PHOTOELASTIC STRESS ANALYSIS OF DISTAL EXTENSION REMOVABLE PARTIAL TELESCOPIC DENTURES WITH DIFFERENT CONICAL CROWNS

Konusları Farklı Sonlu Hareketli Bölümlü Protezlerde Fotoelastik Stres Analizi

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Summary: *Distal extension removable partial denture (RPD) can cause stress on supporting hard tissues, which may lead to harmful effects. The purpose of this study is to investigate the pattern of these stresses over the residual alveolar ridge and alveolar bone around the abutment teeth by distal extension conical crown retained telescopic dentures (CCRTDs) with different taper angles using three dimensional photoelectric stress analysis.*

Thirty distal extension photoelastic mandible models with simulated periodontal ligaments and mucosa were divided into five groups. Vertical and oblique 50 N loading forces were applied over the dentures. These dentures involved one claps denture and four CCRTDs that conical crowns were planned mesial (M) and distal (D) 2°, M and D 4°, M 4° D 2° and M 2° D 4°. Fringes order values (N) of identified measurement points (A, B,C,..G) were measured and the data were evaluated by use Kruskal-Wallis and Mann-Whitney test. While the stress on the RPD with claps was concentrated on the point C where the distal abutment teeth and residual ridge meet, it was concentrated on the apex of abutment teeth in the CCRTDs.

The stress under oblique loading increased significantly at point B, and under vertical loading at points A and C.

Significant changes were observed between the points A, C, D and F in the second denture, points C and G in the 3rd, and B; in the 5th, unlike the points in the 1st and 4th dentures

Key words*: Telescopic denture, photoelastic stress, distal extension, conical crown, oblique load*

Özet: *Sonu serbest biten hareketli bölümlü protezler [HBP] sert ve yumuşak destek doku üzerinde strese sebep olabilir ve bu stres zararlı etkilere yol açabilir. Bu çalışmanın amacı 3 boyutlu fotoelastik stres analiz yöntemiyle farklı taper açılı konik tutuculu teleskopik sonu serbest biten HBP lerin ve kroşe tutuculu HBP'nin dişsiz alanlarında ve destek diş etrafındaki alveol kretinde oluşturduğu streslerin karşılaştırılmasıdır.*

Otuz adet periodontal mebranı ve mukozası olan sonu dişsiz sonlanan fotoelastik mandibular model 5 gruba ayrıldı. Beş farklı HBP; kroşe tutuculu, Mezial [M] ve distal [D] 2°, M ve D 4°, M 4° D 2° ve M 2° D 4° olacak şekilde dört adet farklı konik açılı teleskopik HBP olarak hazırlandı. Bu protezler üzerine dikey ve eğik 50 Newtonluk kuvvetler tek taraflı olarak uygulandı. Belirlenen ölçüm noktalarının (A. B, C,…G) frinç değerleri (N) olarak ölçüldü, Elde edilen değerler Kruskal Wallis ve Mann - Whitney testleriyle istatistiksel olarak değerlendirildi. Kroşe tutuculu HBP de stres yoğunluğu distaldeki destek diş ile dişsiz alveol kretinin birleşme yerinde (C noktasında) görülürken konik tutuculu teleskopik HBP lerde destek dişlerin kök uçlarında yoğunlaştı. Eğimli kuvvet B noktasında, dik kuvvet ise A ve C noktasında istatistiksel olarak anlamlı bir artış göstermiştir.

2. protezde A,C,D ve F, 3. protezde C ve G, 5. protezde B ölçüm noktaları arasında istatistiksel olarak anlamlı fark görülürken 1. ve 4. protezlerde ölçüm noktaları arasında anlamlı fark görülmedi.

Anahtar kelimeler*: Teleskopik protez, fotoelastic stres, distal uzantılı, konus kuron, eğik kuvvet*

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A common clinical problem confronting prosthodontists is the design and maintenance of bilateral distal extension removable partial denture [RPD], as support is required from the teeth, the mucosa and underlying residual alveolar ridges. There has been concern over the control of destructive force (1). The direction of the force on an abutment should be through its long axis of the teeth, the potential for tilting and torque the abutment teeth should be minimized (2,3).

In the bilateral distal extension RPD, the functional force applied to the denture base creates an axis of rotation around the most distal abutment teeth (4). This problem occurs mainly in the mandible since it has less supporting tissue (5). Three types of stresses are induced on the abutment teeth by a bilateral distal extension RPD as vertical, horizontal and oblique stress. In all types of stress abutment becomes a fulcrum (4). Therefore, mechanical and biomechanical aspects are generally agreed to be significant, particularly during the planning of restorative treatments and design of prosthetic application (6).

