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IN VITRO RETENTION OVERALL PULL-OFF FORCE OF TELESCOPIC CROWNS MADE FROM TWO DIFFERENT MATERIALS AT THREE TAPER ANGLES

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ABSTRACT

Objective: The objective of the study is to measure the in vitro retention overall pull-off force of telescopic crowns made from two different materials and with different taper angles.

Materials and methods: The telescopic crowns were digitally fabricated from two materials, Polyether-ether ketone (PEEK) disc and graphene-nano reinforced acrylic disc (GN) at three taper angles (0˚, 1˚ & 2˚). Retention force for each specimen was measured 20 times in a pull off-Test, the machine was set to a crosshead speed 50 mm/min applying tension mode of force up to crown dislodgement. Twenty cycles of insertion and removal were performed for each sample and then the retention force was computed and recorded using computer software. Statistical analysis was carried out using Two-way analysis of variance (ANOVA) to explore the effect of different materials and degree of taper on the retention load. Independent sample t-test was conducted to explore the difference between materials.

Results: The retention force of 2 ° taper showed a statistically significant lower value than 0° and 1° tapers. The specimens of the PEEK groups showed significantly higher initial retentive force values than (GN) groups.

Conclusions: Telescopic crowns fabricated from PEEK milled material showed better retention force than the GN milled material. Increasing the degree of taper angle of the telescopic crown above 1° could jeopardize the resultant retention. However, long-term clinical studies are still recommended.

KEY WORDS: Telescopic, Taper angle, PEEK

INTRODUCTION

A telescopic or double crowns consist of two main parts: a primary component that is permanently fixed to an abutment tooth or implant, and a secondary part. They provide a number of benefits, including cross-arch stability of the abutment teeth, axial loading of the teeth, good retention, and durability, and are therefore appropriate for elderly people, providing them with oral comfort and self-confidence. [1, 2]. Double crowns are commonly

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constructed of precious and non-precious metal alloys. Gold alloys have proven to be the greatest option for achieving clinically acceptable retention force, durability, and biocompatibility after decades of usage [2, 3]. Despite the many benefits of double crowns, they have been mostly phased out of use due to the high cost of gold alloy. Recently, new materials have been chosen, new production processes have been implemented, and new designs have been examined, all with the goal of increasing accuracy and precision. Modern systems of double crowns are based on zirconia ceramics (ZrO2) and polyether ether ketone (PEEK). For producing double crowns, PEEK material was used using a computer-aided design and computer-aided manufacturing (CAD/CAM) technology. It's about to become the centre of attention. PEEK (polyetheretheretherketone) is a high-performance thermoplastic polymer made composed of an aromatic backbone molecular chain linked by ketone and ether functional groups. Its structure provides excellent chemical resistance as well as thermal and post-irradiation degradation resistance. Its melting point is about 343 degrees Celsius, and its elastic modulus is between 3 and 4 GPa [4-6]. PEEK is chemically inert and has a lower solubility and water absorption than contemporary aesthetic computer-aided-design/computer-aided-manufacturing (CAD/CAM) polymers [7]. Furthermore, biofilm development on the surface of PEEK is comparable to or even lower than that on titanium and zirconia dental materials. Moreover, it provides many advantages. When compared to non-precious metal alloys, titanium, and ceramics, it is a low-cost, light-weight, and easy-to-work-with material. Because of its insolubility, it is a good substance for allergy sufferers. [8-13].

Another recent advancement is the introduction of polymethyl methacrylate (PMMA) doped with graphene nanoparticles, which has demonstrated promising characteristics and might be the future of restorative dentistry. [14].

Recent developments in nanotechnology have enabled the use of graphene family materials as a reinforcement phase in several polymers [15, 16].

The use of GO in PMMA resins for prosthetic rehabilitation appears to be a viable alternative. However, further research is needed to guarantee that these procedures and materials have scientific backing. Graphene is a single sheet of one atom thickness arranged in a honeycomb-like lattice[16]. Xie et al., 2017 found out that GO can be functionalized and combined with polymers to produce composites with tailored properties Recently, graphene nanofibers and nanosheets have been incorporated into PMMA resins [17].

