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CLASS II KENNEDY IMPLANT ASSISTED MANDIBULAR REMOVABLE PARTIAL DENTURES WITH AND WITHOUT CROSS ARCH STABILIZATION: A STRAIN GAUGE IN VITRO STUDY

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ABSTRACT

Introduction The use of a dental implant placed in the distal extension space, and an extracoronal attachment on the terminal abutments next to that space in Kennedy class II situation improves the mechanical behavior and reduce the size of the implant assisted removable partial dentures (IARPD) that can possibly be used without a major connector. However, controversies exist about placement of the implant at either the first or second molar positions, and about the microstrains generated around the abutments and dental implants in the presence or absence of a major connector, strain gauges were used for such assessment.

Materials and Methods Thirty replicas of acrylic resin simulation models of a mandibular class II Kennedy arch received 3 RPD designs; a clasp retained RPD in group I, a unilateral clasp retained RPD without a major connector supported by a dental implant placed once at the first molar and once at the second molar position in group II, and a clasp free RPD with extracoronal attachments on the abutments next to the edentulous space and supported by a dental implant placed once at the first molar and once at the second molar position in group III. Strain gauges were attached to the facial and lingual aspects of the alveolus of the abutment teeth and implants in order to determine which design generated significant loads more than the other under average biting forces. The recorded microstrains were statistically analyzed using the Kruskal-Wallis and Mann-Whitney tests of the SPSS statistical package for social science V22 (SPSS Inc., Chicago, Ill).

Results Significantly greater loads around abutment teeth were reported in group II and group III than in group I. The distal placement of the implants resulted in significantly greater microstrains more than the mesial placement in groups II and III, and both placements were of more intensity in group II than in group III.

Conclusions A Kennedy class II IARPD can effectively be altered to a bounded space prosthesis by placement of a dental implant in the first rather than the second molar position, and together with an extracoronal attachment, the clasp and major connector can be omitted once the edentulous span is short, and the clinical situation is favorable.

KEYWORDS Dental implant, unilateral implant assisted removable partial denture (IARPD), extracoronal attachment, strain gauges.

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INTRODUCTION

Millions of people around the globe suffer from partial edentulism, and when treated with removable partial dentures (RPDs) may complain about the dentures size and its interference with speech. Dental implants can help provide patients with less bulky, retentive, and more comfortable prostheses, which by implant assistance perform in a manner similar to bounded rather free end space situations. [1-15]

Placement of a solitary dental implant, in the distal extension edentulous space, improves the mechanical behavior of implant assisted RPD (IARPD); where the effort arm is reduced and the fulcrum line is moved to a better position, which in turn reduce the abutment titling. It was also claimed that the destructive forces associated with IARPD were eliminated, and secure retention was obtained, which minimized the risk of accidental swallowing, and decreased the effects of nocturnal parafunctions, as patients can remove the prostheses at night. One additional advantage was that the patients did not have to undergo ridge augmentation procedures, which might be needed for placement of several implants to support fixed prostheses. [16-21]

Yet, there are controversies about the implant position in the distal extension edentulous space, whether to be placed mesially, next to the abutment teeth, or as distally as possible. However, in either case, it was found that implant ball and socket attachments reduced the microstrains around abutment teeth in Kennedy class II IARPD, compared to magnet and locator attachments, especially when combined with resilient extracoronal attachments on such abutments, as proven by in vitro and clinical studies. [22-35]

Accordingly, since the dental implants were proven to improve the IARPD retention, support, and stability, and the extracoronal attachments provided retention and eliminated the clasp and its metal display, this study suggested the use of dental implants and/or extra coronal attachments in a trail to eliminate the major connector, to make the IARPD less bulky and more comfortable, and assessed the resulting stresses through evaluation of the microstrains generated around the abutments and dental implants, placed at the first and second molar positions in the edentulous spaces of mandibular Kennedy class II arches, using strain gauges.

MATERIALS AND METHODS

This study used exact replicas of a self-cured acrylic resin simulation model, of a mandibular class II Kennedy arch, in which the left first and second molars were missing, the models received 3 different chrome cobalt RPD designs; a clasp retained conventional design RPD, a unilateral clasp retained RPD, without a major connector, that received custom made laboratory dental implants placed at either positions of the missing molars, and a clasp free RPD, with extracoronal attachments emerging from the distal aspects of prosthetic splinted crowns on the premolars next to the edentulous space, that received custom made dental implants placed at either positions of the missing molars, with ball attachments. Strain gauges were attached to the facial and lingual aspects of the alveolus of the abutment teeth and implants in order to determine which of the previous designs generated significant loads more than the other.

