Qualitative data were expressed as frequency and percentage.

The following tests were done

- Mann Whitney U test: for two-group comparisons in non-parametric data.
- Descriptive statistics were used in the form of median and interquartile ranges.
- The P-value was considered significant as the following:

Probability (P-value); P-value < 0.05 was considered significant (S) while P-value < 0.001 was considered as highly significant (HS) and P-value > 0.05 was considered non-significant (NS).

RESULTS

The results of the present study are demonstrated in the next tables and figures.

Table (1) shows statistically significant higher mean bone loss in group I compared to group II at measurements “After 6 m, 9 m, 12 m and 18 m from the baseline”.

Table (2) shows statistically significant higher mean pocket depth in group II compared to group I at measurements “After 6 m and 18 m”.

Table (3) shows statistically significant higher VAS score in group II compared to group I according to chewing, while it was high mean VAS in speech, digestion and psychological but insignificant with p-value > 0.05 NS.

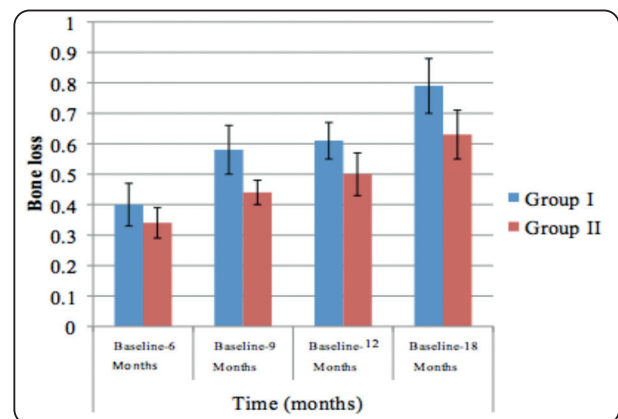


Fig. (4): Comparison of bone loss around the implants between group I and group II.

TABLE (1): Comparison of bone loss around the implants between group I and group II

Follow up intervals	Groups	Median	Standard deviation	Range	P
Baseline - 6 months	I	0.40	0.07	0.15	0.029*
	II	0.34	0.05	0.05	
Baseline - 9 months	I	0.58	0.08	0.20	<0.001**
	II	0.44	0.04	0.05	
Baseline - 12 months	I	0.61	0.06	0.15	<0.001**
	II	0.50	0.07	0.1	
Baseline -18 months	I	0.79	0.09	0.20	<0.001**
	II	0.63	0.08	0.15	

Using: z-Mann-Whitney test to comparison between two groups *p-value < 0.05 S; **p-value < 0.001 HS Values

TABLE (2): Comparison of pocket depth around the last abutment between group I and group II

Follow up intervals	Groups	Median	Standard deviation	Range	P
Baseline - 6 months	I	0.75	0.2	0.5	0.010*
	II	1	0.2	0	
Baseline - 9 months	I	1	0	1	0.072
	II	1.18	0.37	0	
Baseline - 12 months	I	1.25	0.26	0	0.221
	II	1.5	0.52	0	
Baseline - 18 months	I	1.57	0.18	0	<0.001**
	II	2	0	0	

Using: z-Mann-Whitney test to comparison between two groups p -value >0.05 NS; * p -value <0.05 S; ** p -value <0.001 HS Values

TABLE (3): Patient's satisfaction according to visual analogue scale.

Visual analogue scale	Groups	Median	Standard Deviation	Range	p-value
Chewing	Group I	0.57	0.51	1	0.050*
	Group II	1.00	0.55	0	
Speech	Group I	0.71	0.61	1	0.255
	Group II	1.00	0.68	1	
Pain	Group I	0.71	0.61	1	0.919
	Group II	0.71	0.73	1	
Digestion	Group I	0.57	0.51	1	0.249
	Group II	1.07	1.07	2	
Psychological	Group I	0.86	0.86	1	0.437
	Group II	1.43	1.50	4	

Using: z-Mann-Whitney test for comparison between two groups & Wilcoxon Signed-Rank Sum test to comparison between measurements within group; p -value >0.05 NS; * p -value <0.05 S

Values in each row which have different letters are significantly different at ($P<0.05$).