Telescopic crown systems were initially introduced as retainers for RPD (7). The system is currently used as the conus crown. The conus crowns have a double crown system which consists of exactly fitting conical inner (primary) that provides retentive force by the angle of inner crown and outer (secondary) crowns(8,9). Conical crown retained telescopic denture [CCRTD] have been documented to retain dentures more effectively than the conventional claps system because of their ability to transmit occlusal loading to the long axis of the abutment tooth and to provide guidance, support and protection from movement (7,8,10).

Because the intra oral environment is a complex bio -mechanical system, many studies of stress and strain are to be performed in vitro(6,7,11,12). The photoelastic technique is used to visualize the whole filed distributions stress(13). To determine this stress distribution accurately, compensation technique can be selected. Point per point compensation techniques are employed to establish the fringe order (*N*) (14).

The purpose of this in vitro study is provide information about the stress distribution to the residual ridge and alveolar bone around the abutments' root by using 3 dimensional photoelastic analyses by various conus crowns having different tapers and compare with clasp removable partial denture.

MATERIAL AND METHODS

A simulated model of mandible with bilateral posterior edentulous arch and teeth that were right mandible second premolar to left mandible second premolar (Kennedy Class I) was fabricated using commercial available model (Frasaco, Germany). Bilateral mandible premolar teeth were prepared with standard metal-plastic shoulder bevel tooth without sharp line angles. The life size roots of abutment teeth were prepared by adding autopolimerized acrylic resin that were coated with 0,2 mm silicon material (Alphasil, Omicron, Germany) to simulated the periodontal membrane. The edentulous residual ridge under the denture base were replaced with 2 mm silicon material (Alphasil, Omicron,Germany) to simulated the mucosa (15).

Thirty photoelastic mandible models in PL -2 and PLH-2 (Photoelastik Division Measurments Group Inc USA) and 120 Photoelastic mandible premolar teeth models as abutment teeth, in PL-1 and PLH-1(Photoelastik Division Meas urments Group Inc USA) were duplicated according to the manufacturer's instructions.

In the above mentioned mandible model, 5 different Kennedy Class I mandible RPDs were fabricated. These RPDs had two different direct retainer that were a RPA claps (R: rest, P: proximal plate, A: akers) denture and four CCRTDs with different tapered angle. The distal extension RPDs designs included in this investigation were as follows; First denture with a RPA claps, second denture with conical crowns of mesial and distal 2^o, third denture with conical crowns of mesial and distal 4^o, forth denture with conical crowns of mesial 4^o, distal 2^o , fifth denture with conical crowns of 2^o

mesial, 4^o distal . All conical crowns had vestibule 2 ^{o}, lingual 0^o. Five distal extension RPD frameworks with lingual bar were made of chrome-cobalt alloy (Magnum H50 MESA Italy). Five loading pyramids were soldered in the region of mandible right first molar for each of the five frameworks.

Metal to plastic veneer crowns soldered together were made for the abutment teeth of the design first denture.

All of the inner and outer crowns were made of gold alloy (Solar 3, Metalor, Switzerland). All the frameworks and crowns were produced by one laboratory.

All of the veneer crowns and four conical crowns of telescopic retainer were cemented using zinc-phosphate cement (Spofa Dental, Kerr Company, Czech Republic) according to the manufacturer's instructions.

Three dimensional photoelastic stress analysis was used to evaluate the stress distributions.

Before loading procedure, it has to be ensured that there is no residual stress in photoelastic model, a casting and polymerization of the models and\or fitting of denture. To discharge residual stress all of the models were heated and cooled according to the manufacturer's instructions. Next, the models were checked under transmission polariscope (14).

Each of the photoelastic models with the dentures were placed into the loading apparatus. A 50-Newton static load was applied on mandible right first molar region by means of a load pyramid. Fifteen photoelastic models were vertically loaded and the other 15 models were 33^o obliquely loaded. The oblique load was applied by changing the slope of the plate (Fig. 1). Each of the models was heated from 24 ^{o}C to 120 ^{o}C by increasing 10 ^{o}C per hour, then cooled at the rate of 10 ^{o}C per hour (from 120 ^{o}C to 24 ^{o}C) to freeze stresses in to models. The term 'frozen' derives from the analogy of a loaded spring in a beaker of water, if the water is frozen and the load is removed, the spring will be held in its state by the ice which surrounds it. If it were possible to cut the solid mass without generating sufficient heat to melt the ice, the spring and ice could then be sliced into strip for examination (16).