Thirty mandibular Kennedy Class II acrylic resin models were prepared by pouring self-cure acrylic resin into a rubber readymade mold (Nissin dental products Inc. Koyoto, JAPAN) as seen in figure 1. Using the confined dough technique, 2 mm of autopolymerizing soft liner (PROMEDICA, USA) were added to the distal extension edentulous spaces to provide the cushioning effect of the mucosa. (Fig. 2)

The models were distributed to 3 groups as follows:

Group I: consisted of 6 models, where each model received two strain gauges, one attached buccally, and the other attached lingually to the alveolus of the principal abutment of the edentulous sides. The models in this group were modified to receive a conventional design RPD. (Fig. 3)

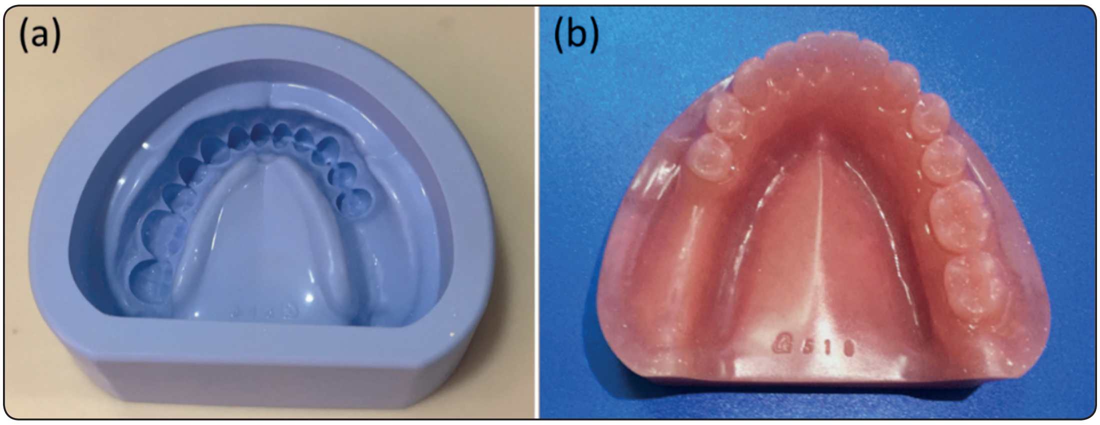

Fig. (1) (a) The rubber mold used for casting the models of the study, (b) The acrylic resin cast produced from the rubber mold in a hot water bath under steam pressure.

Fig. (2) The kit used to cover the edentulous ridge of the acrylic model with a 2 mm layer of soft liner.

Group II, consisted of 12 models, and were further divided into 2 subgroups, each subgroup consisted of 6 models, the first sub-group received a dental implant placed at the first molar approximate position, and the second subgroup received a dental implant placed at the second molar approximate position. Strain gauges in this group were placed on the buccal and lingual aspects of the alveolus of the principal abutment of the edentulous sides, and on the buccal and lingual sides of the dental implants. The models of this group were modified to receive a unilateral, clasp retained RPDs, without a major connector, and with a housing space, for the rubber O-ring of the implant ball abutment, in their fitting surface. (Fig. 4)

Group III: consisted of 12 models and were further divided into 2 subgroups, each subgroup consisted of 6 models, where each model received 2 splinted crowns on the premolars, next to the edentulous spaces, with ball and socket extracoronal resilient attachments projecting from their distal aspects, and a dental implant placed at the first molar approximate position in the first sub-group, and a dental implant placed at the second molar approximate position in the second sub-group. Strain gauges in this group were placed in a similar distribution to group II. The models of this group were modified to receive a unilateral claspless metallic removable partial denture, without a major connector, with the metal housings for the rubber O-ring of the relative implant ball abutments, and housings for the resilient extracoronal attachments in their fitting surfaces. (Fig. 5)

Strain gauges (BX12-6AA, Biosensor for polymers, Sensor World, PRC) were cemented using its cyanoacrylate adhesive on the acrylic resin model surface at the previously mentioned locations as seen in figures 3, 4, and 5. The lead wires of the strain gauges were connected to a full bridge circuit (120-1000 Ω) of a digital multi-channel strain meter (DRA-30A, Tokyo, Sokki, Kenkyujo, Ltd, JAPAN) using a software (DRA-730AS for static measurements), with a fixed gauge factor of 2.00, which was consistent with the strain gauge used.

