

# Strain Gauge Analysis of the Stresses Induced by Different Secondary Coping Materials in Tooth Supported Telescopic Overdentures

## Keywords

PEEK  
Zirconia  
Stress Analysis  
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## ABSTRACT

*Purpose:* To compare the stresses induced on the supporting abutments by different secondary coping materials: zirconia, Polyetheretherketone (PEEK) and Polyetherketone ketone (PEKK) in tooth supported telescopic overdentures using strain gauge analysis. *Materials and Methods:* A virtual model simulating a completely edentulous mandibular arch with two telescopic overdenture abutments in the canine region was designed and printed. The abutments received a milled zirconia primary coping. The secondary coping was milled out of zirconia in the model ZR, PEEK in the model PE and PEKK in the model PK. Five overdentures were made for each model. Strain gauge rosettes were bonded mesial and distal to each abutment. Unilateral and bilateral loadings were applied. An ANOVA test was used for statistical analysis between the three models ( $\alpha=0.01$ ). *Results:* Significant differences were found between the three models during unilateral and bilateral loading. Post Hoc Tukey tests showed significant difference between ZR and PE models, ZR and PK models in addition to PE and PK models during unilateral and bilateral loading. *Conclusion:* Zirconia copings induced the highest stress while the lowest stress values were induced by the PEKK copings.

## INTRODUCTION

Telescopic tooth supported overdenture provides superior retention and stability compared to the conventional complete denture. Moreover, patient satisfaction is improved, and the rate of residual ridge resorption is decreased.<sup>1,2</sup> On the other hand, its fabrication is technique sensitive, time consuming, expensive in addition to the need for sufficient interarch space.<sup>3</sup>

The telescopic attachment consists of a primary and a secondary copings. The primary coping is cemented to the abutment tooth and helps to protect the underlying tooth structure from dental caries. It also provides retention for the overlying structure. However, the secondary coping is placed within the denture base.<sup>4-6</sup> The retentive force of telescopic overdenture abutment depends on a number of factors as technique and material of coping fabrication, its degree of taper, abutment height, precision of fit and aging.<sup>7</sup>

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Different methods for fabrication of telescopic copings can be used as casting, electroforming and milling. Thanks to the digital innovations in prosthetic dentistry, the CAD/CAM technology helped with the production of telescopic copings from different materials with high precision as well.<sup>8,9</sup>

Several materials have been used for the fabrication of telescopic copings as gold alloys, base metal alloys, zirconia in addition to the recently introduced polymers polyetherether ketone (PEEK) and polyetherketoneketone(PEKK).<sup>7,10,11</sup> Metallic copings have been used for a long period of time for the high strength properties and elastic modulus. Nowadays, zirconia is widely used as a primary coping material for its biocompatibility, excellent wear resistance and strength properties.<sup>12</sup> PEEK and PEKK are promising high performance polymers with wide applications in the field of prosthetic dentistry. They are reported to have unique resilient properties, shock absorption, biocompatibility and modulus of elasticity similar to bone. However, PEKK has higher strength properties than PEEK as stated by the manufacturer due to its additional ketone group.<sup>13-15</sup> These polymeric materials have been investigated as telescopic copings for their retentive capacity and gave promising results. They maintained their high capacity with aging as well.<sup>7,12,16-18</sup> However, to the best of our knowledge, the stresses induced by these materials when used as a secondary coping material in telescopic tooth supported overdentures were not investigated and mentioned in the literature. So, the primary aim of this study was to compare the stresses induced on the supporting abutments by different secondary coping materials; zirconia, PEEK and PEKK in tooth supported telescopic overdentures using strain gauge analysis. The null hypothesis is that there was no difference in the stresses induced by zirconia, PEEK and PEKK when used as secondary coping material coupled with zirconia primary coping in telescopic tooth supported overdenture.

