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ORIGINAL ARTICLE

Effect of metal and acetal removable partial denture frameworks on the stresses around implant-supported removable partial dentures

Ahmed Mohammed Salah[1], Mohammed Ezzat Elsayed[2], Sayed Mohammed Elmasry[2], Moataz Mostafa Bahgat Elmahdy[2]

[1]Department of Prosthodontics, Faculty of Dentistry, Sinai University, Cairo, Egypt, [2]Department of Prosthodontics, Faculty of Dentistry, Suez Canal University, Ismailia, Egypt

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Correspondence:
Ahmed Mohammed Salah, Department of Prosthodontics, Faculty of Dentistry, Sinai University, Cairo, Egypt.
E-mail: dentsalah15@gmail.com
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Abstract

Background: The problem with the connection of implant to natural teeth-supported prosthesis develops from the reality that the tooth and the osseointegrated implants have dissimilar mobility patterns and this may expose the implant to excessive load.

Aim: The purpose of this study was to evaluate the effect of metal and acetal removable partial denture (RPD) framework materials on the stresses around implant-supported RPDs.

Materials and Methods: The study was carried out on mandibular epoxy Class I partially edentulous models with two parallel implants placed at lower first molar area and according to framework materials, two groups were created: Group I**:** Acetal partial denture framework, Group II: Metallic partial denture framework, for both groups, acrylic record block was made and adjusted to apply occlusal force on the center of the metal plates, regarding the models from the right and left side, stress analysis images were recorded for both groups and for both sides at stresses from 20 to 100 newton, using photoelastic machine and mean stress values were recorded for both groups, tabulated, and statistically analyzed.

Results: There was a difference in significance between acetal and metallic partial denture frameworks where metallic partial denture framework showed higher stress fringes order around implant compared to acetal denture base.

Conclusions: Within the calibrations of this *in vitro* photoelastic analysis, it was concluded that acetal partial denture frameworks are preferred to use with implant-supported RPD when compared with metal partial denture frameworks, for the preservation of bone around implant.

Clinical Significance: Acetal denture bases are the treatment of choice.

Introduction

There are many problems associated with Kennedy Class I cases. The main problem is support due to the composite form of the supporting structure. Another problems appear with Kennedy Class I cases which are loss of posterior abutments which may lead to loss of vertical dimension of occlusion, reduce the masticatory efficiency and attrition of the anterior teeth.[1]

Numerous studies have adopted pronounced marginal bone loss or failure of implant to osseointegrate, especially those closest to implants. This led to the argument of whether connecting implant to the natural teeth is a viable choice. Various complications such as teeth intrusion, mechanical failure, occlusal contact loss, and caries have been reported in the studies associated with this treatment approach. In addition, there is no lucid guideline on when and how implant to natural teeth connection should be achieved.[2,3]

The stability and retention of an implant-supported prosthesis have great improvements overconventional removable dentures. Using an implant as a way to decrease the vertical movement of prosthesis in the alveolar ridge was shown to be effective. Implant support of the definite prosthesis varies, depending on the position and number of implants; yet, all treatment options demonstrate highly increase of patients' functions.[4]

It was proved that oral rehabilitation by means of implant-supported mandibular overdentures is known to enhance the oral function, by measuring the electromyographic response of the jaw muscles and jaw movement during chewing.[5]

Titanium or cobalt-chromium is biocompatible metals which are the best metals for use in removable partial denture (RPD) frameworks. The benefits of metal-based frameworks over acrylic resin are that they are less bulky and used in thin sections, provide high strength and rigidity, conduct cold/hot for a more natural sensation, enable designs that decrease the covering of the gingival margins, allow for a stable denture base, undergo repassivation, and are resistant to corrosion.[6]

Thermoplastic acetal resins have superior flexibility and exert less force than the metals. The acetal resin clasps were up to 10 times as flexible as the metal one, and after being stretched they returned to their original dimensions. In addition, they apply more stresses on the abutment teeth that fall within the range that considered safe for use. This coupled with their good esthetics makes them suitable for use on periodontally affected teeth, those with anterior teeth and on anterior teeth.[7]

