The Effect of the Different Computerised Telescopic Crowns Materials on the Supporting Structures of Unilateral Free-End Saddles

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ABSTRACT:
Background and Objectives: Unilateral free-end partial edentulism represents a challenge in prosthodontics due to the unfavorable load distribution on the last abutment and other supporting natural structures. Telescopic crown retained partial dentures are one of the solutions to improve stress distribution more evenly, and this study aims to evaluate the effect of two different materials used in the construction of these appliances, PEEK and metal (titanium), on stress distribution around the abutment and supporting natural structures, as well as the site of applied stress. Methods: a vertical static load of 100 N was applied on Kennedy class II mandibular casts, which were fabricated from PEEK and metal materials on two locations: tooth #45, which was the last abutment, and tooth #46, which was replaced on the free end saddle to compare microstrain using strain gauge rosettes positioned distal to the abutment and on the residual ridge. Results: telescopic crowns made from titanium showed significantly higher micro-strain values than PEEK ($p = 0.0001$), especially distal to the abutment ($p \leq 0.0001$). The application of the load on the free-end saddle resulted in a higher microstrain value compared to the load on the abutment, $p \leq 0.0001$. And no statistical difference was observed between the two materials in the value of microstrain when the load was applied to the free-end saddle, $p = 0.08$. Conclusions: Telescolic PEEK crowns might provide a more favorable stress distribution around the abutment and free-end saddle in Kennedy class II edentulous patients, while metallic crowns will provide greater rigidity to the prosthesis.

Keywords: Kennedy Class II, Microstrain, PEEK, Stress distribution, Telescopic crowns.

1. Introduction

The rate of oral conditions that lead to tooth loss remains high among older individuals, affecting quality of life through negative social impacts, especially difficulty eating (Leong, Beh, & Ho, 2024). The options for replacing missing teeth in partially edentulous patients include fixed, removable partial dentures, or implant-supported prostheses, each with its own pros and cons (Duong et al., 2022). Tooth-supported overdentures, while they are not a new concept, have been overshadowed by newer methods in the field (Samra, Bhide, Goyal, & Kaur, 2015). The method, which is also called telescopic crowns, can be defined as "an overdenture which is a dental prosthesis that covers and is partially supported by natural teeth, natural tooth roots, and/or dental implants" (Kamel, Badr, Fekry, & Tsoi, 2021). This method consists of two fabricated crowns: one attached to the abutment, the inner crown, and the other attached to the fabricated denture, the outer crown. Retention is generated by friction between them (Hakkoum & Wazir, 2018).

Generally, different types of materials can be used for fabricating the distal extension of the dentures, a novel one of them called polyether-ether ketone, which is also known as PEEK (Zoidis, Papathanasiou, & Polyzois, 2016). and others include titanium or nickel-titanium, cobalt-chromium, silver-palladium, zirconia, and many others, which are chosen for a variety of designs and manufactured by conventional wax reduction or CAD/CAM to utilize the different properties of each design and material (Tardelli & dos Reis, 2024).

Regardless of the material type, design, and fabrication protocol, unilateral free-end saddles in partial prostheses face complications (Ferraço et al., 2013), Due to the long distance from the abutment to the end of the denture, which creates a class I lever action on the abutment, destabilizing the prosthesis's retention (Dahab, El-Gendy, & Eltorky, 2015). For this reason, telescopic overdentures were suggested as a solution that distributes the occlusal forces evenly among the soft tissue under the denture and the long axis of the abutment, which can withstand lateral forces, as well as dislodgement forces (Ghorab & Rostom, 2019). However, unilateral saddles apply a torque on the last abutment, which may damage it and lead to loss of the prosthesis (Rostom, 2023). Hence, this in vitro study aims to investigate the effect of material PEEK or titanium, and the location of the abutment, on the stress distribution of unilateral free-end partial dentures supported by telescopic crowns.

2. Methodology

This in vitro experimental study was conducted to analyze and compare stress distributions of PEEK and metal telescopic crowns used to retain a free-end removable partial denture in the Kennedy Class II mandibular ridge, and the methodology was adapted from a study conducted by Ghorab and Rostom with some modifications (Ghorab & Rostom, 2019).

The used model was a commercially available rubber mandibular E50-520 model with replaceable acrylic teeth and roots from NISSIN, as shown in Figure (1). It presented a unilateral free-end saddle (Kennedy class II), with the first premolar as the last abutment. Teeth were removed, and roots were wrapped in 0.3 mm tin foil to represent the periodontal ligaments before fabricating silicon molds, and then teeth were reinserted. A rubber base material was used to simulate the oral mucosa covering the free-end area, and its thickness was standardized using a plaster index, and this step is shown in Figure (2) (Kosewski, Kosewski, & Mielczarek, 2025).