## MATERIALS AND METHODS

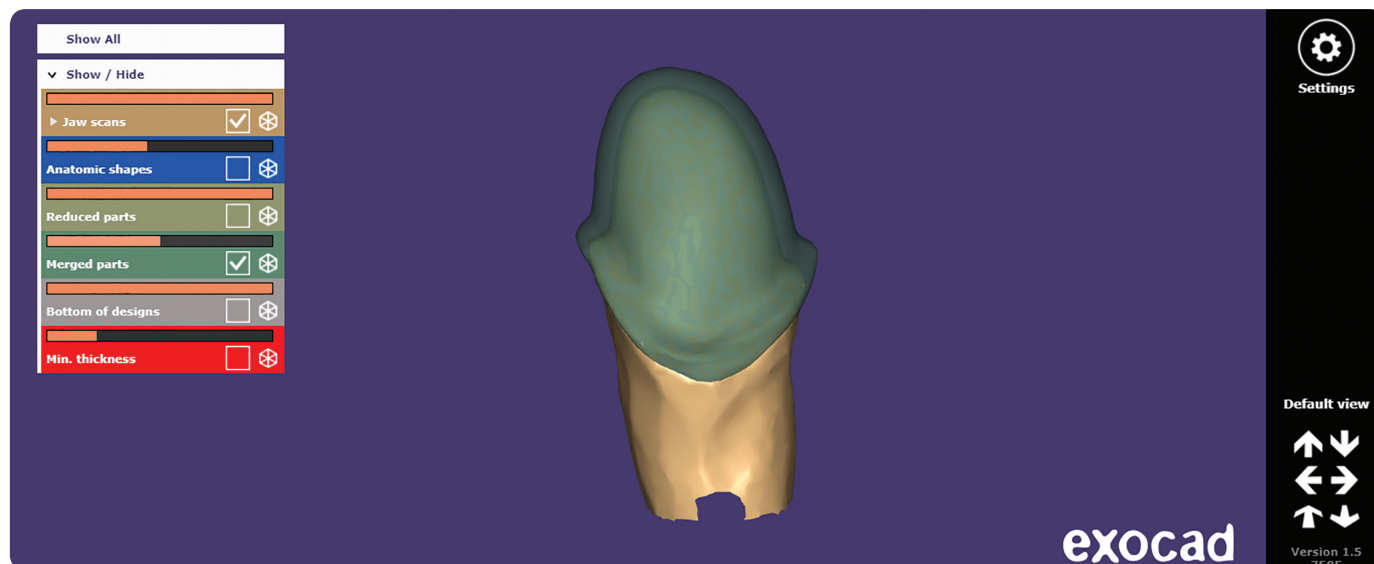
This study was conducted using a digitally produced model simulating a completely edentulous mandibular arch with two telescopic overdenture abutments in the canine region.<sup>19</sup> Three models were used in this study. The primary coping of the telescopic overdenture abutments was made out of zirconia in the three models. However, the secondary coping was made out of zirconia in model ZR, PEEK in model PE and PEKK in model PK. Five telescopic overdentures were made for each model. The sample size was calculated based on 95% confidence interval and power 80% with  $\alpha$  error 5% (MedCalc® version 12.3.0.0 program, Ostend, Belgium). A study published by Emera *et al* was used for sample size calculation. Emera *et al* showed statistically significant difference between PEEK and zirconia when being used as secondary crown overlying primary zirconia crown in implant supported telescopic overdentures.<sup>20</sup>

## MODEL CONSTRUCTION

An educational mandibular completely edentulous cast (Ramses edentulous cast; Ramses medical products, Cairo, Egypt) was used in this study. A waxed-up mandibular denture was made for this cast. The cast was then scanned (DOF swing scanner; DOFlabs, Seoul, South Korea) and a standard tessellation language (STL) file was generated. The cast with the overlying waxed up denture was then scanned and the STL file was generated. Both STL files were superimposed to determine the position of mandibular canines' sockets in the virtual model on the CAD software (Exocad Dental CAD; Exocad GmbH, Darmstadt, Germany).