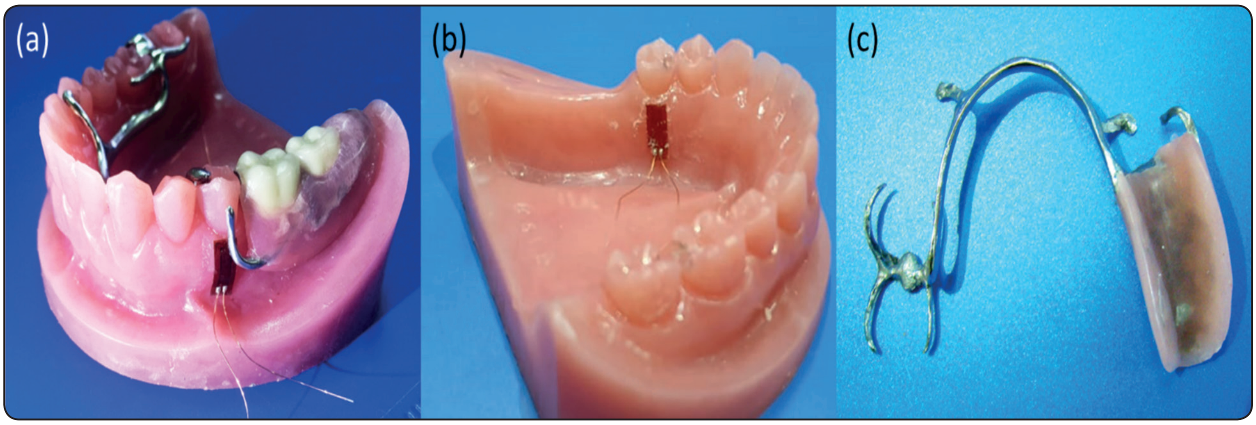

Fig. (3) (a) A group I cast with the conventional design RPD seated in place, and a strain gauge attached to the buccal aspect of the second premolar alveolus, (b) A strain gauge attached to the lingual aspect of the second premolar alveolus, (c) The tissue surface of the RPD.

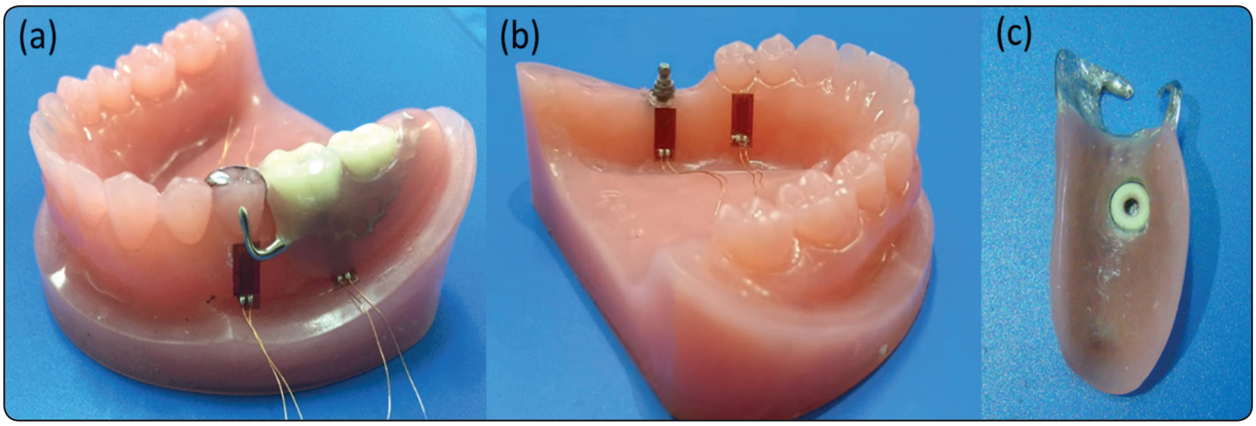

Fig. (4) (a) A group II cast with a unilateral clasp retained RPD seated in place, and a strain gauge attached to the buccal aspect of the second premolar alveolus, and to the buccal aspect of an implant placed at the position of the first molar representing the first sub-group of group II, (b) Strain gauges attached to the lingual aspect of the second premolar alveolus and to that of the implant, (c) the tissue surface of the RPD showing the implant ball abutment rubber O-ring in its housing.