The biocompatibility and biodegradability of GO, as well as its strength, antibacterial adhesive qualities, and flexibility, making it a material with promise in prosthodontics. [14-17].

In recent decades, when parameters are set appropriately, digital technologies have been characterized by great accuracy, even in the micrometer range [7]. Furthermore, the adoption of CAD-CAM technologies, which eliminates mistakes connected with the pressing process, has resulted in an improvement in efficiency [8,9]. The pressed PEEK material subjected to the pressing process included a more difficult sequence with a higher number of potential sources for errors. Especially the unpredictable expansion coefficient of the investment material caused incalculable dimensional changes hence interacting with the telescopic fitting the pre-heating procedure is determined by the oven's specific heating characteristics. Even at the inner surface, the material's contraction during the chilling process affects the fitting results. The retention forces and even the estimated fitting might have been affected by the inner surface, which was roughened by airborne particles to remove the investment material. Aside from that, the heating procedure may have affected the PEEK material's unique chemical structure. Several heating procedures, particularly in the PEEK pellet conversion process, alter the ratio of amorphous and crystalline fractions in PEEK.

A modification of the previous system was developed to make the inner crown has a cone-like shape [18]. As a result, its axial surfaces taper occlusally in a particular angle known as the convergence angle (or taper). Retention is obtained by the wedging action.

The conical type is more commonly utilised than the cylindrical design because it is less difficult in fabrication [20], and less harmful to abutments and their supporting tissues [19, 20] this design also offers the benefit of deciding the forces that would be applied to each abutment. The conical design, on the other hand, has the drawback of decreased retention after a period of usage [10,18-20].

Based on our knowledge no studies tested the use of PEEK and graphene reinforced resins as telescopic crowns and check their retention forces. Accordingly, the current study aims to measure the in vitro retention overall pull-off force of telescopic crowns made from two different materials Polyether-ether ketone (PEEK) CAD-CAM disc and graphene-nano reinforced acrylic disc (GN) tested at three taper angles (0˚, 1˚& 2˚). It is hypothesized that both different taper angles and materials used may affect the retention force of the telescopic crowns.

MATERIALS AND METHODS

Creation of the subject models

Two materials were studied using different taper angles. Polyether-ether ketone (PEEK) CAD-CAM disc (DISCO SMILE PEEK, Milano, Italy) and graphene-nano reinforced acrylic disc (GN) (G-CAM, Graphenano Dental, Valencia, Spain) were tested at three taper angles (0°, 1° & 2°). A 3D model was designed in CAD software (MOI v2, Triple squid software design, USA) to simulate a maxillary premolar tooth prepared for the telescopic crown. The dimensions of the tooth die were prepared as an average of the premolar tooth anatomy. The model was converted to STL to