Models were cut with water Jet (WaterJet, SRL, Italy) without causing extra stress. Within each section, strategic measurement points were identified as A, B…G (Fig. 2).

The fringe orders (*N*) on identified points were measured with the transmission polariscope using the compensator apparatus (Photoelastic, Inc., Malvern, Pa)(14). The samples were photographed (Canon G2 Power shot, USA) by using the transmission polariscope.

The numerical data of fringe (*N*), by using the compensator technique, of the 210 point were subject to statistical analyses using a Kruskal-Wallis test and Mann-Whitney U test ($P< 0.05$).

RESULTS

When each denture was compared for each measurement points under oblique and vertical loading, under oblique loading significant differences were noted between the 1st and 5th denture on the points of B and D, between the 2nd and 4th denture on the point of A, between the 2nd and 5th denture on the points of B and C. However, under oblique loading differences was not noted between the 4th denture and the other (Table I, Fig 3).

Under vertical loading, significant differences were noted between 1st and 4th denture on the points of A, between 1st and 3th denture on the points of C, the1st and the both the 2nd and 4th on the point of D and finally, between 1st and 2nd on the point E. Significant differences were found between the2nd and the both the 3th and 4th on the point of A, between the2nd and the both the 1st and 4th on the point of D, between the2nd and the 1st on the point of E, between the2nd and the 3th on the points of F and G (Table II).

DISCUSSION

Although this is an in vitro study, which may or

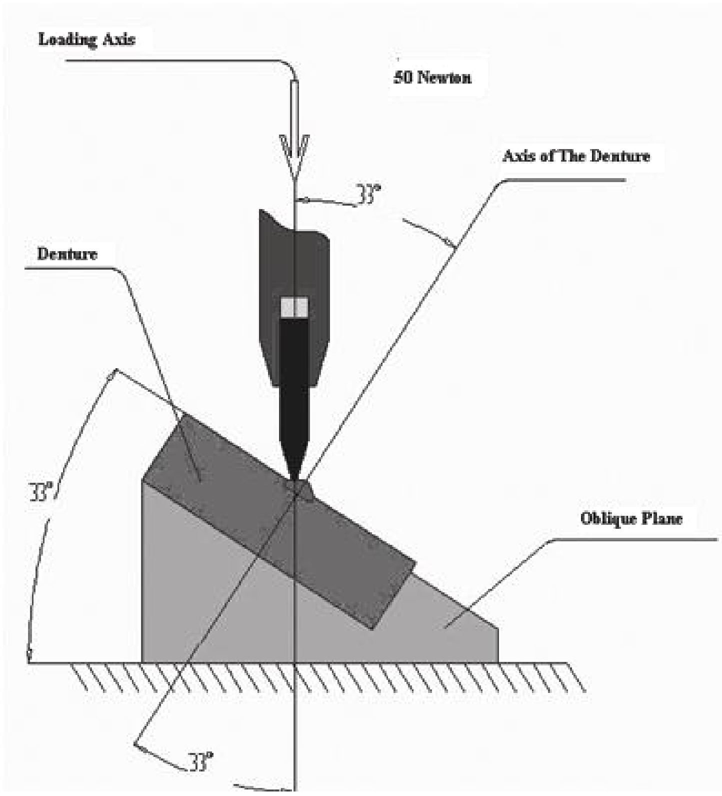

Fig 1. Schema of oblique loading

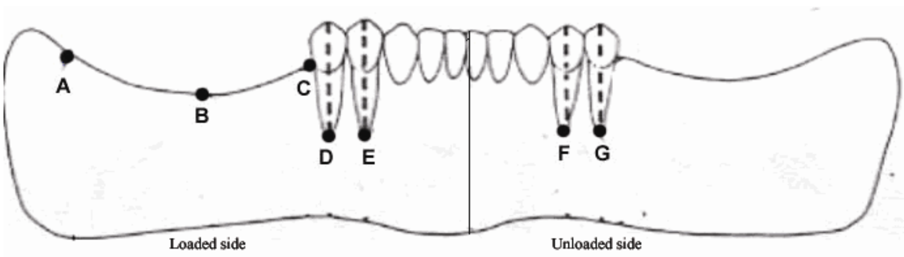

Fig 2. The examination points of the model

Table I. Statistical comparison of fringe value (N) in the each measurement point (A, B, C,..G) by each denture under oblique force (p<0.05)(n=3).

