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PHOTOELASTIC STRESS ANALYSIS FOR COBALT CHROMIUM AND NYLON DENTURE BASE ON MANDIBULAR KENNEDY CLASS I IMPLANT SUPPORTED REMOVABLE PARTIAL OVERDENTURE

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ABSTRACT

Objective: The purpose of this study was to evaluate stresses induced on implant supported cobalt chromium and nylon overdenture bases in free end saddles cases using photoelastic stress analysis. **Materials and Methods:** Ready-made mandibular stone cast fabricated according to Kennedy Class I to replace 2nd premolar, 1st and 2nd molars. Implant analogue was inserted at site of first molar by using milling machine. Closed tray silicone impression was taken to the stone cast after transfer coping insertion. The transfer coping was inserted on its place in the impression. The implant was placed on its position in the impression. The impression was poured with epoxy resin material. Metallic and nylon denture bases were constructed with same design. Forces of 20, 40, 60, 80, 100 (Newton) were applied to detect photoelastic stresses. **Results:** With application of loads 80 and 100 N, the nylon framework recorded higher stress values than the vitalium framework at apical, middle and cervical area bilaterally. **Conclusion:** Cobalt chromium denture base showed better stress distribution compared to nylon denture base.

KEYWORDS: Cobalt chromium, stress distribution, nylon overdenture base, flexible denture, Photoelstic analysis.

INTRODUCTION

Loss of posterior abutments usually compromise the support of bilateral distal extension removable partial denture as consequence for the composite nature of the supporting structures. The placement of endosseous osseointegrated implants under a removable prosthesis was proved to provide bone preservation. Various denture base materials are used to improve function and esthetics. Different methods for evaluation of stress around dental implant include: finite element analysis, strain gauge analysis and photoelastic stress analysis.

Prosthetic management of partial edentulism especially free end saddles cases remain challenge due to the variability affecting both esthetic and functional results. Periodontal condition, caries susceptibility, the amount of alveolar ridge resorption, as well as other functional and psychosocial factors have to be considered in treatment planning of partially edentulous patients. Traditionally, the condition of the abutment teeth and the surrounding structures directed the treatment decision toward either fixed or removable restoration.

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To overcome this clinical challenge, single implants may be placed bilaterally at the distal extension of the denture base to minimize the potential for dislodgement of the denture. The chief goal of placing an implant under the posterior-most molar of the distal extension denture base is to stabilize the removable partial denture (RPD) in a vertical direction. Distal implants effectively convert a Kennedy Class I or II denture to a Kennedy Class III denture(1).

The placement of endosseous osseointegrated implants under a RPD was proved to provide bone preservation, prosthetic retention, stability, and a degree of occlusal support resulting in improved function, facial esthetics and comfort(2).

The problem with the connection of implant to natural teeth supported prosthesis arises from the fact that the tooth and the osseointegrated implants have dissimilar mobility patterns and this may subject the implant to excessive stresses. Numerous studies have reported pronounced marginal bone loss or failure of implant to osseointegrate especially those closest to implants. This led to the controversy of whether connecting implant to the natural teeth is a viable option. Various complications like, intrusion of the teeth, mechanical failure, caries and loss of occlusal contacts have been reported in the literature associated with this treatment approach. In addition, there is no clear guideline on when and how implant to natural teeth connection should be achieved(3, 4).

Today, more dentists are advising flexible RPD because they make better and stronger appliances that are comfortable and long lasting. The strong and flexible nature of the material is perfectly suited to the variety of natural conditions in the mouth, simplifying design and enabling the flexible nylon resin to act as a built-in stress-breaker in order to provide superior function and stress distribution in a RPD(5).

Photoelastic stress analysis is a full-field technique for measuring the magnitudes and directions of principal stresses. The technique has been used traditionally to study plane polymer models of structures by passing polarized light through transparent, loaded models and interpreting stress fields from the formation of interference fringes. The fringes appear because the chosen materials become optically anisotropic when loaded(6).

The dental literature had shown many studies that approach the distribution of forces in order to collect better background information for planning of overdentures. A photoelasticity method through images has been widely applied in dentistry and allows a direct observation of stress distribution on structures, based on the ability of certain transparent materials to display colour standards named isochromatic fringes when they are loaded and observed through a polarized light(7).

A photoelastic method allows a direct observation of stress distribution on structures, based on the ability of certain transparent materials to display color standards named isochromatic fringes when they are loaded and observed through a polarized ligh, that provide good qualitative information on the overall location and concentration of stresses but it has a limited quantitative information(7-9).