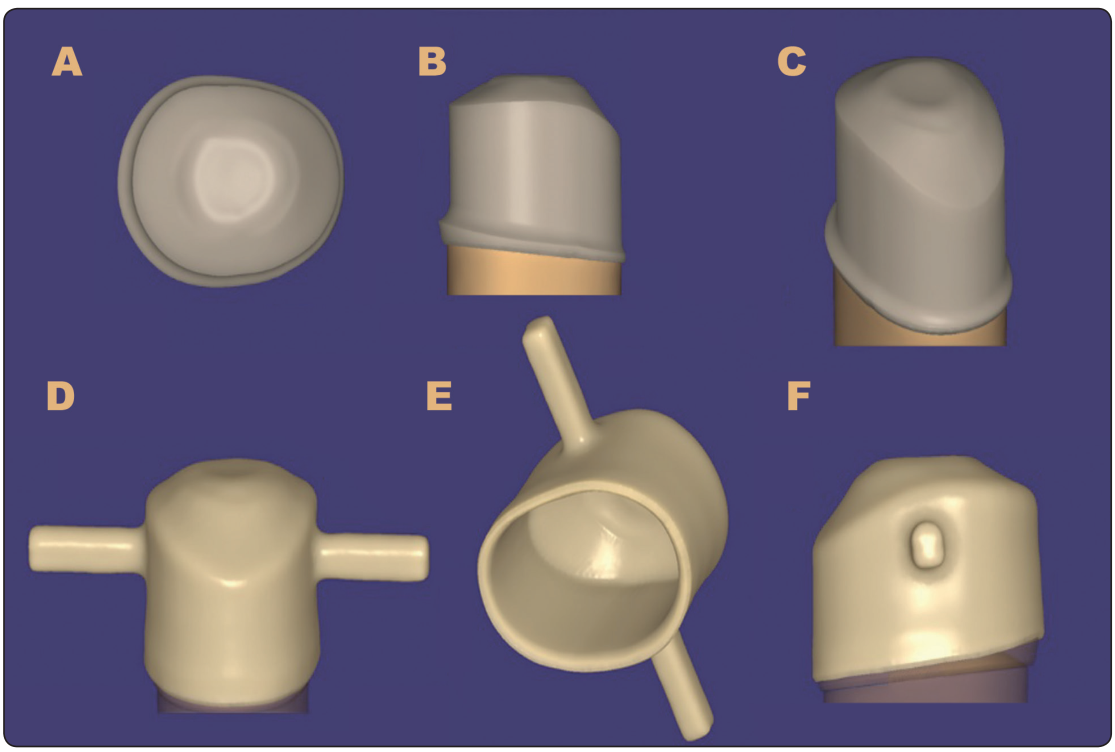

Fig. (1): A, B & C; primary coping of the telescopic crown designed at 0° taper at top, lateral and isometric view. D, E & F showing secondary coping design in, front, lateral and isometric bottom view, with two extension arms as added to enable testing machine attachment.

be used in the Dental CAD-CAM software (Exocad DentalCad Matera, v.2.3, Germany). Primary copings were designed as a telescopic crown with frictional areas required for telescopic crowns based on three taper angles (0°, 1°& 2°). Simultaneously, the primary coping was merged with the prepared tooth as one solid 3D object (fig.1A, B & C) [10].

Primary copings were 3D scanned with a bench scanner (D700, 3shape, Copenhagen, Denmark). Secondary coping was designed as offset coping using the dental CAD software. Two extension arms were added on the same horizontal level to the secondary coping design to be used later for holding the wire attachment of the mechanical testing machine during insertion and removal. A slight spacer (10 μm) was considered between the 1ry and the 2ry copings to enable insertion and removal. (fig. 1D, E & F) [12].

Fig. (2): Samples milled in the CAD-CAM machine from two disc materials (PEEK and GN CAD-CAM discs).

Both primary and secondary copings were milled in the CAD-CAM 5-axis milling machine (DWX-520, Roland, California. USA). Based on the study groups two material discs were installed and milled using the milling pre-customized setting. Thirty primary and secondary 3D models were milled based on the materials (PEEK and GN) and taper (0°, 1°& 2°) under study, (fig. 2). Accordingly, samples were categorized, 5 in each group, based on the following chart, (fig. 3).

All samples were fitted in acrylic resin blocks attached to the root part of the tooth die to enable firm grip areas for the machine attachment. The primary coping die was attached to the universal mechanical testing machine (Instron, model 3345, Instron England) arms then the secondary coping was placed with 5 kg weight on the top of the primary coping for 20 seconds. The machine was set to a crosshead speed 50 mm/min applying tension mode of force up to crown dislodgement. The secondary coping extension arms were firmly gripped with attachment wires with the machine jig positioned perpendicular to the loading direction allowing insertion and removal parallel to the tooth long axis, (fig. 4).

