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EVALUATING THE STRESSES INDUCED BY PEKKTON® AND ZIRCONIA PRIMARY COPING ON THE SUPPORTING STRUCTURES OF MANDIBULAR TELESCOPIC PARTIAL DENTURE (AN IN VITRO STUDY)

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ABSTRACT

Purpose: This in vitro study was conducted to evaluate the effect of Pekkton and zirconia primary crowns on the stresses induced on the supporting structures of Pekkton telescopic retained mandibular partial denture using strain gauge stress analysis method

Material and methods: This study was applied on a mandibular Kennedy class I scanned educational model. The second premolars bilaterally were the last abutments. In Excad software, designing and preparing the four abutments (the first and second premolars bilaterally) was done to receive primary coping of telescopic partial denture. The modified virtual model was 3D printed using model resin to obtain two identical 3 D casts Thus, two groups were defined according to the material of primary coping: Group (1): (PEKK) - Pekkton® RPD frameworks were constructed on (PEKK) - Pekkton® primary crowns. Group (2): (PEKK) - Pekkton® RPD frameworks were constructed on Zirconia primary crowns. The STL file was imported into the 3D system. The STL file was sent to the milling machine. Eight primary crowns from Pekkton and zirconia were fabricated (Four for each group). Designing and milling of The telescopic Pekkton partial denture framework including secondary coping were done .For each cast, four strain gauge sensors were placed and a universal testing machine LD Series were used to apply a static load of 100N bilaterally at the second molar and distal the last abutment then unilaterally on the right side. The arithmetic mean and the standard deviation of the recorded readings (micro strain) of each loading point were calculated tabulated and statistically analyzed.

Result: The result of this in-vitro study revealed that under bilateral loading, the mean values of the stresses found distally to the last abutment and in second molar area for group 1(Pekkton primary crown) were (124.70), (49.00) respectively while in group 2 (zirconia primary crown) the mean values were (347.10), (79.30) and the results showed statistically significance difference. During unilateral loading, the results showed higher strain values on the predetermined site in group 2 than group 1, and the calculated values were statistically significance.

Conclusion: In telescopic RPDs, Zirconia induces higher strain values at the abutments and the distal aspect of the ridge than Pekkton during bilateral and unilateral loading.

Key words: Telescopic. Partial denture, Zirconia, Pekkton, CAD/CAM

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INTRODUCTION

Rehabilitation of mandibular bilateral distal extension cases has been always a challenging situation. Thus, the provision of a stable, retentive, and biomechanically acceptable removable partial denture (RPD) is mandatory to preserve the remaining abutments and residual supporting structures. [1]

Telescopic PRD can be considered an attractive treatment option due to the splinting action of abutment teeth in addition to combining positive stabilizing and retentive properties. Using double crowns as retentive elements allows better esthetics than clasps. Good esthetics can be provided by using ceramic faces and a suitable color selection. They also can be easily repaired and adjusted even when an abutment is lost. Thus good patient satisfaction rates with telescopic dentures were achieved. [2-4]

The major disadvantages are the high demand on precision and special skills required from both the dental technician and the clinician in the fabrication of double crowns, consequently increasing the total cost and treatment period.[2]

With the emergence of CAD/CAM technology, telescopic crown retainer can be virtually designed and milled precisely to ensure a passive fit of the retainer parts and maximal function of the RDP. It is also decreases the number of visits, as well as produces accurate prosthesis. [6]

The high performance thermoplastic polyetherketoneketone (PEKK) **-** Pekkton® ivory originates from the polyaryletherketone (PAEK) polymer family recently introduced as a dental material.[7]Furthermore, it displays a combination of crystalline as well as amorphous material properties, which leads to a wider range of possible products.[8]

Pekkton® can replace metal and glass ceramics due to their acceptable fracture resistance, excellent stress distributions, and shock absorbing abilities.it can be used for RPD framework to the replace the metal alloy as it is lighter in weight and compatibility [9,10] with different veneering materials. Also, it is gaining popularity because of its manufacturing versatility (it can be milled or heat-pressed).[11,12]

Zirconia is a ceramic material has many merits used as it provides good esthetic appearance, high mechanical strength, and high biocompatibility. It is used in fabrication of frameworks, implants, and abutments. [13] Recently it can be used for fabrication of primary crowns in the telescopic retainer and has featured itself as an alternative to gold alloys. The low surface roughness and low surface energy characteristic of zirconia result in low biofilm accumulation. [14.15]

So, this study was conducted to evaluate the effect of pekkton and zirconia primary crowns on the stresses induced on the supporting structures of pekkton telescopic retained mandibular partial denture.