Mandibular right and left acrylic canine teeth (Ramses acrylic teeth; Ramses medical products, Cairo, Egypt) were prepared having a heavy Chamfer finish line and a height of 7 mm.<sup>7</sup> The occlusal convergence was adjusted to 4 degrees per side using a paralleling device (Frasgerat AF30; Nouvag AG, Switzerland).<sup>21,16</sup> The prepared mandibular canines were scanned and the STL file was generated. This STL file was then used for virtual superimposition of the prepared mandibular canines in their corresponding sockets in the previously scanned mandibular model. A space of 0.25 mm was left between inner surface of the socket and the canine root surface simulating the periodontal membrane space.<sup>21</sup> Two slots 1 mm mesial and distal to each socket were designed parallel to the longitudinal axis of the socket for placement of the strain gauge rosettes. A 2 mm layer thickness was removed from the scanned model crest representing the mucosal layer that was added later.<sup>21</sup> The design of the virtual model was checked and the STL file was sent to the additive manufacturing device. (ULTRA 3SP; EnvisionTEC Inc, Michigan, USA). Similarly, three pairs of the prepared mandibular acrylic canines were 3D printed. The model sockets and the root portion of the overdenture abutments were painted with adhesive (3M VPS adhesive; 3M ESPE, USA). Light body silicone rubber base impression material (Speedex, C-silicone; Coltene Whaledent AG, Switzerland) was placed into the sockets and the abutments were seated in their sockets.<sup>21</sup>

The 3D printed mandibular right and left mandibular canines were then scanned. A primary coping was designed to have a chamfer finish line, 0.5 mm wall thickness, 30  $\mu$ m spacer and 4 degrees occlusal convergence on the CAD software (Exocad Dental CAD; Exocad GmbH, Darmstadt, Germany)(*Figure 1*).<sup>2,16</sup> Primary copings for the three mandibular telescopic overdentures' abutments were milled out of zirconia (Katana; Kuraray Noritake Dental Inc, Okayama, Japan) and sintered.<sup>2,7,12,22</sup> Zirconia primary copings were then checked for perfect fit with prepared abutments and cemented in place with adhesive resin (Supercem; Dentkist Inc, Gunpo, Korea).<sup>7</sup> The telescopic overdenture abutments were then scanned and the secondary copings were designed (Exocad Dental CAD; Exocad GmbH, Darmstadt, Germany) (*Figure 2*). The secondary copings were milled out of zirconia (Katana; Kuraray Noritake Dental Inc, Okayama, Japan), PEEK (Brecam Biohpp; Bredent medical group GmbH,



**Figure 1:** Primary coping was designed overlying the prepared abutment to have a chamfer finish line, 0.5 mm wall thickness, 30 µm spacer and 4 degrees occlusal convergence using Exocad software



**Figure 2:** Secondary coping was designed overlying the primary coping using Exocad software

Germany) and PEKK (Pekkton Ivory; Cendres+Metaux Medtech, Switzerland).<sup>7,8,12,18,22</sup> The telescopic overdenture abutments with the overlying primary and secondary copings were seated in the corresponding sockets in the model. The edentulous ridge was covered with 2 mm thick light body silicone rubber base impression material (Speedex C-silicone; Coltene Whaledent AG, Switzerland) for mucosa simulation.<sup>21</sup> The overdentures with metallic reinforced bases were made. The secondary copings were then bonded to the overdenture base according to the manufacturer instructions.

The strain gauges (Kyowa strain gauges; Kyowa Electronic Instruments Co., Ltd, Tokyo, Japan; length: 1 mm; width: 2.4 mm; resistance: 120 Ohm) were placed in their slots on the distal and mesial aspects of each abutment and bonded in position with delicate layer of cyanoacrylate adhesive (Amir Alpha; Amir Alpha Co., Cairo, Egypt). The strain gauges were positioned parallel to the longitudinal axis of each abutment

(Figure 3). The terminals of the strain gauge wires were attached to a four channel strain-meter (Kyowa strainmeter; Kyowa Electronic Instruments Co., Ltd, Tokyo, Japan) to measure the microstrains induced by the applied load.