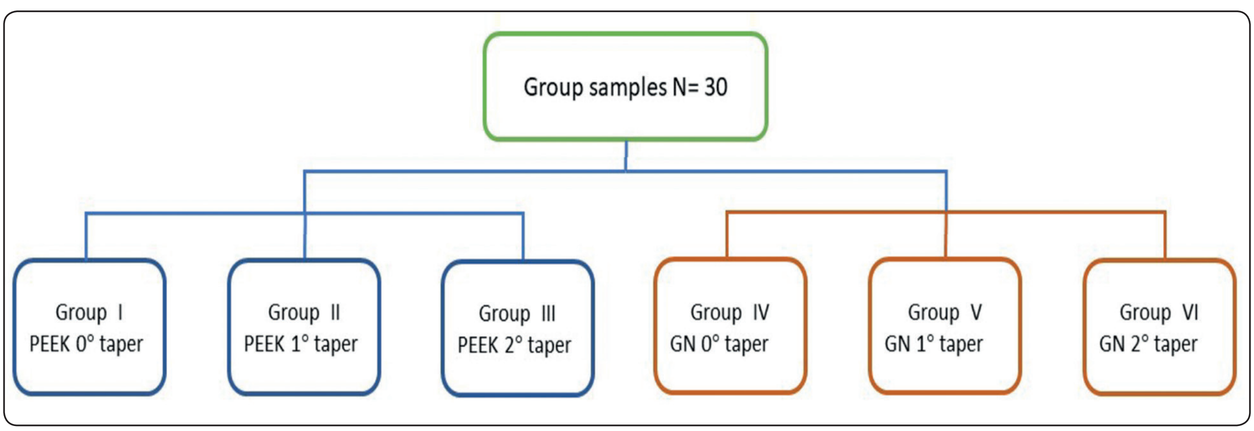

Fig. (3): Different studied groups categorized based on the material (PEEK and Graphene-based resin) and taper angle (0,1 and 2°) used.

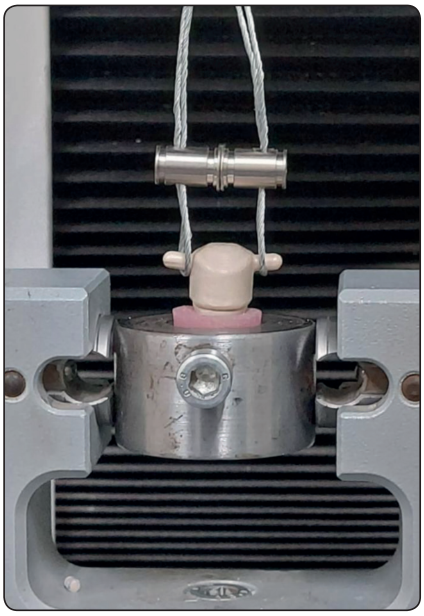

Fig. (4): Universal testing machine holding the sample in place and the jig wires attached to the extension arms of the secondary coping after preloading.

Twenty cycles of insertion and removal were performed for each sample and then the retention force was computed and recorded using computer software (BlueHill universal Instron, England).

Statistical analysis was computed using S-plus statistical package for social sciences (SPSS, IBM SPSS Statistics for mac, version 24 software, Armonk, NY: IBM Corp, USA). Descriptive analysis was represented as mean and standard deviation. Data were checked for normality using Wilk test and were found normally distributed.

A One-way analysis of variance (ANOVA) was conducted to explore the effect of different degrees of taper of each material on the retention load. Post-hoc comparison using Tukey's test were used to investigate differences between groups and the significance level was set at ($p \leq 0.05$). An independent sample t-test was used to compare the effect of different materials within the same taper angle on the retention load at ($p \leq 0.05$).

RESULTS

The results of the mean and standard deviation of the retention force of the PEEK milled groups showed highest value for tested taper 0° (6.88±0.64 N), followed by the taper 1° group (6.43±0.75 N), then 2° taper group (5.09±0.48 N) that had the lowest value. No significant difference was shown between 0° and 1° tapers at ($p \leq 0.05$). A statistically significant difference was shown between 0° and 2° tapers and also between 1° and 2° tapers, as shown in (Table 1).

Mean and standard deviation of the retention force of the GN milled groups showed highest value for tested taper 0° (5.01±0.60 N), followed by the taper 1° group (4.84±0.44 N). then 2° taper group (4.14±0.36 N) that had the lowest value. No significant difference was shown between 0° and 1° tapers at ($p \leq 0.05$). A statistically significant difference was shown between 0° and 2° tapers and also between 1° and 2° tapers.

Regarding the effect of the materials, the PEEK material groups showed higher retention force than GN tested groups for all the tested taper degrees with significant difference at ($p \leq 0.05$), as shown in (Table 1).

TABLE (1): Mean, standard deviation (in Newton) and significant difference of the effect of different taper angles and materials on the retention force.