Others (8-11) reported that the metallic framework can distribute load on underneath structures better than flexible frameworks, while others mentioned that the metallic denture base recorded higher stress around implants than thermoplastic nylon denture. Also using nylon as removable partial overdenture base material in cases of free end saddles supported distally with implant is still questionable, so this study was aimed to evaluate stresses induced on implant supported cobalt chromium and nylon overdenture bases in free end saddles cases using photoelastic stress analysis.

MATERIAL AND METHODS

This in-vitro study was carried out on mandibular Kennedy class I epoxy resin model which was constructed by duplication of ready-made partially edentulous stone model. Two dummy implant were inserted at site of second molar, two ball and socket attachments were used and picked up on the fitting surface of metal and nylon denture base and auto-polymerizing soft liner material was used to simulate the oral mucosa covering the ridge.

Fabrication of epoxy models

Ready-made lower Class I Kennedy classification dental stone cast (replacing second premolar, first and second molars) was used. Acrylic artificial teeth were arranged at the edentulous area on the dental stone cast and duplication of the cast was made. Clear acetate surgical guide stent was fabricated (Cavex vacuformer sheets, Germany) on the dental stone cast using vacuum machine. The lower model was placed on a table of parallometer milling device (Milling unit BF2, Breden, Gmbh, co, KG Werssenhornerstr, 2-89250 Senden, Germany) and adjusted to be parallel to the floor using water weighting scale. Implant placement sites at the area of 2^{nd} molar were prepared by consecutive drills of increasing diameter using the milling machine. Transfer copings (JD EVOLUTION plus+, Italy) were attached to the implant analogues then the assembly was inserted inside the prepared implant sites. Closed tray silicone impression technique was used (Zetaplus, Zhermack, Italy) for fabrication of negative replica for stone model. The transfer copings were unscrewed from the implant analogues then attached to the dummy implant fixtures (JD EVOLUTION plus+, Italy) with diameter (3.7x11.5mm). Transfer copings attached to dummy implants assemblies were fixed to their place on the silicone impression. The silicone impression was poured by epoxy resin (Chemicals for modern building international, Alharm, Giza, Egypt) then left 24 hour for complete setting. Removal of the epoxy resin cast from the impression. The transfer copings were unscrewed from the epoxy model, then epoxy model was finished and polished.

Groups: The epoxy resin model was used to fabricate two framework base materials and divided into two groups:-

Group I: Nylon framework materials.

Group II: Conventional cobalt-chromium framework materials.

Simulation of the covering mucosa of the edentulous ridge

For epoxy resin model auto polymerizing silicone soft liner material was used to simulate the oral mucosa covering the ridge through the following steps:

Wax spacer of 2mm thickness (Cavex modelling waxes, Cavex, Holland BV) was covered the residual ridge and a hole was made on the wax above the implant sites. A plaster index (Sinai star, Sinai, Egypt) was constructed and extended on the model buccally and lingually to act as stopper for accurate repositioning. After hardening the plaster index, the wax was removed from the ridge. Soft liner material (Promedica, GmbH, Neuwünster, Germany) was packed inside the plaster index and placed over the epoxy model until complete soft liner setting and adherence to the model.

Fabrication of the investment and stone models

Epoxy model was prepared for class I design (RPA) using dental surveyor. The cast preparation included: blocking of the undesirable undercuts, ledging of the RPA clasp, and RPA clasp design preparation. After epoxy model preparation, duplication of the prepared cast was made by silicone impression material (Zetaplus, Zhermack, Italy). The silicone impression was poured two times, the first time was poured by hard dental stone (Bayer dental, Leverkusen Germany) for nylon denture base construction and the second time was poured by investment material (COBAVEST Yeti Dental, Engen, Germany) for construction of cobalt-chromium denture base.

Construction of Cobalt-Chromium and nylon denture bases:

Wax pattern framework for Kennedy class I design were constructed on the refractory and stone casts as following:

RPA clasps on the first premolars abutment tooth on both sides, auxiliary extension cingulum rests, and rest lingual bar major connector, sufficient openings were made around implant abutment area. Metal and nylon frameworks were made according to the manufacturers. Sufficient openings in the meshworks were made corresponding to the implant to accommodate the ball and socket attachment. After that the frameworks were constructed and tried on the epoxy model. Then readymade wax rim blocks were adjusted for both cobalt-chromium and nylon frameworks, then the wax blocks were converted to acrylic resin blocks.