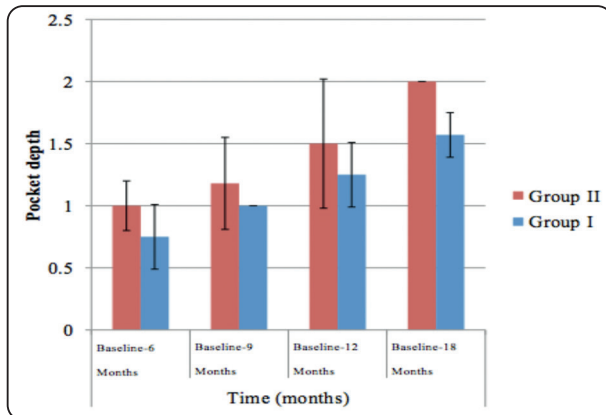


Fig. (5): Comparison of pocket depth between group I and group II.

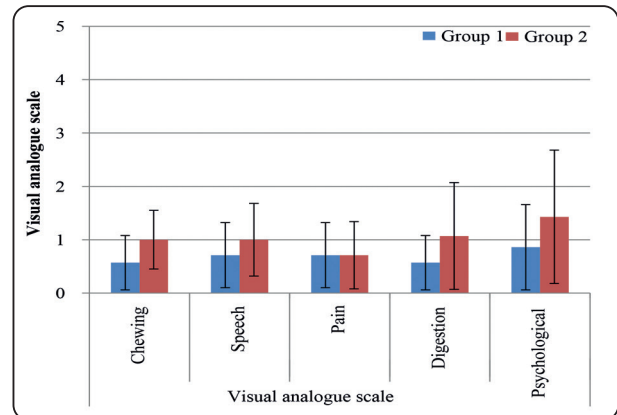


Fig. (6): Visual analogue scale for group I and group II.

DISCUSSION

The use of dental implants for the rehabilitation of partial or complete edentulism is currently a well-accepted treatment modality ⁽¹³⁾. Any extrusion of the opposing teeth or tilting of teeth was corrected guided by the mounted diagnostic cast and T-scan, as the development of harmonious occlusion is important to control lateral stresses on the remaining teeth and implant ^(26,27). Furthermore the patients having sufficient inter-ridge space were selected to allow insertion of the partial overdenture on abutments without encroaching on the vertical dimension of occlusion. Theoretically, the implants should be positioned as distally in the edentulous area as possible to provide maximum support ⁽²²⁻²⁴⁾.

The dental implants were carefully positioned parallel to the path of insertion of the planned prosthesis and perpendicular to the occlusal plane as possible thus the implants were loaded axially (favorable direction) and reducing the production of bending moments. Non-parallel implants could hinder passive insertion of the removable prosthesis that later causes premature wear of the ball attachment components ⁽²⁸⁾. The ball retained overdenture has been recognized to be a simple and effective treatment modality for the edentulous patient rehabilitated with endosteal dental implants ⁽²⁹⁾.

All patients were motivated and attempted to follow oral and denture hygiene measures. This was probably a key factor in explaining most of the clinical insignificant changes.

The null hypothesis was rejected in this study. The location of an implant in the free end saddle area is supported by a Finite element study, which found out that the maximum displacement recorded was located in a control model where no implants were placed and the lowest in a model where the implant was located in the first molar area ⁽²⁴⁾.

Hence, the inclusion of an implant in the RDP treatment modality resulted in a reduction of stresses in these structures. This evidence was additionally verified in other similar studies. ^{30,31} Beside that the insertion of the implant improves the denture stability and relieves stresses in the biological structures, additionally it increases stress in non-living tissues such as the implants, metal framework, and resin of the RPD ⁽³⁰⁻³²⁾.