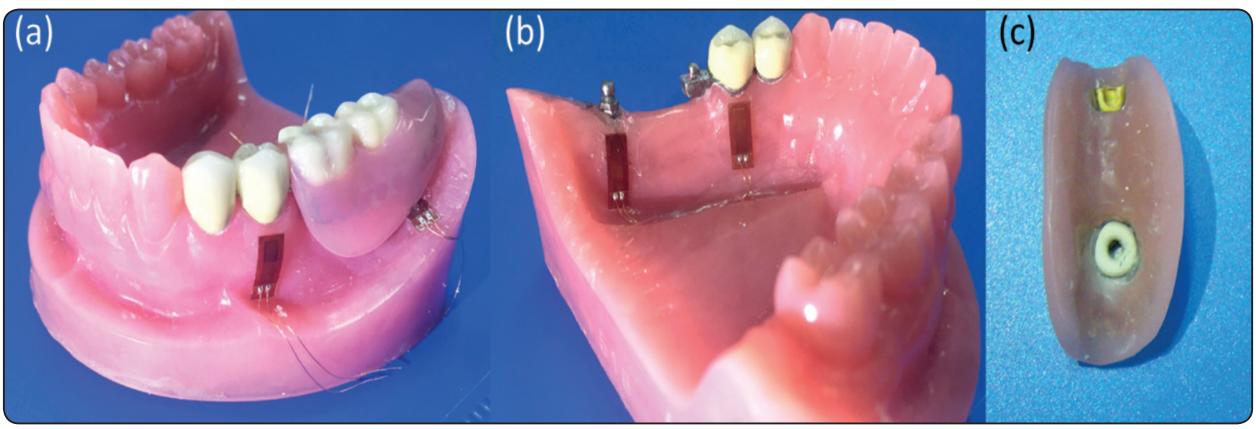

Fig. (5) (a) A group III cast with a unilateral clasp free RPD seated in place, and a strain gauge attached to the buccal aspect of the second premolar alveolus, and on the buccal aspect of an implant placed at the position of the second molar representing the second sub-group of group III, (b) Extracoronal attachment projecting from the distal surface of the second premolar, and strain gauges attached to the lingual aspect of the second premolar alveolus and to that of the implant, (c) the tissue surface of the RPD showing the implant ball abutment rubber O-ring in its housing (white), and the rubber housing of the extracoronal attachment (yellow).

To age the strain gauges and minimize hysteresis, their calibration was done by cyclically loading the prostheses several times using the mechanical testing machine (BISON, St Charles, Illinois, USA),[25,26] which was then used to unilaterally load the prostheses with a custom made attachment as seen in figure 6. A 60 N load was then used at an increasing constant load of 0.5 mm/min, which was repeated 10 times with 5 minutes' intervals of rest.[22] The recorded microstrains were statistically analyzed using the Kruskal-Wallis test of the SPSS statistical package for social science V22 (SPSS Inc., Chicago, Ill).

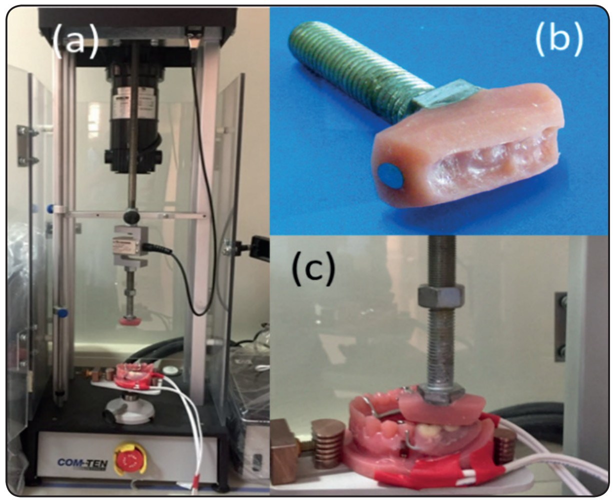

Fig. (6) (a) The mechanical testing machine used to load the prostheses, (b) The custom made occlusal index used to the load the prostheses of the different groups of this study, note that for every prosthesis the index was readjusted to its occlusal surface details using self-cured acrylic resin, (c) The prostheses loading process, note that the strain gauges are attached to the data loggers through the white wires.

RESULTS

This research aimed at evaluating the amount of microstrains around the abutment teeth and dental implants assisting two RPD designs, without a major connector, compared to a conventional RPD design. Table 1 demonstrates microstrains recorded by the strain gauges for the 3 groups in this study, whereas, tables 2 and 3 report the statistical analysis of these readings.