### LOAD APPLICATION

The model was placed on the lower metal plate of the universal testing machine (Lloyd LRX; Lloyd Instruments Ltd, Fareham, United Kingdom). For calibration 10-60 Newton (N) loads were applied five times in 10 Newton (N) steps.<sup>21</sup> For unilateral loading, an I bar shaped load applicator was placed in the central fossa of mandibular left first molar (Figure 4). However, the T shaped load applicator was used for bilateral loading (Figure 5). The magnitude of the applied load was 100 Newton (N) and was increased from 0 to 100 Newton (N) at a constant rate of 0.5 mm/min.<sup>21</sup> For each telescopic overdenture, five measurements were made. A recovery period of five minutes



**Figure 3:** Strain gauge rosettes were bonded on the mesial and distal sides of both abutments using cyanoacrylate adhesive



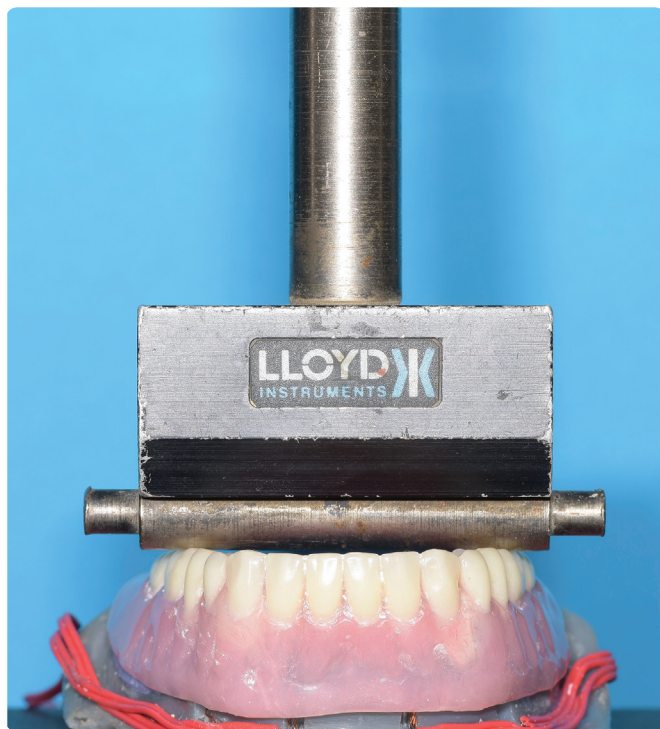
**Figure 4:** Unilateral load of 100 Newton (N) was applied on the central fossa of the mandibular left first molar using I bar applicator of the Universal testing machine

was allowed between the measurements.<sup>21</sup> The authors were blinded and the measurements were performed by a single operator in the Biomaterials laboratory available in their university. The laboratory operator was instructed about the site and magnitude of load application. A trial measurement for demonstration was made before the actual measurements.

Once the load was completely applied, the data were analyzed using the software (PCD-30A; Kyowa Electronic Instruments Co., Ltd, Tokyo, Japan) and microstrain values were recorded. All data were collected and tabulated.

## STATISTICAL ANALYSIS

Statistical analysis was performed using statistical package for social sciences (version 21.0 SPSS Inc; IBM Corporation, Chicago, Illinois, USA). The recorded data followed normal distribution as



**Figure 5:** Bilateral load 100 Newton (N) was applied on the central fossae of the mandibular first molars using T shaped applicator of the Universal testing machine

indicated by Shapiro-Wilk normality test. One way ANOVA and Post Hoc Tukey tests were used for comparison between the microstrain values for the three models. Repeated ANOVA and Post Hoc Tukey tests were used for comparison between the microstrain values in each model. P-value < 0.01 was considered to be the statistical significance level. Negative values indicated compressive strain while positive values indicated tensile strain.