The implant placed in the first molar area provided a more favorable distribution and dissipation of stress along the whole length of the bone around the implant compared with models where implants were in the second molar and second premolar areas, where such stress was concentrated in the prosthetic interface ⁽²⁴⁾. In Memari et al's study ⁽³¹⁾ locating the

implant in the first molar area showed the lowest stress value in the cortical bone. These differences could be explained by the different location of the displacement strain.

Cunha et al.⁽³⁰⁾ found that the model with the implant located in the premolar area decreased the stress values of the periodontal ligaments, getting the lowest value of 10.772 MPa. The maximum strain was shown in the control model (27%), and the minimum strain was found with the implant located in the second premolar (21%), supporting the idea that IARDP can decrease the strain forces in the periodontal ligaments, especially when the placed implant is located in the second premolar area.

A study agrees that the implant placed in the first molar area obtained the lowest values and more favorable stress distribution along the implant length while the more near the implant is placed in the direction of the supporting tooth positively affected the tension distribution on the abutment⁽²⁹⁾.

The visual analogue scale didn't show any difference regarding speech, physiology, appearance, digestion and pain suggesting that implant position has no effect on these factors. Nevertheless, it should be acknowledged that participants were apparently aware of having a sophisticated and modern implant treatment modality, that could have made them satisfied with their dentures and this is in agreement with a study done⁽³³⁾.

Partial or complete prosthetic replacement of missing dentition is associated with reduced chewing efficiency and consequently decreased patient satisfaction⁽³⁴⁾. The positioning of posterior teeth and the bite force are the most important factors affecting the efficiency of the masticatory system⁽³⁵⁾. Several researchers concluded that the more posterior biting force is, the greater the contribution of anterior fibers of temporalis assessing the action of masseter which runs in consistent with the results of other studies which showed increases in the

activity of temporalis in implants placed in molar area than in premolar area^(36,37). Also, the results of the present study are in accordance with Grossman et al.⁽³⁸⁾ who recommended the molar area for installation of posterior implant in distal extension cases.

CONCLUSION

Within the limitations of this study, it was concluded that placing implant in premolar area near the abutment tooth caused more marginal bone loss at the implant site and less periodontal disease to the last abutment than being placed at the second molar site, and this difference was not clinically significance. Patient's satisfaction was not affected by different implant locations, all participants were satisfied with the treatment modality except for mastication; where in patients with implant located in second molar region were more satisfied.

REFERENCES

1. Frank R.P., Brudvik J.S. and Noonan C.J.: Clinical outcome of the altered cast impression procedure compared with use of a one-piece cast. *J Prosthet Dent.* 2004; 91(5):468–476.
2. Meffert R.M.: Issues related to single-tooth implants. *JADA.* 1997; 128: 1383.
3. Aydinlik E., Dayangac B. and Celik E.: Effect of splinting on abutment tooth movement. *J. of Prosth. Dent.* 1983; 49(4): 477.
4. De Freitas R., Kaizer R., Hamata M., De Resende D. and Kaizer R.: Prosthetic rehabilitation of a bone defect with a teeth-implant supported, removable partial denture. *Implant Dent.* 2006; 15:241.
5. Costa M.M., D.A. Silva M.A., Oliveira S.A., Gomes V.L., Carvalho P.M., and Lucas B.L.: Photoelastic study of the support structures of distal-extension removable partial dentures. *J. Prosthodont.* 2009; 18(7):589.
6. Kapur K.K.: Veterans administration cooperative dental implant study. Comparison between fixed partial dentures supported by Blade-Vent implants and removable partial dentures. Part IV: Comparison of patient satisfaction between two treatment modalities. *J Prosthet Dent.* 1991; 66:517.