Gruops	Fringe value (N) of the measurement points (A,B;C,..G)						
	A	B	C	D	E	F	G
	Median (Min Max)	Median (Min-Max)	Median (Min Max)	Median (Min-Max)	Median (Min Max)	Median (Min-Max)	Median (Min-max)
I	2.33 (1.35-2.55) ab	2.91 (2.45-2.91)a	3.76 (3.14-4.27)	3,43 (3.02-3.90)a	2,98 (2.87-3.43)	0.60 (0.13-0.60)	0.37 (0.24-0.50)
II	1.25 (1.19-1.65) a	2.63 (2.58-2.90)a	3.83 (3.24-3.90)	3.67 (3.28-3.85)a	3.52 (3.48-3.81)	0.28 (0.23-0.32)	0.03 (0.03-0.32)
III	1.97 (1.58-2.69)ab	3.23 (3.06-3.46)ab	4.32 (4.19-4.52)	4.13 (3.52-4.73)a	3.58 (2.69-4.35)	0.23 (0.19-0.52)	0.19 (0.12-0.29)
IV	2.98 (1.89-3.32)b	3.75 (2.90-4.29)ab	3.97 (2.77-4.25)	4.02 (3.81-4.18)a	3.49 (3.10-3.64)	0.52 (0.20-0.56)	0.20 (0.03-0.29)
V	2.75 (2.19-2.89)b	3.96 (3.92-4.10)b	4.56 (3.71-4.69)	4.23 (4.04-4.56)b	3.65 (3.39-3.77)	0.31 (0.23-0.36)	0.32 (0.15-0.43)
P*	<0.05	<0.05	>0.05	<0.05	<0.05	0.05	0.05

P^* (<0.05) the result of Kruskal Wallis multiple comparison Min; minimum, Max; maximum.

^{a,b}: values with different superscripts' within the same colon differ significantly. *N* ; Fringe value

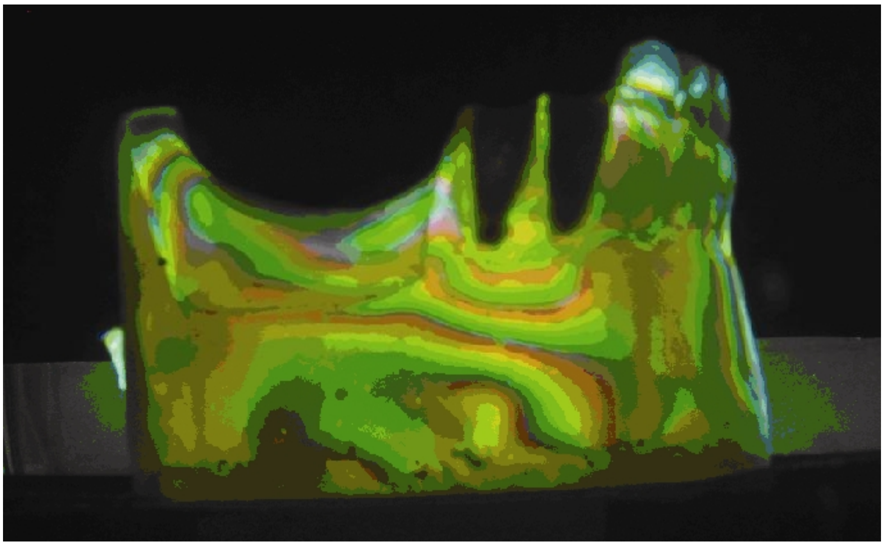

Fig 3. Fringe orders in the *fourth group in the loaded* side under oblique load (**Sample)**

Tablo II. Statistical comparison of stress produced in the each measurement point (A, B, C,..G) by each denture under vertical force (p<0.05)(n=3)