## RESULTS

During unilateral loading, the strains were compressive in nature for the three models in the left side; loaded side. One way ANOVA test showed statistically significant difference between them on the distal side of the abutment ( $F=32.23$ ;  $p=.0000$ ). Post Hoc Tukey test revealed statistically significant difference between the models ZR and PE, PE and PK, in addition to ZR and PK on the distal side of the abutment. The highest value was for the model ZR and the lowest was for the model PK. Similar statistically significant difference with the same pairwise comparisons were also found on the mesial side of the abutments ( $F=20.92$ ;  $p=.0000$ ). The microstrain values recorded on the left side during unilateral loading are listed in table 1.

For the right side; unloaded side, compressive strains were recorded in the PE and PK models while in the ZR model, strains were tensile in nature. One Way ANOVA test showed statistically significant difference between the three models on the distal sides of the abutment in the right side ( $F=816$ ;  $p=.0000$ ). Post Hoc Tukey test revealed statistically significant difference between the ZR and PE in addition to ZR and PK models on the distal side of the abutment. Similar results

were attained on the mesial side of the abutments (F=232.09; p=.0000). The microstrain values recorded on the right side are shown in table 1.

Repeated ANOVA showed statistically significant difference in the recorded microstrain values between different strain gauge positions in each model (F=233.1; p=.0000 for ZR, F=119.1; p=.0000 for PE, F=237.4; p=.0000 for PK). Post Hoc Tukey test revealed statistically significant difference between the left and right sides in each model. Moreover, statistically significant difference was found between microstrain values recorded in the distal and mesial aspects of the abutments in the left side. However, there was no statistically significant difference between microstrain values recorded in the distal and mesial aspects of the abutments in the right side. The microstrain values recorded at each strain gauge in each model are summarized in table 2.

During bilateral loading, compressive strains developed in the three models. One way ANOVA test showed statistically significant difference between the three models regarding the microstrain values recorded distal to the abutments (F=20.73; p=.0000 for the left abutment, F=18.71; p=.0000 for the right abutment). Post Hoc Tuckey test revealed statistically significant difference between ZR and PE, PE and PK, in addition to ZR

and PK models. Similar statistically significant difference was found on the mesial side of the abutments with similar pairwise comparisons (F=22.61; p=.0000 for the left abutment, F=20.74; p=.0000 for the right abutment). The microstrain values recorded on the left and right sides during bilateral loading are shown in table 3. Repeated ANOVA showed statistically significant difference in the recorded microstrain values between different strain gauge positions in each model (F=54.22; p=.0000 for ZR, F=49.35; p=.0000 for PE, F=26.88; p=.0000 for PK). Post Hoc Tukey test revealed statistically significant difference between strain values recorded on the distal and mesial sides of the abutment. However, there was no statistically significant difference between right and left sides. The microstrain values recorded at each strain gauge in each model are summarized in table 4.

## DISCUSSION

Telescopic overdentures are still used for their favourable survival, axial load transmission in addition to high retention, easy hygiene access and pledged patient satisfaction.<sup>16,17</sup> Recent materials as zirconia, PEEK and PEKK have been introduced for fabrication of primary and secondary copings in

**Table 1. Comparison between the three models regarding the microstrain values recorded during unilateral loading.**

	ZR		PE		PK		F value	P-value
	X(με)	SD	X(με)	SD	X(με)	SD		
Left side distal to the abutment	-232.4	101.3 <sup>a</sup>	-161.6	79.5 <sup>b</sup>	-109.4	33.7 <sup>c</sup>	32.23	.0000
Left side mesial to the abutment	-78.9	53.8 <sup>a</sup>	-52.1	35.1 <sup>b</sup>	-28.8	19.2 <sup>c</sup>	20.92	.0000
Right side distal to the abutment	38.6	5.4 <sup>a</sup>	-18.4	12.1 <sup>b</sup>	-18	4.7 <sup>b</sup>	816	.0000
Right side mesial to the abutment	20.3	4.5 <sup>a</sup>	-17.2	9.8 <sup>b</sup>	-14.5	12.9 <sup>b</sup>	232.09	.0000