7. Petridis H., and Hempton T.J.: Periodontal considerations in Removable partial denture Treatment, A review of the literature. *Int J. Prosthodont.* 2001;14(2):164.
8. Keltjens H.M., Kayser A.F., Hertel R. and Battistuzzi P.G.: Distal extension removable partial dentures supported by implants and residual teeth: considerations and case reports. *Int J Oral Maxillofac Implants.* 1993; 8(2):208- 213.
9. Rangert B., Krogh P.H., Langer B., and Van Roekel N.: Bending overload and implant fracture: A retrospective clinical analysis. *Int J Oral Maxillofac Implants.* 1995; 10:326.
10. Threeburuth W., Aunmeungtong W. and Khongkhunthian P.: Comparison of immediate-load mini dental implants and conventional-size dental implants to retain mandibular Kennedy class I removable partial dentures: A randomized clinical trial. *Clin Implant Dent Relat Res.* 2018; 20(5):785–792.
11. Kang S.H., Kim S.K., Heo S.J. and Koak J.Y.: Survival rate and clinical evaluation of the implants in implant assisted removable partial dentures: Surveyed crown and overdenture. *J Adv Prosthodont.* 2020;12(4):239–249.
12. Nogawa T., Saito M., Murashima N., Takayama Y. and Yokoyama A.: Influence of rigidity of retainers on dynamic behavior of implant-supported removable partial dentures. *Int J Implant Dent.* 2020; 6(1).
13. Chatzivasileiou K., Kotsiomiti E. and Emmanouil I.: Implant-assisted removable partial dentures as an alternative treatment for partial edentulism: A review of the literature. *General Dentistry.* March/April 2015, 21-25.
14. Mijiritsky E., Lorean A., Mazor Z. and Levin L.: Implant tooth-supported removable partial denture with at least 15-year long-term follow-up. *Clin Implant Dent Relat Res.* 2015;17(5):917–922.
15. Suzuki Y., Kono K., Shimpo H., Sato Y. and Ohkubo C.: Clinical evaluation of implant-supported removable partial dentures with a stress-breaking attachment. *Implant. Dent.* 2017; 26, 516–523.
16. Misch C.E.: *Dental implant prosthetics.* St Louis: Mosby; 2005. Misch C.E. and Silc J.T. A Key Implant Position For A Fixed Prosthesis: The First Molar Rule
17. Monteiro D.R., Silva E.V.F., Pellizzer E.P., Filho O.M., and Goiato M.C. Posterior partially edentulous jaws, planning a rehabilitation with dental implants. *World J Clin Cases.* 2015 Jan 16; 3(1): 65–76.
18. Verri F., Pellizzer E., Rocha E. and Pereira J.: Influence of length and diameter of implants associated with distal extension removable partial dentures. *Implant Dent.* 2007 Oct; 16(3):270–280.
19. Bortolini S., Natali A., Franchi M., Coggiola A. and Consolo U.: Implant-retained removable partial dentures: An 8-year retrospective study. *J Prosthodont.* 2011; 20(3):168–172.
20. Lemos C., Nunes R.G., Santiago-Júnior J., Gomes J.M.D, Limirio J.P.J.O., Rosa C.D.D.R.D., Verri F. and Pellizzer E.: Are implant-supported removable partial dentures a suitable treatment for partially edentulous patients? A systematic review and meta-analysis. *The Journal of prosthetic dentistry.* July 2021. DOI:10.1016/j.prosdent.2021.06.017
21. Blum I.R. and McCord J.F.: A clinical investigation of the morphological changes in the posterior mandible when implant-retained overdentures are used. *Clin Oral Implant Res.* 2004; 15(6):700-708.
22. Rungsiyakull P., Kujarearntaworn K., Khongkhunthian P., Swain M. and Rungsiyakull C.: Effect of the location of dental mini-implants on strain distribution under mandibular Kennedy Class I implant-retained removable partial dentures. *Int J Dent.* 2021;2021.
23. Kihara M., Ogino Y., Matsushita Y., Morita T., Sawae Y., Ayukawa Y., et al.: In vitro assessment of the effect of implant position on biomechanical behaviors of implant-supported removable partial dentures in Kennedy class II condition. *Materials (Basel).* 2021;14(9):1–10.
24. Ortiz-Puigpelat O., Lázaro A., de Medrano-Reñé J.M., Gargallo-Albiol J., Cabratosa-Termes J. and Hernández-Alfaro F.: Influence of implant position in implant-assisted removable partial denture: A three-dimensional finite element analysis: Implant Position and Kennedy Class I RPDs. *J. of Prosthodontics.* December 2017; 28(2): 1-7
25. Rostom D. and Faroukabdulla M.: Melatonin effect on short implant supporting Kennedy class I removable partial denture in atrophied posterior mandibular alveolar
26. Chun Y.S., Row J., Yang S.J., Cha H.S. and Han J.S.: Management of extruded maxillary molars to accommodate a mandibular restoration: A clinical report. *J Prosthet Dent.* 2000; 83:604.
27. Rudd R.W., Bange A.A., Rudd K.D. and Montalvo R.: Preparing teeth to receive a removable partial denture. *J Prosthet Dent.* 1999; 82:536.