Attachment loading

For the two models ball and socket attachments (H 1.5 (JD EVOLUTION plus+, Italy) were used to attach the denture base to the implants.

The ball and socket attachment consist of:

Ball abutment: - the female component, gingival height 1.5mm, screwed to the implants by ball insertion key. Socket attachment: consist of metal cap with inner retention elastic cap, attachment to the fitting surface of the overdenture. Retention elastic cap: - fitted to the inner surface of metal cap.

Picking up of the ball and socket attachments

The ball abutments were screwed to the internal hex of the dummy implants using ball insertion key. Clearing of sufficient amount of acrylic resin from the fitting surface for both nylon and cobalt-chromium denture bases for socket attachment picking up. Vents holes were made in the lingual surfaces of the denture bases to allow verification of cap housing and escapement of excess material of self-cure acrylic resin (Acrostone, Acrostone Dental Manufacture, Egypt), cap housing were picked up to the frameworks using self-cure acrylic resin. A metal plates were adjusted on the occlusal surface of acrylic record blocks for stress application.

Application of forces: Photoelastic models were photographed without any stress application to ensure it's free from inherent stresses before force application. The epoxy models with the different denture bases (nylon- metal) were seated at the fixed base of the photoelastic machine and vertical forces 20, 40, 60, 80, and 100(newton) were applied to the lower frameworks using a mechanical stress-strain system at the centre of metal plate. By the photoelastic analysis the results of the stresses were photographed on the different values of forces. All photographs were evaluated visually for stress induced fringes. The stress intensity and their locations were subjectively compared. In the evaluation of these results, the following categories were adopted: 1 fringe or less denoted low stress; between 1 and 3 fringes denoted moderate stress, and more than 3 fringes denoted high stress[12].

RESULT

Stresses around implant supported removable partial overdenture metal and nylon frameworks were studied at different levels (apical, middle and cervical areas) for left and right sides using the photoelastic analysis with different load applications (20, 40, 60, 80, and 100 newton), (Table 1 and Figs. 1& 2).

At stresses of 20N and 40N the nylon framework recorded higher stress value at apical area than that of vitalium framework, but they were identical (zero stress) at middle and cervical area for left and right sides.

While at stress of 60N the nylon framework recorded higher stress values than that of vitalium framework at apical and middle area in left and right sides, however they were identical (zero stress) at cervical area for both left and right sides.

TABLE (1): Stresses around implant supported removable partial overdenture metal and nylon frameworks at different levels (apical, middle and cervical areas) for left and right sides with different load applications (20, 40, 60, 80, and 100 Newton).

Stress	Material	Apical	Middle	Cervical
20N	Nylon L	1.25	0	0
	Metal L	1	0	0
	Nylon R	1	0	0
	Metal R	1	0	0
40N	Nylon L	1.75	0	0
	Metal L	1.25	0	0
	Nylon R	1.5	0	0
	Metal R	1.25	0	0
60N	Nylon L	2.25	1	0
	Metal L	2	0.5	0
	Nylon R	2	0.75	0
	Metal R	1.75	0.25	0
80N	Nylon L	2.5	1.25	1
	Metal L	2	0.75	0.5
	Nylon R	2.375	1.25	1
	Metal R	2	0.5	0.5
100N	Nylon L	3.5	1.5	1.25
	Metal L	3	1.35	1
	Nylon R	3.375	1.5	1.25
	Metal R	3	1.25	1