Photoelastic stress analysis is based on the property of some transparent materials to show colors fringes patterns when viewed with polarized light. With this method, internal mechanical pressure and stresses occurring inside of the complex structures are converted to visible light sketches. When photoelastic material is exposed to a load, passed through the Nicol prism, and observed by polarized light, colored structures directly comparable with stresses and strains can be observed. When a ray of polarized light passes through the loaded photoelastic model, it turns into vertical vibrations, which pass through the material in different velocities. This is called the photoelastic effect. This effect can be observed with a polarized filter or polariscope.[8]

Materials and Methods

A readymade lower dental stone cast with Class I Kennedy partial denture classification was used. The missing teeth were (5, 6, and 7) on both sides. Implant placement sites at the area of the 1st molar were prepared by consecutive drills (Dentis Co., Ltd., South Korea) of increasing diameter using the milling machine (Milling unit BF2, Bredent, Gmbh, Co., KG Weissenhorner Str., 2-89250 Senden, German). Transfer copings were attached to the implant analogs then the assembly was inserted inside the prepared implant sites.

Silicone closed tray implant transfer impression was used for making negative replica of the stone model. The transfer copings were unscrewed from the implant analog then attached to the dummy implant fixtures (Dentis Co., Ltd., South Korea) with diameter (3.8 × 10 mm).

Transfer copings and dummy implant assemblies were fixed to their place on the silicone impression then the silicone impression was poured by epoxy resin (Kemapoxy 150, chemicals for modern building international, Egypt) and left 24 h for complete setting. The transfer copings were unscrewed from the epoxy model. Steps were repeated 4 times to construct four epoxy models.

The four epoxy resin models were used to construct two different framework base materials and divided into two groups:

Group I: Acetal framework materials [Figure 1],

Group II: Conventional cobalt-chromium framework materials [Figure 2].

Epoxy teeth and model were prepared for Class I design (RPA) using dental surveyor. The cast preparation includes blocking of the undesirable undercuts, ledging of the RPA clasp, and RPA clasp design preparation.

After epoxy teeth and model preparation, duplication of the prepared cast was made by silicone impression material (Zetaplus, Zhermack, Italy). The silicone impression was poured 2 times, the 1st time was poured by hard dental stone for acetal frame work construction (Biocetal, Roko Dental System, Czestochowa, Poland) and the 2nd time was poured

Figure 1: Conventional cobalt-chromium framework materials

Figure 2: Acetal framework materials

by investment material for construction of cobalt-chromium frame work. Wax pattern framework for Kennedy Class I design was applied on the refractory and stone casts. RPA clasp on the first premolar abutment tooth on both sides, lingual bar major connector, and sufficient openings was made around implant abutment area.

Readymade wax rim blocks were adjusted for both cobalt-chromium and acetal frameworks, recesses were made inside the blocks to receive metal plates for vertical load application, then the wax blocks were converted to acrylic resin blocks.

For the two groups, locator attachments (Dentis. Kerator Overdenture Attachment System, Korea) were used to attach the denture base to the implants. A metal plate was adjusted on the occlusal surface of acrylic record blocks for stress application. Photoelastic models were photographed without any stress application to ensure that they were free from inherent stresses before force application. The epoxy models with the different frame work materials (acetal- metal) were seated at the fixed base of the photoelastic machine and successive vertical forces (20–40–60–80–100 Newton) were applied to the lower frameworks using a mechanical stress-strain system at the center of metal plate.