MATERIAL AND METHODS

An in-vitro study was applied on a mandibular educational model with bilateral free end saddles (Kennedy class I). The first and the second premolars bilaterally were the last abutments, and they were prepared to receive primary crowns of telescopic partial denture frameworks. Thus, two groups were defined according to the material of primary coping: Group (1): (PEKK) - Pekkton® RPD frameworks were constructed on (PEKK) - Pekkton® primary crowns. Group (2): (PEKK) - Pekkton® RPD frameworks were constructed on Zirconia primary crowns.

The cast was scanned with desktop scanner **(Medit Identica hybrid 3D dental Scanner, Auckland.)** after coated with scanable spray **(SHERAscan spray, SHERA Werkstoff-Technologie GmbH & Co. KG, Germany)**. Standard Tessellation Language (STL) file was generated. The STL file was imported into the 3D system Exocad software to be modified. The modification of the virtual cast to create four abutments in the place of the first and second premolars bilaterally was done**. (Fig1a)**

The design and the preparation of the abutments were selected from the Exocad software library to be perpendicularly aligned to the ultimate occlusal plane. the prepared abutments were 6 mm height, 5 mm width with 1.5 millimeters (mm) chamfer finish line and 2^{0} taper occlusally. They were aligned with a common path of insertion and removal.

The saddle areas were outlined, and the selected areas were depressed 1.5 mm for the soft tissue simulating material (Multisil-Mask, berdent GmbH &Co.KG, Germeny). Additional two grooves were outlined with 2mm width, 4mm length & 0.25 mm depth one distal to the last abutment and the other on the distal part of the saddle bilaterally to receive the strain gauge rosettes .

The modified virtual model was 3D printed **(DentCase 3D printer K5, Mogassam Co. LLC., Egypt.)** using model resin (**NextDent™ Model resin, Vertex-Dental B.V., The Netherlands**) to obtain two identical 3 D casts **(Fig 1b)**

Fig. (1) (a&b) the virtual &the printed cast

Soft tissue simulating material (Multisil-Mask soft Assortment, bredent GmbH & Co.KG) was applied into the printed models using the clear vacuum formed stent to simulate the mucosa, guided by the remaining teeth

The printed cast were sprayed and scanned to produce a new STL file to design the primary telescopic coping using the partial denture module of Exocad software to confirm the Marburg double crown design system. The STL file was imported to the Exocad software to design the primary crowns with 1mm thickness and 1mm edge height from the finish line with the minimum amount of cement gap (0.4 mm). The STL file was sent to the milling machine. **Group (1):** The primary crowns (4) were millied from Pekkton® blank (Cendres+Metaux SA,USA) of 20 mm that was inserted in the 5 axes milling machine (K5, vhf, Germany) to fabricate the crowns. The crowns were finished, polished (Visio.link finishing kit) and seated on the cast. **Group (2):** The primary crowns (4) were milled from a pre-sintered zirconium-dioxide blank (Kerox ZircoStar®, HT Zirconia Disc White, K12-0188, Hunga) of 98x14 mm was used to fabricate the zirconia primary crowns applying the same construction parameters. The blanks were milled and sintered according to the manufacturer's instructions. Each zirconia crown was finished by diamond burs and polished for with the diamond polishing zirconia set (Eve Diasint set HP 321, 9077, Germany)**. (Fig 2)**

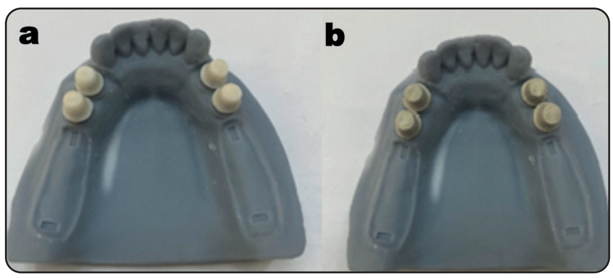

Fig 2 (a&b): pekktoon & zirconia primary coping placed on the printed cast

The 3D cast with PEKK (Pekkton®) primary crowns in place was coated with scanable spray and scanned to generate STL file to be imported to the Exocad software to design The telescopic partial denture framework including secondary coping, denture base and mandibular major connector. The design of the secondary copings were done with minimal wall thickness of 0.6 mm and an occlusal space 0.3mm was preserved between the primary and secondary coping. Splinted coping with anatomical tooth form was selected from Exocad software library covering the primary coping. The teeth forms were adjusted, scalped, and adapted to the finish line. Then, they were splinted together on each side with mandibular major connector**.** The RPDs framework was designed following the conventional design principles. **(Fig3)**