TABLE (1): Readings obtained from the strain gauge measurements

Group	Sub-group	Value	Abutment		Implant	
			Buccal	Lingual	Buccal	Lingual
I	-	M	-54.00	55.00		
		Min	-67.00	71.00		
		Max	-52.00	81.00		
II	1	M	-343.00	318.00	-598.00	490.00
		Min	-353.00	310.00	-714.00	414.00
		Max	-330.00	340.00	-653.00	553.00
	2	M	-1251.00	998.00	-1685.00	1365.00
		Min	-1234.00	920.00	-1220.00	1120.00
		Max	-1273.00	1010.00	-1872.00	1632.00
III	1	M	-165.00	171.00	-190.00	210.00
		Min	-170.00	175.00	-210.00	220.00
		Max	-160.00	165.00	-153.00	240.00
	2	M	-274.00	210.50	-420.00	440.00
		Min	-317.00	182.00	-440.00	430.00
		Max	-237.00	297.00	-400.00	460.00

M=median, min=minimum, max=maximum, negative values denote compression.

Statistical analysis of the results of this study has revealed a significantly greater amount of load around abutment teeth in group II and group III than in group I, furthermore, the distal placement of the dental implants resulted in more strains around the abutment teeth in the second sub-groups than the first sub-groups of groups II and III, with the loads being greater in group II than in group III. (table 2)

With the distal, compared to the mesial placement of the implants, significant differences stared to appear; where greater microstrains were recorded in groups II and III than, being of more intensity in group II than in group III, and more in the second subgroups than the first sub-group of these groups. (table 3)

TABLE (2): Statistical analysis: Comparison of microstrains around abutment teeth in the three groups.

Groups	Sub-group comparison	Kruskal Wallis test (p value)
Group II	Sub-group 1 versus subgroup 2	0.02*
Group III	Sub-group 1 versus subgroup 2	0.05*
Group I versus Group II	Group I versus sub-group 1 of group II	0.05*
	Group I versus sub-group 2 of group II	0.01*
Group I versus Group III	Group I versus sub-group 1 of group III	0.05*
	Group I versus sub-group 2 of group III	0.05*
Group II versus Group III	Sub-group 1 of group II versus sub-group 1 of group III	0.05*
	Sub-group 2 of group II versus sub-group 1 of group III	0.02*

= p value is significant at 5% level of significance.

TABLE (3): Statistical analysis: Comparison of microstrains around the dental implants in the second and third groups.

Groups	Sub-group comparison	Mann-Whitney test (p value)
Group II	Sub-group 1 versus subgroup 2	0.05*
Group III	Sub-group 1 versus subgroup 2	0.05*
Group II versus Group III	Sub-group 1 of group II versus sub-group 1 of group III	0.04*
	Sub-group 2 of group II versus sub-group 1 of group III	0.02*

= p value is significant at 5% level of significance.

DISCUSSION

Kennedy class II partially edentulous arches suffer two problems, namely support and retention, a solitary dental implant placed in the edentulous ridge can solve both problems, however, buccolingual rotation of the prostheses is generally prevented by the major connectors providing cross arch stabilization from the other side of the dental arch. This work studied the effect of the absence of such cross arch stabilization on the abutment teeth and implants in unilateral IARPDs, retained with conventional clasp assemblies, and/or extracoronal attachments.

The suggested locations for dental implants placement in this study came in agreement with Halterman et al [13] who reported that strategically placed dental implants can reduce the effort arm, improve the fulcrum line position, and improve support in Kennedy class II RPDs, Mitrani et al [11] further added that this implant placement improved stability, retention, and obtained more patients' satisfaction, and in cases of bilateral free end saddles, Keltjens et al [12] found that these implant positions can prevent the undesired derangements of the combination syndrome. In addition, ball abutments were selected due to their significant role in stress breaking and dissipation of occlusal forces delivered to the abutment teeth, compared to locator and magnetic attachments, as proven by Kuzmanovic et al [15], Omran et al [26], and ELsyad et al. [35]

Together with single molar implants, extracoronal resilient attachment used in this study, were reported by Giffin [14] to retain the RPDs, help in prevention of their tissue ward movement, and generate a similar effect to cross-arch stabilization, this finding was also proved by Jain et al [22] and Ramchandran et al. [23] In a similar design to the first sub-group in group III of this study, a clinical trial conducted by Alam-Eldein et al [28] used one implant with ball abutment, placed at the first molar location, with an extracoronal attachment on the mandibular first premolar, that was splinted to its neighboring tooth, the canine, and concluded that despite the absence of a major connector, the prostheses movements were reduced, and more comfort and better speech were obtained. The same design was applied to a longer edentulous span by Turkyilmaz [24] who used two implants instead of one, and reported similar success.