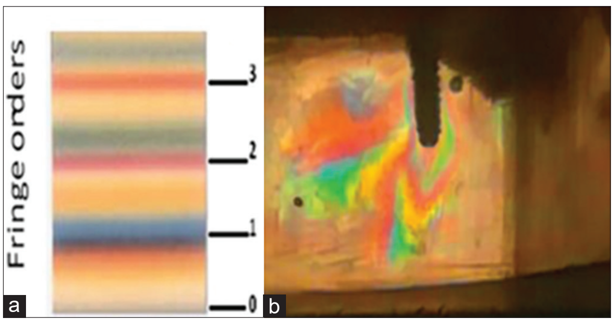

Figure 3: (a and b) Relation between stress level and fringe order used

All photographs were evaluated for stress effect fringes. The stress intensity and their locations were compared. In the evaluation of these stress data, the following terminology was adopted Figure 3 a and b: Low stress = 1 fringe or less, moderate stress – between 1 and 3 fringes, and high stress – more than 3 fringes.[9] Records to each group were calculated, tabulated, and statistically analyzed.

Results

Stresses around implant supporting Kennedy Class I RPD, acetal (Group I) and metal (Group II) frameworks were studied on the left and right side at different levels (coronal, middle, and apical areas) by the photoelastic analysis. Data were tabulated, coded then analyzed using the computer program Statistical Package for the Social Sciences version 23.0. In the statistical comparison between the two groups, the significance difference was tested using one of the following tests: Mann–Whitney test used to compare between two different groups of numerical (non-parametric) data and Friedman test was used to compare between more than two related groups of numerical (non-parametric) data followed by *post hoc* Tukey test.

Mean of difference of load stress around implants between two groups

From Figure 4 a and b and Table 1, at apical areas of the right and left side, there was a difference in significance between Groups I and II at all stresses 20, 40, 60, 80, and 100 N. At middle areas of the right and left side, there was a significant difference between Groups I and II at stress (60, 80, and 100 N) while no significant difference at stress (20 and 40 N). At coronal areas of the right and left side, there was a difference in significance between Groups I and II at stress 80 and 100 N while no significant difference at stress (20, 40, and 60 N).

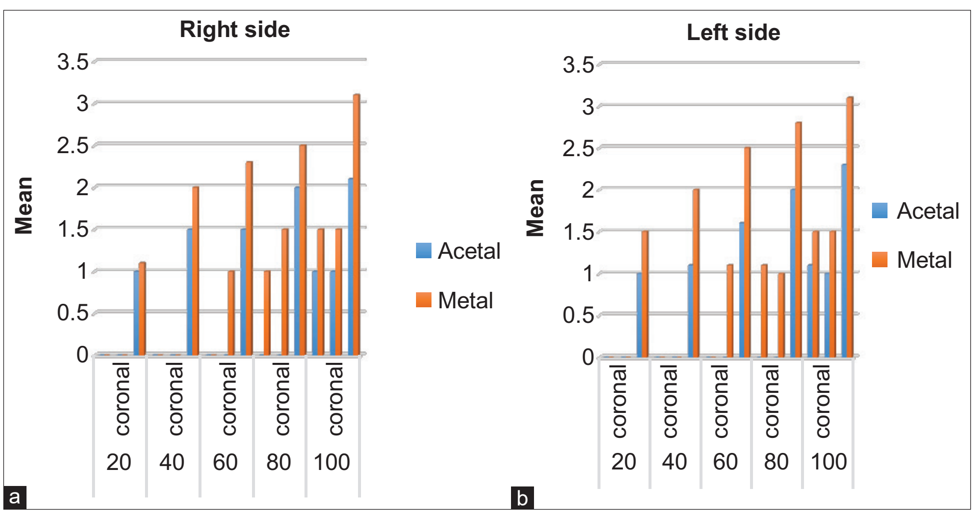

Figure 4: Mean of difference of load stress around implants between two groups

Table 1: Difference of load stress around implants between acetal and metal group