The design was finalized using the sculpt tool to add or remove materials from the design, smoothening of the needed areas was done to avoid any sharp undesirable areas. External finish line was drawn at the junction between the denture base and the major connector, the finish line was inverted so that it faces occlusally. Finally the STL file of the removable partial denture framework design was sent to the milling machine. The framework was milled from the PEKK (**Pekkton®) blank. Pekkton® ivory milling blank ø 98.5/20mm 01060020, Cendres+Metaux SA, USA).(fig 3)** The frameworks were finished then the seating of the partial denture frameworks were verified for proper fit.

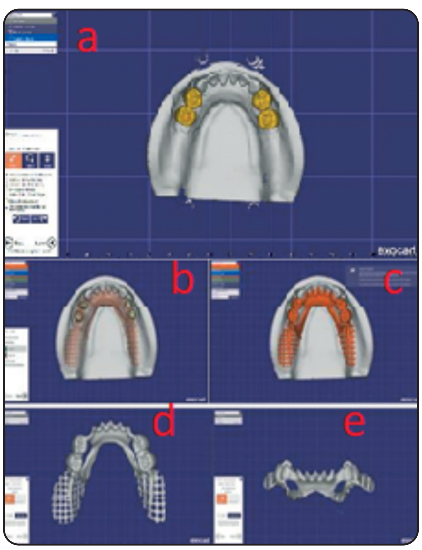

Fig 3: Designing the secondary coping and the framework

Preparations for primary coping to receive the cement were done. The Pekkton and zirconia primary copings were sandblasted (Renfert Basic eco Fine sandblasting unit, German) at a pressure of 2-3 bars using 110 μm aluminium oxides. Then, they were cleaned with alcohol and a clean brush. The inner surfaces of the Pekkton primary crowns were conditioned with adhesive primer **(visio.link primer, bredent UK, Chesterfield County)** and polymerized in an extra-oral light polymerization unit for 90 seconds .The Zirconia primary coping were conditioned by drops of MKZ Primer (**MKZ Zirkonia Prime, Bredent, UK, bredent UK, Chesterfield County**) and left to dry for approximately 30 seconds. The casts were also sandblasted. Then, they were cleaned with compressed air for 15 seconds (s). The surfaces of the abutments were also wetted with light-curing Visio.link adhesive primer using a brush and polymerized in an extra-oral light polymerization. Self-adhesive resin cement **(Theracem® automix, Bisco, Schaumburg, USA)** was injected into inner surface of all the primary coping. Then, the primary coping were seated into their places and initially light cured for 2 seconds. The excess cement was removed, and the framework was seated. Then, the polymerization was completed by the light cure for 30 seconds. The framework was removed and the crowns were exposed to the light curing for further 20 seconds and finally, allowed to continue set chemically. Finally artificial teeth were set up to the framework with self-curing acrylic resin**. (Fig4 a)**

For each cast, four strain gauge sensors **(Kyowa-Electronic Instruments Co, LTD, Tokyo, Japan.)** of 3 mm length, electric resistance 119.6 ± 0.4 Ω were installed at the predetermined sites with cyano-acrylate adhesive **(Amir Alfa Cairo Egypt)**. **(Fig4 b)**

For each cast, universal testing machine LD Series **(bench mounted, ©2015 AMETEK. Inc**.) were used to apply a static load of 100N bilaterally at the second molar and distal the last abutment then unilaterally on the right side.

The arithmetic mean and the standard deviation of the recorded readings (micro strain) of each loading point were calculated tabulated and statistically analyzed.

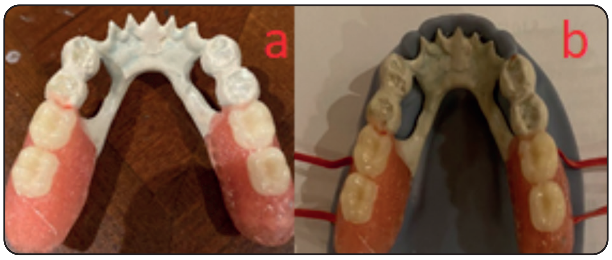

Fig 4 (a&b): Final framework &installation of the strain gauge sensor

RESULT:

Analysis and management of data were performed using Statistical Analysis Systems. SPSS software (version 13.1: SPSS Inc). The Shapiro-Wilk tests was used to evaluate data normality and showed normal distribution. Data were summarized using means and standard deviations Probability values ≤0.05 to indicate significant relationships between variables. Independent t-test was used to compare between the two groups.