Figure (1): Rubber mandibular model with Kennedy class II unilateral free saddle

Figure (2): Stimulation of oral mucosa by a rubber base material

Regarding the tooth preparation, the premolar teeth were prepared as follows: axial reduction: 0.5 mm, occlusal reduction: 1 mm, 0.3 mm depth of chamfer finishing line, and tapering; 6° convergences. And then, the models were scanned digitally to design and mill 7 PEEK coping crowns and 7 metal coping crowns. After that, refractory casts were constructed by duplicating the epoxy models, and primary copings were cemented, followed by secondary copings (Goodacre, Campagni, & Aquilino, 2001). The removable partial denture design includes a lingual bar major connector, mesh connectors over the edentulous area, mesial occlusal rest over the second molar, and distal occlusal rest over the first molar, a butterfly clasp, and an indirect retainer over the canine (Stock et al., 2016). And the framework was cast in cobalt-chromium alloy, then finished and polished, and finally, acrylic teeth were arranged and processed using hot-cured acrylic resin.

Strain was recorded using 3 mm × 1 mm strain gauge rosettes with a resting resistance of 120 Ω. Two 1 mm-deep vertical grooves were created on each model to accommodate the sensors: one distal to the first premolar and the other on the ridge in the first molar area. The strain gages were secured with cyanoacrylate adhesive, and the lead wires were secured with self-cured acrylic resins (Karl & Holst, 2012).

A vertical static load of 100 N was applied to represent a moderate posterior masticatory load (Ameen, El-Khodary, Abdel-Hamid, & Fahmy, 2023). While the model was fixed horizontally in the testing machine called STRAIN INDICATOR P-3500 from VISHAY measurements group, at two points: the second premolar and the first molar. Strain gauges were connected to a strain meter to record microstrains on the selected points, which were distal to the abutment, and the other one on the free-end saddle area. A 15-minute recovery period was allowed between the measurements. The device is presented in Figure (3).

Figure (3): Strain indicator machine, P-3500, from VISHAY

Ethical approval for this study was obtained from the research and ethics committee of the Kurdistan Higher Council for Medical Specialties, with a formal letter dated and numbered 8th September 2022, 1563, after the Directorate of Specialty Committees Office assigned a supervisor for the study.

The recorded data were arranged and analyzed using IBM SPSS Statistics version 15. After presenting descriptive statistics, the significance of differences in measurements was assessed using the Wilcoxon Signed-Rank Test within groups and the Mann-Whitney U Test between groups.

3. Results

In total, 56 readings of microstrain were recorded, 7 PEEK group and 7 metal group, the force applied twice, once on tooth #45 and once on tooth #46, and each time microstrain was recorded from two sensors, one distal to the abutment, and one on the tooth #46 pontic. values from our data weren't normally distributed; therefore, non-parametric tests were performed, and descriptive statistics are presented in Table (1), which shows mean, standard deviation, confidence intervals, and interquartile range.

Table (1): Descriptive statistics of microstrain values

Material (tooth)	Location of the load application	Location of the strain Gauge rosette	Mean (SD)	95% CI	Interquartile range
PEEK	#45	Distal to the abutment	27(4.39)	22.9-31.07	7
		Residual ridge	20.28 (2.62)	17.8-22.72	4
	#46	Distal to the abutment	30.71 (3.03)	27.9-33.53	5
		Residual ridge	89.71 (10.64)	79.87-99.56	21
Metal	#45	Distal to the abutment	47.57 (4.11)	43.76-51.38	7
		Residual ridge	36.43 (2.14)	34.44-38.42	5
	#46	Distal to the abutment	58 (3.14)	54.84-61.16	6
		Residual ridge	101 (3.46)	97.8-104.2	7

Microstrain in general ranged from 16 to 106, but varied across materials and sensors. For the PEEK material, when the load was applied on #45, the sensor distal to the abutment gave a read of 20-33, while the sensor in the residual ridge had a read of 16-24, and this difference was statistically significant when tested using the Wilcoxon Signed Ranks Test, with p value≤0.0001. When the load was applied on tooth 46, the first sensor read 27-36, and the second sensor recorded 79-106, and also this difference was statistically significant with the same value as the previous test.

For the metal abutment group, when the load was applied on #45, the readings for microstrain on the first sensor were 42-54 and on the second

sensor were 34-39, and when the load was applied on #46, while when the load applied to #46, the first sensor recorded 53-63 and the second sensor recorded 97-106, these differences aldo tested using the Wilcoxon Signed Ranks Test and it was statistically significant, p value≤0.0001. for more clarification, key statistical tests with their p values are presented in the Table (2).

Table (2): Key statistical tests regarding the mean difference of microstrain between different scenarios

Material (tooth)	Location of the load application	Location of the strain Gauge rosette	P value among sensors Wilcoxon Signed Ranks Test	P value among the load locations Wilcoxon Signed Ranks Test	P value among materials Mann-Whitney Test
PEEK	#45	Distal to the abutment	0.0001	≤0.0001	0.0001
		Residual ridge			
	#46	Distal to the abutment	0.0001		
		Residual ridge			
Metal	#45	Distal to the abutment	0.0001	≤0.0001	
		Residual ridge			
	#46	Distal to the abutment	0.0001		
		Residual ridge			

For both materials, the location of the applied force produced different microstrains that were recorded by the sensors, and the difference was statistically significant, p value≤0.0001. Cumulatively, the metal group demonstrated significantly higher microstrain than the PEEK group, mean= 60.75 and 41.9 respectively, and this difference was statistically significant, p=0.0001, but according to strain gauge location, the microstrain on the sensor that was located distal to the abutment was significantly higher in the metal group, p value≤0.0001, and there was no significant difference in microstrain between materials on the second sensor that was located on the residual ridge at tooth #46 location, p value= 0.08.