Different superscript lowercase letters indicate significant difference. X: mean; SD: standard deviation

**Table 2. Comparison between different strain gauge positions in each model during unilateral loading.**

	Left side distal to the abutment		Left side mesial to the abutment		Right side distal to the abutment		Right side mesial to the abutment		F value	P value
	X(με)	SD	X(με)	SD	X(με)	SD	X(με)	SD		
ZR	-232.4	101.3 <sup>a</sup>	-78.9	53.8 <sup>b</sup>	38.6	5.4 <sup>c</sup>	20.3	4.5 <sup>c</sup>	233.1	.0000
PE	-161.6	79.5 <sup>a</sup>	-52.1	35.1 <sup>b</sup>	-18.4	12.1 <sup>c</sup>	-17.2	9.8 <sup>c</sup>	119.1	.0000
PK	-109.4	33.7 <sup>a</sup>	-28.8	19.2 <sup>b</sup>	-18	4.7 <sup>c</sup>	-14.5	12.9 <sup>c</sup>	237.4	.0000

Different superscript lowercase letters indicate significant difference. X: mean; SD: standard deviation

**Table 3.** Comparison between the three models regarding the microstrain values recorded during bilateral loading.

	ZR		PE		PK		F value	P-value
	X( $\mu\epsilon$ )	SD	X( $\mu\epsilon$ )	SD	X( $\mu\epsilon$ )	SD		
Left side distal to the abutment	-120.2	99.4 <sup>a</sup>	-77.5	36.6 <sup>b</sup>	-40.1	20.6 <sup>c</sup>	20.73	.0000
Left side mesial to the abutment	-44.5	25.1 <sup>a</sup>	-30.4	16.9 <sup>b</sup>	-19.1	12.6 <sup>c</sup>	22.61	.0000
Right side distal to the abutment	-116.7	102.1 <sup>a</sup>	-78.9	35.5 <sup>b</sup>	-39.2	18.9 <sup>c</sup>	18.71	.0000
Right side mesial to the abutment	-42.1	24.2 <sup>a</sup>	-29.2	17.4 <sup>b</sup>	-17.9	13.1 <sup>c</sup>	20.74	.0000

Different superscript lowercase letters indicate significant difference. X: mean; SD: standard deviation

**Table 4.** Comparison between different strain gauge positions in each model during bilateral loading.

	Left side distal to the abutment		Left side mesial to the abutment		Right side distal to the abutment		Right side mesial to the abutment		F value	P value
	X( $\mu\epsilon$ )	SD	X( $\mu\epsilon$ )	SD	X( $\mu\epsilon$ )	SD	X( $\mu\epsilon$ )	SD		
ZR	-120.2	99.4 <sup>a</sup>	-44.5	25.1 <sup>b</sup>	-116.7	102.1 <sup>a</sup>	-42.1	24.2 <sup>b</sup>	54.22	.0000
PE	-77.5	36.3 <sup>a</sup>	-30.4	16.9 <sup>b</sup>	-78.9	35.5 <sup>a</sup>	-29.2	17.4 <sup>b</sup>	49.35	.0000
PK	-40.1	20.6 <sup>a</sup>	-19.1	12.6 <sup>b</sup>	-39.2	18.9 <sup>a</sup>	-17.9	13.1 <sup>b</sup>	26.88	.0000