During bilateral loading, the lower strain mean values and standard deviation of pekkton group were **(124.7±15.14)** and **(49.00±8.28)** distal to the abutment and second molar respectively. A higher strain mean values and standard deviation of zirconia group was **(347.1±18.2**) and **(79.3±12.78)** distal to the abutment and second molar respectively, with statistically significance difference where p value =0 as shown in table 1

Under unilateral load, the strain mean values and standard deviation of Pekkton group were **(83.00±6.48**) and **(31.20±5.53)** distal to the abutment and second molar respectively. A higher strain mean values and standard deviation of zirconia group were **(232 ±10.3**) and **(40.2±2.86)** distal to the abutment and second molar respectively, with statistically significance difference where p value =0 as shown in table 2

TABLE (1): Mean values, standerd deviation S.D, T and P value of the strain resulting in bilateral loading between pekkton and zirconia group using independent T Test

Groups	Pekkton		Zirconia		95% Confidence Interval of the Difference		T value	P value
	Mean	S.D	Mean	S.D	Upper	Lower		
Bilateral loading distal to the abutments	124.70	15.144	347.10	18.224	-238.142	-206.658	-29.681	0.000
Bilateral loading on second molar area	49.00	8.287	79.30	12.781	-40.542	-20.058	-6.291	0.000

TABLE (2): Mean values, standerd deviation S.D, T and P value of the strain resulting in unilateral loading between Pekkton and zirconia group using independent T Test

Groups	Pekkton		Zirconia		95% Confidence Interval of the Difference		T value	P value
	Mean	S.D	Mean	S.D	Upper	Lower		
Unilateral loading distal to the abutments	83.00	6.481	232.00	10.371	-157.125	-140.875	-38.529	0.000
Unilateral loading on second molar area	31.20	5.534	40.20	2.860	-13.138	-4.862	-4.569	0.000

DISCUSSION

Mandibular kennedy Class I faced many problems due to different in nature of support which induce torque on the distal abutment and excessive load on the residual ridge. This could be controlled by using splinted crowns over the two last distal abutments for better distribution of the forces.[1] The use of telescopic retainer provides stability against horizontal dislodging forces gives highly retentive force & allows better load distribution that produce less rotational torque on the abutments. [3]

CAD CAM technology was used in this in vitro study to allow the standardization of all the parameters used and insured the accuracy of the framework, secondary & primary coping construction. It provides creation of three-dimensional objects as easier as faster than any other conventional technique.[16.18]

The abutments were prepared 6 mm height, 5 mm width to allow circumferential clearance to accommodate the thickness of the primary and secondary telescopic copings. Nextdent model resin was used to print the model because it has adequate mechanical properties to withstand the stresses applied during loading. Soft tissue simulating material was injected into the modified saddles to ensure a natural stress pattern during loading. The primary and secondary copings were designed with the minimum thickness that provides adequate mechanical properties required for function. [19]

Two identical printed casts with Pekkton frameworks for both groups were fabricated to standardize all the study variables. The only variable is the type of material used for fabrication of primary crowns. PEKK was the material of choice for fabrication of the frameworks for both groups because of its light weight and biocompatibility. Also, it exhibits outstanding mechanical properties such as high wear resistance as well as high compressive, flexural, and tensile strengths. The material allows shock absorption, and can be veneered with various commercially available dental materials. [20.21]

The results of this study showed that during bilateral & unilateral loading, group 1 (Pekkton) induced less strain on the abutments and the distal aspect of the ridge than group 2 (Zirconia). This may be attributed to the reduced modulus of elasticity of Pekkton (5GPa) than Zirconia (210GPa) which results in a cushion effect reducing the stresses transmitted to the supporting structures.[22]

The results agree with a previous study that stated that PEKK material induced lower stress values on the periodontal ligament than metal alloys.[23]

In terms of stress magnitude, PEKK based full crowns show low-stress magnitude, Therefore, it is reported that PEKK crowns offer a stable treatment option for patients that suffer from metal allergy. These findings complement the outcomes of the present study, as low-stress magnitude support the use of PEKK as a suitable telescopic attachment system for over-dentures.[24]

CONCLUSION

Within the limitation of this study, it could be concluded that; In telescopic RPDs, Zirconia induces higher strain values at the abutments and the distal aspect of the ridge than Pekkton during bilateral and unilateral loading.

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