Side	Newton		Group				*P* value
			Acetal		Metal		
			Mean	±SD	Mean	±SD	
Right	20	Coronal	0.0	0.0	0.0	0.0	1.00
		Middle	0.0	0.0	0.0	0.0	1.00
		Apical	1.0	0.0	1.1	0.2	0.04
	40	Coronal	0.0	0.0	0.0	0.0	1.00
		Middle	0.0	0.0	0.0	0.0	1.00
		Apical	1.5	0.0	2.0	0.0	<0.001*
	60	Coronal	0.0	0.0	0.0	0.0	1.00
		Middle	0.0	0.0	1.0	0.0	<0.001*
		Apical	1.5	0.0	2.3	0.3	<0.001*
	80	Coronal	0.0	0.0	1.0	0.0	<0.001*
		Middle	0.0	0.0	1.5	0.0	<0.001*
		Apical	2.0	0.0	2.5	0.0	<0.001*
	100	Coronal	1.0	0.0	1.5	0.0	<0.001*
		Middle	1.0	0.0	1.5	0.0	<0.001*
		Apical	2.1	0.2	3.1	0.2	<0.001*
Left	20	Coronal	0.0	0.0	0.0	0.0	1.00
		Middle	0.0	0.0	0.0	0.0	1.00
		Apical	1.0	0.0	1.5	0.0	<0.001*
	40	Coronal	0.0	0.0	0.0	0.0	1.00
		Middle	0.0	0.0	0.0	0.0	1.00
		Apical	1.1	0.2	2.0	0.0	<0.001*
	60	Coronal	0.0	0.0	0.0	0.0	1.00
		Middle	0.0	0.0	1.1	0.2	<0.001*
		Apical	1.6	0.2	2.5	0.0	<0.001*
	80	Coronal	0.0	0.0	1.1	0.2	00.01*
		Middle	0.0	0.0	1.0	0.0	<0.001*
		Apical	2.0	0.0	2.8	0.3	<0.001*
	100	Coronal	1.1	0.2	1.5	0.0	0.01*
		Middle	1.0	0.0	1.5	0.0	<0.001*
		Apical	2.3	0.3	3.1	0.2	<0.001*

Discussion

Kennedy Class I partially edentulous model was selected in this study because this case represents the most frequently partially edentulous cases, also great amount of problems is present in such cases due to flexibility of the mucosa that provides different support to the denture and limited denture bearing area for the partial denture.[10]

Due to the wide variation of histological structure between cases, the use of *in vitro* studies is widely used than *in vivo* studies. It would not be possible to control variables such as bone density of the mandible, implant angulations, fitness of the suprastructures, and resilience of the soft tissue of the ridge.

The photoelastic model is a different homogeneous plastic material that simulates human bone constituted of cortical bone and cancellous bone. It shows that the magnitude of the stresses in real bone can be different from those in a model. However, the location and general standard of these stresses are similar. The technique used also facilitates a two-dimensional view of the stress concentration.[11]

Unlike other attachments, the locator attachment uses a straight abutment and relies on the male component, which lies within the removable prosthesis and includes a nylon liner, to resolve any problems related to angulation. Depending on the axial divergence between the implants, dual retention inserts (inner stud and external retention) can be used, or inserts with only external retention can be selected for extended use.[12]

In the current study, central load was applied over a steel plate positioned on the occlusion block between the right and left denture bases at the level of the occlusal plane in the region of the first molar according to the recommendation of other studies to provide even and flat surface to facilitate vertical load application.[13]

There was a statistically significant difference around implants between Group I (acetal denture base) and Group II (metallic denture base). Group II recorded a significant higher stress around implants than Group I. This result may be due to the resiliency of thermoplastic acetal assembly which led to reduction of stress applied on the abutments.[14]

A previous study in agree with our results stated that the stress distribution of the flexible partial dentures is accomplished by flexibility in the major connector behaving as a stress breaker. The tissue-supported saddles rested on the edentulous ridge independently, without make any stress or load on the abutment teeth.[15]

Conclusions

Within the limitations of this *in vitro* photoelastic analysis, the following was concluded: Acetal denture bases were preferred to use with implant-supported RPD when compared with metal denture bases. It is recommended that for preservation of bone around implant, acetal denture bases are the treatment of choice.

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