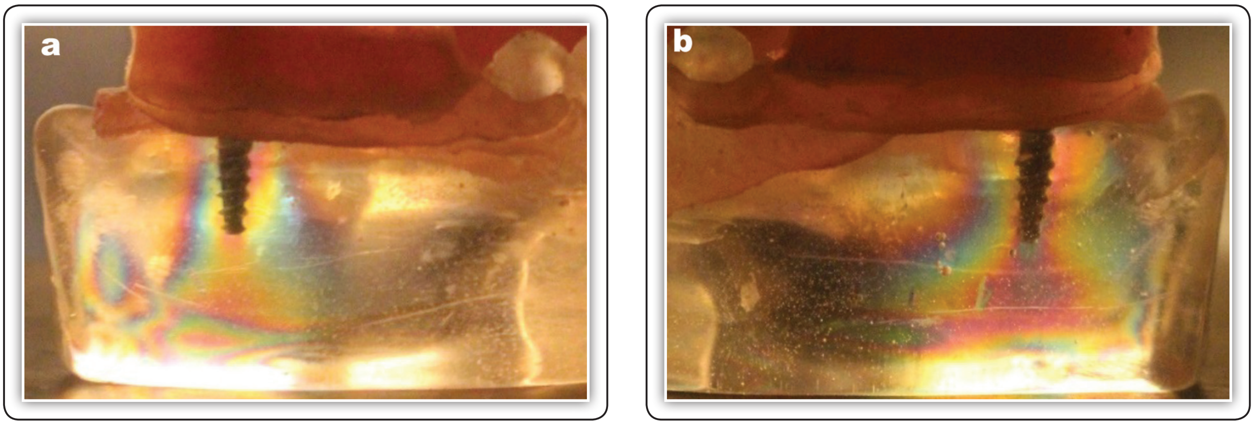

FIG (1) (a&b): Fringes order around dental implant with nylon framework under stress

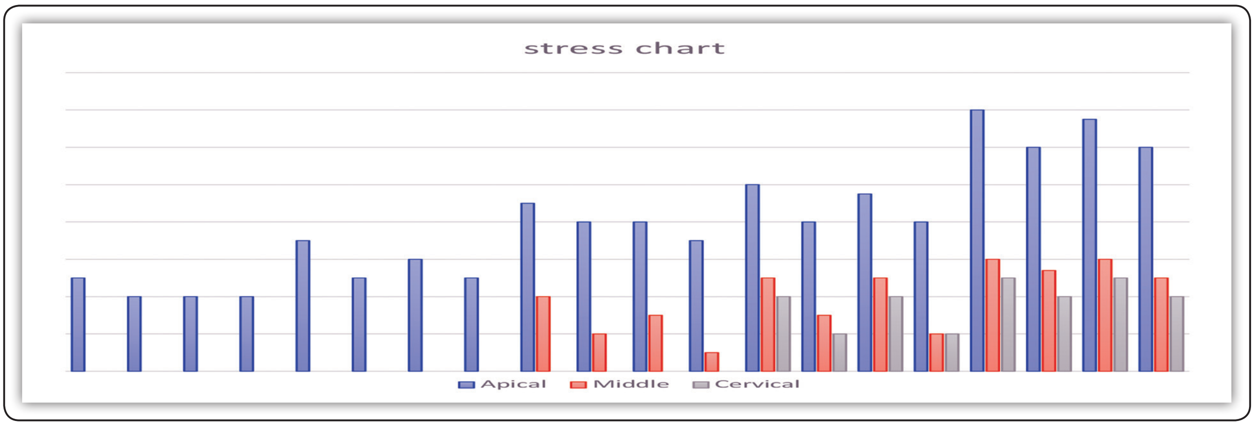

FIG (2): The stresses (20, 40, 60, 80, and 100 N) at apical, middle and cervical areas of left and right sides for two types of removable overdenture framework materials (nylon/metal).

At stresses of 80N and 100N the nylon framework recorded higher stress values than that of vitalium framework at apical, middle and cervical area for left and right sides.

DISCUSSION

An attempt to understand the stress distribution behavior around implant supported metallic and nylon removable partial overdentures was carried out on photoelastic model using photoelastic analysis.

All results showed that nylon framework recorded higher stress value than vitalium framework at apical, middle and cervical area of left and right sides. This was in agreement with others[13] who reported that the metallic framework can distribute load on underneath structures better than flexible frameworks. This result could be due to the polymeric material seems to be crashed early and submitted the load to the fixture and subsequently to the bone.

The result of our study differ with the hypothesis that a nylon framework can distribute stress as same as the Co-Cr framework, this was in accord with others [8-11].

On the other hand, the result of the current was in disagreements with Thakral[5] who stated that The strong, flexible nature of flexible denture material is perfectly suited to the variety of natural conditions in the mouth, flexible nylon resin to act as a built-in stress-breaker that provides superior function and stress distribution. The metallic denture base recorded higher stress around implants than thermoplastic nylon denture. This result may be due to the resiliency of thermoplastic Nylon denture assembly which led to reduction of load exerted on the abutments other studies were disagreed with our results due to different designs used. A previous in-vivo study was agree with our results stated that the metallic RPD appear to make less adverse effect on the residual ridge in Kennedy Class I partially edentulous patients[14].

This report recommended to use the metallic partial overdenture in case of distally placed implant at free end saddle cases.

CONCLUSIONS

Within the limitations of this study, the following conclusion can be drawn:

Cobalt chromium denture base showed better stresses distribution in comparison to nylon denture base.

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