28. Ramchandran A., Agrawal K.K., Chand P., Ramashanker, Singh R.D. and Gupta A.: Implant-assisted removable partial denture: An approach to switch Kennedy Class I to Kennedy Class III. *J Indian Prosthodont Soc.* 2016 Oct-Dec; 16(4): 408–411.
29. Ortensi L., Martinolli M., Borromeo C., Ceruso F.M., Gargari M., Xhanari E. and Tallarico M.: Effectiveness of Ball Attachment Systems in Implant Retained- and Supported-Overdentures: A Three- to Five-Year Retrospective Examination. *Dent J (Basel).* 2019 Sep; 7(3): 84.
30. Cunha D.P.L., Pellizzer E.P., Verri F.R. and Pereira J.A.: Evaluation of the influence of location of osseointegrated implants associated with mandibular removable partial dentures. *Implant Dent.* 2008;17(3):278–287.
31. Memari Y., Geramy A., Fayaz A., Abadi R.H.S. and Mansouri Y.: Influence of implant position on stress distribution in implant-assisted distal extension removable partial dentures: A 3D Finite Element Analysis. *J Dent (Tehran).* 2014;11(5):523–530.
32. Shahmiri R., Das R., Aarts J.M. and Bennani V.: Finite element analysis of an implant-assisted removable partial denture during bilateral loading: Occlusal rests position. *J Prosthet Dent.* 2014;112(5):1126–33.
33. Wismeijer D., Tawse-Smith A. and Payne A.G.T.: Multicentre prospective evaluation of implant-assisted mandibular bilateral distal extension removable partial dentures: Patient satisfaction. *Clin Oral Implants Res.* 2013; 24(1):20–27.
34. Lee S.K.Y., Salinas T.J. and Wiens J.P.: The effect of patient specific factors on occlusal forces generated: best evidence consensus statement. *J Prosthodont.* 2021;30:52–60.
35. Gonçalves T.M.S.V., Schimmel M., van der Bilt A., Chen J., van der Glas H.W., Kohyama K, et al.: Consensus on the terminologies and methodologies for masticatory assessment. *J of Oral Rehab.* 2021;48: 745–761.
36. Tortopidis D., Lyons M.F., Baxendle R.H. and Gilmour W.H.: The variability of bite force measurements between sessions, in different positions within the dental arch. *J. Oral rehabil.* 1998; 25:681–686.
37. Braun S., Freudenthaler J.W. and Honigle K.: A study of maximum bite force during growth and development. *Angle Orthod.* 1996; 66:261–264.
38. Grossmann Y., Nissan J. and Levin L.: Clinical effectiveness of implant-supported removable partial dentures: A review of the literature and retrospective case evaluation. *J Oral Maxillofac Surg.* 2009; 67(9):1941–1946.