Different superscript lowercase letters indicate significant difference. X: mean; SD: standard deviation

such overdentures.<sup>7,12</sup> Although the retentive capacity of such materials have been examined yet there is lacking data about the stresses induced by them as secondary coping materials in telescopic overdentures.<sup>7,12,16,18</sup> The null hypotheses that there was no difference in the stresses induced by the three secondary coping materials was rejected. In this study, a three dimensional model was virtually designed and printed for standardization between the three models. Virtual designing of the model enabled the authors to determine exact position of the abutment teeth and placement of strain gauge slots in relation to them. Standardized placement of the slots on both sides of the abutments in both sides of the arch was more guaranteed by this way rather than a manual way. Furthermore, the slots were made even and smooth to minimize the possibility of obtaining strains that may result from rough surfaces. Digitally printed models are also reported to have high accuracy and minimal amount of internal stresses as they are fabricated layer by layer.<sup>19</sup>

The primary coping was made of zirconia in this study for its excellent biocompatibility and reduced plaque adhesion in clinical situations.<sup>12</sup> Minimized plaque adhesion reduces the

incidence of gingival inflammation, pocket formation and periodontal breakdown; problems that may occur with tooth supported overdentures. Improved retention was also reported when using zirconia as a primary coping material rather than metallic, PEEK and PEKK copings.<sup>2,7,12</sup> The improved retention was attributed to the excellent wear resistance offered by Zirconia compared to the other materials.<sup>12</sup> Primary coping was designed with 4 degrees taper as zirconia coping was reported to offer excellent retention with such a degree of taper.<sup>2,16</sup> Primary and secondary copings were fabricated by a digital milling technique. Milled copings have better adaptation, internal fit and marginal precision compared to pressing and casting techniques.<sup>8</sup> Retentive force values for milled copings also last for a long period of clinical use.<sup>7,12,18,22</sup>

The null hypothesis in this study was rejected as there was statistically significant difference between the three secondary coping materials. The highest microstrain values were recorded for the ZR model and the lowest for the PK model. The shock absorbing property of the PEEK and PEKK materials may account for the lower microstrain values recorded when the secondary coping was made of any of these materials compared to

the zirconia coping material. Their elastic modulus being closer to bone and acrylic compared to zirconia may have also helped with better stress distribution.<sup>22</sup>

In accordance with the results of Keiling *et al*, PEKK delivered less stress to the underlying supporting structures.<sup>23</sup> The results of this study partially match the results published by Lee *et al* who showed less stress values with implant supported PEKK frameworks near the site of load application. However, higher values in distant regions were recorded while using the same frameworks compared to zirconia and titanium frameworks.<sup>24</sup> The use of PEKK material for post and core also yielded lower stress values within the tooth structure with better stress distribution compared to other post and core materials.<sup>25,26</sup> Similarly, PEEK generated less stress in the remaining dentin wall when used as an endodontic post compared to commonly used fiber post. Such a result was attributed to the modulus of elasticity of PEEK being close to dentin tissue.<sup>27</sup> Moreover, PEEK exerted less stress on the abutments compared to Co-Cr alloy when evaluated as a clasp material in removable partial dentures.<sup>28</sup>

The pledged strength properties and the higher modulus of elasticity in the PEKK material compared to the PEEK explains the lower microstrain values recorded in the case of PK model compared to PE model.<sup>15,22,29,30</sup> The additional ketone group in PEKK material accounts for the improved strength properties.<sup>17,31</sup>

The application of unilateral loading in this study resulted in compressive micro strains in the supporting abutments in the loaded side in the three models. However, in the unloaded side tensile microstrains developed in ZR model and compressive microstrains developed in PE and PK models. The development of tensile microstrain in the unloaded side could be explained in the light of the rotation of the overdenture around the fulcrum axis formed by the ridge and the abutment in the loaded side and development of antirotational moment counteracting movement of the denture base away from the supporting tissues in the unloaded side. The change in the microstrains from being tensile in ZR model to compressive in the case of PE and PK models can be explained in the view of better retention offered by PEEK and PEKK materials compared to zirconia. This result comes in line with findings of Warin *et al* who showed that microstrains changed from tensile to compressive in the unloaded side during unilateral loading when retention was improved.<sup>32</sup> Moreover, Scherer *et al* stated that the less the number of the implants used in overdentures, the more the rotation of the base in the contralateral side during unilateral loading.<sup>33</sup>