Gruops	Fringe value (N) of the measurement points (A,B;C,..G)						
	A	B	C	D	E	F	G
	Median (Min Max)	Median (Min-Max)	Median (Min-Max)	Median (Min-Max)	Median (Min-Max)	Median (Min-max)	Median (Min-max)
I	2.33 (2.30-2.40)ad	3.00 (2.63-3.56)	3.32 (2.48-4.17)a	3.13 (2.98-3.21)ac	2.98 (1.83-3.10)a	0.10 (0.10-0.58)ac	0.10 (0.10-0.33)ac
II	2.23 (2.17-2.25)a	3.96 (2.58-4.46)	4.53 (4.00-4.73)ac	4.73 (4.65-4.73)b	4.11 (3.94-4.42)bc	0.21 (0.03-0.21)a	0.06 (0.02-0.25)a
III	2.87 (2.61-2.92)cd	3.50 (3.29-3.52)	4.67 (4.54-4.73)bc	4.10 (4.03-4.21)bd	3.74 (3.63-3.86)ac	0.53 (0.23-0.56)bc	0.42 (0.33-0.65)bc
IV	3.04 (2.92-3.12)bc	2.95 (2.81-3.33)	3.81 (3.12-4.42)a	3.98 (3.60-4.08)cd	3.59 (3.04-4.19)ac	0.11 (0.10-0.23)ac	0.17 (0.10-0.19)a
V	2.74 (2.67-2.86)abc	3.60 (3.54-3.87)	4.12 (3.98-4.43)ac	4.04 (3.98-4.45)bc	3.88 (3.32-3.95)ac	0.32 (0.25-0.32)ac	0.23 (0.20-0.29)ac
P	<0.05	>0.05	<0.05	<0.05	<0.05	<0.05	<0.05

P^* (<0.05) the result of Kruskal Wallis multiple comparison Min; minimum, Max; maximum.
^{a,b}: values with different superscripts' within the same colon differ significantly. *N ;*Fringe value

may not reproduce the conditions in vivo, it is possible to make certain observations about the findings(11). The influence of the CCRTD design on the mechanical behavior of the prostheses was clearly shown by the photoelastic method(6). From among the existing techniques used for analysis of stress and strain, the 3-dimensional photoelastic analysis was selected for two reasons; firstly, teeth and alveolar bone are a 3 dimensional structure, and secondly, the occlusal forces are complex loading condition especially when bilateral distal extension RPD are used (11,12).

In this study was used of two photoelastic materials that have different elastic modules (PL -1 and PL-2) because teeth and alveolar bone are different in physical structures (17-23).

It has been reported that at least two abutment teeth should be splinted when attachment prostheses are used in order to make the pattern more favorable (24). Fifty Newton load was selected because it is realistic functional load level and also provides a satisfactory optical response within the model (17,24,25).

The occlusal forces created during function are conducted to the abutments increasingly because of the leverage as the number of the retainer decreases and the distal extension expand. The type of telescopic dentures and their retention mechanism determine the long term retention of RPD (7).

CCRTDs used in this study are rigid-precision attachments, and researchers showed that telescopic denture distributed more occlusal force to abutment teeth than other precision attachment system (11). CCRTD transmitted more occlusal force to abutment teeth than did clasp denture and insertion of a CCRTD was better for the maintenance of the residual ridge (8, 24). In the present study, the stress was concentrated around the point C, D and E. Stress distributions at CCRTDs were observed to apical areas of abutment teeth (point D and E), contrary to the case in the clasp denture.

Chou et al. (5) reported that a rigid precision attachment produced greater stress and caused more movement of abutment teeth than did clasp, and they pointed out the risk of rigid design denture. Our results were consistent with the finding from Chou et all's (5) result. On the other hand since a tooth can withstand greater force along the long axis than a long horizontal force, high stress especially in apical areas, does not always cause damage to the tooth (3,10, 11).

In comparison with the CCRTDs, the RPD with clasps tend to concentrate the stress at point C that was adjacent to disto cervical of mandible right secondary premolar, whereas CCRTD distributed the stress to C, D and E.

Our results were consistent with the findings from other investigation (26-28) when compared with the 4 conical crown retained telescopic denture with different taper angles. Comparison of the second and third dentures, the concentration of fringe value was obtained at the adjacent alveolar bone of right distal abutment tooth and the apical areas of two abutment teeth. In this situation, the stress reduces at the edentulous alveolar bone.

1. The density of fringe orders in all the dentures occurred between on the point C that is adjacent to disto cervical mandible right secondary premolar and \or apical areas (point D and E) of two abutment teeth.
2. At the bilateral distal extension RPD with clasp (1st denture), the rotation axis is adjacent to the alveolar bone of the right distal abutment (C point) when vertical and oblique load is applied.
3. When the 2th denture was compared to 1 st denture, the stress shifted from the C point to D.
4. Rotation axis of the CCRTD with 2° distal and mesial 2° shifts from point C to D and \or E. The rotation axis of the CCRTD converts into a sustentation plane.
5. As the stress on the apex of abutment roots

rose as the angles of conical crown decreased.

6. The RPD with claps produced les around the abutment teeth than did the CCRTs

More sophisticated methods are needed to solve the problem in vitro and in vivo.

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