For the sake of comparison to other studies, relatively similar materials and methods were used in the current research. Strain gauges were used due to their small dimensions and ability to provide quantitative data about the amount of microstrains around the terminal abutments and implants. The acrylic resin simulation models had an elastic modulus value near to that of compact bone, with the possibility of its surface strains to be indicative of the stresses introduced to the implants, under a 60 newton load, which represents a moderate amount of the occlusal forces applied to the IARPD, however, in this study the occlusal loading process was conducted using a custom made attachment, that applied the occlusal loads in a manner similar to opposing natural dentition functional cusps occluding in the central fossae of the RDPs teeth. [25- 27, 31-35]

This study has shown that, in the absence of a major connector, abutment teeth were subjected a significantly greater amount of load, this came in agreement with the findings of Omran et al [26] on similar studies on IARPD, and Shahmiri et al [27] who found that unilateral loading of the IARPD distributed such forces to the supporting abutments through the major and minor connectors, and by absence of cross arch stabilization, abutments in groups II and III suffered more stresses than those in group I, however, group III abutments experienced less stresses than those of group II due to splinting to their neighbors.

The results of the current work also showed that the mesial placement of the dental implants resulted in less strains around the implants and abutments, than in situations where the implants were placed more further distally, a finding that was also reported in the work of Elsyad et al,[25] but was in contrast to that of Hegazy et al[34]. Such contradiction can be explained on the basis that the work of Hegazy et al[34] included longer edentulous spaces, starting at the canines, and according to a 3-dimensional finite element analysis study by Liu et al,[29] it was found that implants in the premolar region received more forces than implants in the molar area, where the cortical bone cortex dissipates the occlusal loads through its trajectories of force, and according to this hypothesis, both implant positions in this study are considered posterior to the premolar position in Hegazy et al[34] work . Also, it would be more favorable to place the implants in an alignment that facilitate a common path of placement of the IARPD, that is being parallel to the abutment as suggested by Hirata et al [31], and in a more anterior position to the posterior curvature of the bony foundation, which according to Shahmiri et al [27] can create a fulcrum during unilateral loading and result in flection of the IARPD structure, with subsequent overload to the supporting structures.

Accordingly, it can be concluded that a short span unilateral IARPD, assisted with a mesially placed implant and an extracoronal attachment, with no major, can represent an acceptable treatment modality as shown by Alam-Eldein et al [28] clinical trial, in which a similar design gained patients satisfaction and comfort. However, it is important to note that such design may experience slight instability in the horizontal plane as reported by Naser Khaki et al. [30]

Finally, before considering the findings of this work for more clinical trials, it is important to enumerate its limitations, for example,(1) the simulation models were made of homogenous, and solid acrylic resin, which might have an elastic modulus close to that of compact bone, however, the mandibular alveolus is made of a cancellous core surrounded by compact cortical plates, and each of them exhibit unique hierarchy of lamellar patterns that represent the trajectories for load dissipation, (2) the unique mechanical behavior of the periodontal ligament was not considered, (3) the complex pattern of stresses, experienced by abutments and implants, under the IARPD was only evaluated by the strain gauges attached simulation model surface, (4) Only unilateral loading was tested, which is typical for Kennedy Class II RPD to exhibit only working side contacts, however, in clinical situations balancing side interference contacts may happen. (5) the loading force used represented an average biting force for the IARPD, and did not consider different opposing dentition scenarios. (6) the study did not consider the other possible several designs of prostheses tested.

CONCLUSIONS

After considering the above mentioned limitations, the following conclusions can be listed:

1. The major connector, in Kennedy class II conventional design RPD, helped reduce the stresses around abutment teeth through cross arch stabilization.
2. A Kennedy class II IARPD can be effectively altered to a bounded space prosthesis by placement of a dental implant, favorably in the first rather than the second molar position.
3. The use of extracoronal attachment, and a dental implant, in Kennedy class II arches can omit the use of clasp and major connector, once the edentulous span is short, the implant is placed in the first molar position, and the clinical situation is favorable.

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