The coping material was mentioned to be one of the factors that affect retention in telescopic overdentures.<sup>34</sup> The improved retention in the PE and PK models may be related to the better fit of milled PEEK and PEKK secondary copings compared to the zirconia one. Better fitness of PEKK copings in comparison to zirconia ones was reported by Bae *et al*.<sup>35</sup> They related the difference to the sintering process needed for the zirconia coping; a process that may have affected the coping fit.

Similarly, PEEK and PEKK inserts used in overdenture attachments showed significant higher retentive forces compared to the nylon ones. Moreover, they maintained their retentive capacity when subjected to a long period of aging.<sup>18,36</sup> Moreover, removable partial denture clasps made of PEEK and PEKK offered good retention for a longer period of time compared to those made of Co-Cr.<sup>11</sup> Also, PEKK secondary coping coupled with zirconia primary coping yielded the highest retentive force value when any other primary coping material was used; the same combination was used in the current study. This retentive capacity was also maintained for a long period of artificial aging.<sup>12</sup> Similar findings for PEEK secondary copings were reported by Schubert *et al* as well.<sup>7</sup>

In the loaded side, the strain values recorded distal to the abutment were higher than the mesial ones. Such a result comes in line with Elsyad *et al*, Warin *et al*, Tokuhisa *et al* who reported higher distal strain values.<sup>21,32,37</sup> The difference in the compressibility between the resilient mucosa and overdenture abutment causes rotational movement of the overdenture during load application. Such a movement may account for the higher strain values recorded distal to the abutment during load application. Furthermore, the distal gauge being closer to the area of load application could be another reason for the higher strain values recorded distally.

Bilateral loading showed better stress distribution compared to unilateral loading. During bilateral loading, there was no statistically significant difference in the microstrain values between the right and left sides. However, the distal side of the abutment showed statistically significant higher strain values than the mesial side during unilateral loading. Moreover, less strain values were recorded in the abutments during bilateral loading compared to unilateral loading. Similar results were also reported by Elsyad *et al* and Warin *et al*.<sup>21,32</sup> Therefore overdenture wearers should be advised to chew bilaterally rather than unilaterally. Furthermore, in the clinical setting, the use of PEKK secondary coping coupled with zirconia primary coping can be recommended in tooth supported overdentures for the less stress delivered to the supporting abutments, improved plaque control in addition to the high and maintained retentive capacity.

It is worth to be mentioned that the two canine tooth supported overdenture is not totally tooth supported. The residual ridge shares in carrying the load applied as well due to the free end saddles. However, load distribution between the residual ridge and the abutments is affected by how far the load is applied away from the supporting abutments. So, the authors recommend further studies to be performed to evaluate the stresses delivered to the residual ridge induced by different secondary coping materials; zirconia, PEEK and PEKK in tooth supported telescopic overdentures. Moreover, such stresses should be compared with those delivered to the abutments when load is applied at different sites.

Although stress analysis studies help with evaluation of the stresses induced in the supporting structures, yet they have a number of limitations. They do not replicate the exact complex nature of the living tissues. Moreover, acrylic resin does not have the same bone conditions. Furthermore, complex masticatory loads were not applied in this study which could be a further limitation. Static vertical loading was applied for simplification despite the fact that loading is dynamic, complex and occurs in vertical and horizontal directions during chewing functions.

## CONCLUSIONS

Despite the study limitations, it can be concluded that the secondary coping material influenced the stresses induced in the tooth supported telescopic overdenture abutments. Zirconia copings induced the highest stress while the lowest stress values were induced by the PEKK copings.

## DECLARATION OF INTERESTS

The authors declare no conflicts of interest, financial or personal relationships with any organization that may influence the results of this study.

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