4. Discussion

The experimental study presented evaluated the effect of two material types used in telescopic crowns, which are typically used to retain removable partial dentures in unilateral free-end saddles, and the difference in microstrain between the materials when the load location changes. Our findings demonstrated that metallic crowns generated higher microstrain values than PEEK crowns under the same load and conditions, particularly distally from the last abutment, with statistically significant differences. Furthermore, load on the free-end saddle area generated a greater microstrain value than the load on the point immediately after the last abutment, which is tooth #45, in both materials. This indicated that both the rigidity of the prosthesis material and the location of the masticatory force affect load transmission to the underlying supporting structures.

Under ideal conditions, metallic telescopic crowns generate higher microstrain values than PEEK crowns. For example, when the load was applied to the abutment, the mean microstrain was 27 με in the PEEK group, compared with 47.57 με in the metal group. Similarly, when the load was applied to the tooth #46 area, the mean microstrains were 30.71 and 58 με for the PEEK and metallic groups, respectively.

The sensor on the residual ridge detected no statistically significant difference in microstrain readings when the load was applied to the free-end saddle area p = 0.08, although the metallic crowns produced comparable strains. This finding indicates that the resiliency of the mucosa-stimulating material and the distal extension of the denture might reduce the influence of material type in that area. Additionally, it is clinically important to know that the type of material may primarily affect the stress distribution around the abutment tooth rather than the residual ridge.

Given the availability of various materials for the construction of dental prostheses, investigators first tend to study their biomechanical properties, stress concentrations, and deformation under stress (Sirandoni, Leal, Weber, Fuentes, & Borie, 2019). Multiple studies investigated the effect of material on stress distribution using finite element analysis, and together they found that more rigid materials concentrate stress on supporting structures, such as implants or abutments, while less rigid materials allow stress to distribute more evenly (Tardelli & dos Reis, 2024). This fact is consistent with our results, which demonstrated significantly higher microstrain value in the metallic group than the PEEK group, and they consider this fact clinically important, referring to the fact that it will affect the choice of selecting the materials according to cases, as the PEEK material may result in more periodontal ligament and alveolar bone preservation (Ajaj Al-Kordy & Al-Saadi, 2022; Fayyad & Nassouhy, 2017). The mentioned biomechanical behavior of PEEK crowns is particularly advantageous for free-end saddles, where preservation of natural structures is crucial, as undesirable lever action would be destructive (Dahab et al., 2015).

One classical known fact regarding the Kennedy class II prosthesis is increased microstrain on the prosthesis when the load is applied closer to the free-end saddle, which, in this case, is the tooth #46 area, compared to distal to tooth #45, and all these are contant with biomechanical behavior with the Kennedy class II prosthesis when the occlusal force produce a rotational force around the last abutment such as the lever action that wound increase the torque and bending force between the denture and the supporting structures in the free0end area (Camacho, Gallardo, Stegun, Costa, & Sesma, 2018). It's worth noting that the highest microstrain on the residual rigidity was observed when the load was applied to tooth #46, at 101 με, while the lowest was 20.28 με under the same condition. This fact further explains the influence of load position and stress distribution.

Clinically, the lower strain value of PEEK crowns may contribute to more favorable stress distribution around the terminal abutment and free-end saddle area that preserves more supporting structures. On the other hand, the rigidity of metallic crowns may improve the prosthetic stability and durability, but at the expense of more load transmission to the supporting structures. Therefore, the options for material selection should consider both these biomechanical behaviors based on the patient's specific clinical requirements.

This study has several limitations. First, we conducted our investigation under static vertical 100 N conditions, in which intraoral masticatory forces are more multidimensional, cyclic, and dynamic.11 Second, the materials used to stimulate mucosal and periodontal tissue can't represent biologic intraoral vivo conditions. Third, in this investigation, only two materials and two locations of load application were evaluated. For these reasons, we suggest that future investigators include more cyclic and oblique loading, additional framework materials, and in vivo clinical trials to better reflect realistic conditions.

5. Conclusion

Telescolic PEEK crowns might provide a more favorable stress distribution on natural supporting tissues, especially around the last abutment in Kennedy class II edentulous patients, while metallic crowns might provide greater rigidity to the prosthesis. The decision to choose the treatment material should take these factors into account to achieve more long-lasting results. Furthermore, the applied load on the free-end saddle will result in the same stress in both materials, as the load on the abutment remains the same.

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