Taper	Material		P-value
	PEEK	GN	
	Mean (± Standard Deviation)	Mean (± Standard Deviation)	
0°	6.88aA* (±0.64)	5.01aB (±0.60)	0.0001
1°	6.43aA (±0.75)	4.84aB (±0.44)	0.0001
2°	5.09bA (±0.48)	4.14bB (±0.36)	0.0001
P-value	0.0001	0.001	

***** *Different small letters indicate a significant difference within the same column for every material. Different Capital letters indicate significant differences within the same row for every taper.***

DISCUSSION

The current study examined the impact of different materials on retention force values in (PEEK) CAD-CAM telescopic crowns and (GN) reinforced acrylic telescopic crowns subjected to different types of taper. The findings revealed that both taper and material have a substantial influence on retention force values.

The study defined the taper angles of 0°, 1° and a maximum taper of 2°. The reason behind using the maximum value of taper as 2º was that retention was rapidly lost when the taper angle exceeded this range 2° [19].

This study determined the detachment force of the crown as 50mm/min which apply a tension mode of force up to crown dislodgement in all models with different angles. The milled group with 2° taper showed the lowest retention force values. This result might be because the taper angle has increased. The crown would detach more readily as the angle increased, and the tension would be reduced. The retention of parallel telescopes based on the sliding and static friction phenomena between the contacting areas of the primary and secondary crowns. As a result, the larger the retention force, the lower the convergence angle. The result was as expected by [18, 12]. They claimed that the lowest taper angle allows more area of friction and wedging action between the crowns. An increase in the size of friction area increases the retention force. However, some authors disagreed with this conclusion, recommending 2° taper angle to maintain accepted retention [10, 19]. Their Potential explanations focused on the contrasts between the machine's production process and the milling process. Parallel surface area and insertion direction were particularly important in the milling method. Furthermore, the physical properties of different materials as well as different combinations of the materials of the 1ry and the 2ry crowns may play a role explaining the increase of the retention force with the increase in the taper angle.

On the other hand, Shiba mentioned that taper angle may be used according to the crown length and the physiologic movement of the abutment [11].

The present study's findings also revealed that crowns constructed of PEEK material had higher retention force values. This might be attributed to the milling PEEK material's lower elastic modulus as compared to milled GN material. PEEK is a soft and ductile material that yields and adapts well. The low elastic modulus and the ductility were reasons for the good processability of PEEK. The adaption process appeared easy, which resulted in a good marginal fit. Slight plastic deformation of the PEEK material during testing may result in improved adaption of the main and secondary crowns, resulting in higher retention force values.

Many researchers agreed on this [8, 10, 12]. Milic et al. [12] evaluated the total pull-off force of telescopic crowns in vitro using zirconia ceramics and PEEK material as main crowns. They discovered that PEEK specimens had greater initial retentive force values than zirconia specimens. They stated that the phenomena that happened during the crown's settling-in phase was caused by plastic deformation of the materials, which resulted in an increase in the actual contact surface area. As a result, the tension between the surfaces was reduced. The existing tension would decrease as long as the limits of elasticity were exceeded anywhere in the contact area.

Moreover, Stock et al. [10] carried out a study to test the retention force (RF) between polyetheretherketone (PEEK) primary and cobalt-chromium (CoCr), zirconia (ZrO2) and galvanic (GAL) secondary crowns with three different tapers. They found that Putting a CoCr or ZrO2 secondary crown on a PEEK primary crown could led to a strong wedging. They suggested that the cause for this might be related to PEEK's flexibility and elastic modulus variations. This might explain why the retention force ratings of the 2 º tapered crowns are higher than 0 º tapered crowns. They came to the conclusion that PEEK might be a good choice for primary crowns material, regardless of the taper and the material of secondary crown.

CONCLUSION

Telescopic crowns fabricated from PEEK milled material showed better in vitro retention force than the GN milled material. Increase the degree of taper angle of the telescopic crown above 1 ° could jeopardize the resultant retention. However, long-term clinical studies are still recommended.

Recommendations

The specimens should be tested clinically to measure the real retention force intra orally. Taking into consideration thermo-mechanical stress the tested specimens are exposed to, which occurs under daily wear.

Another restriction of the present investigation is that the number of samples was limited by the production costs. Thus, the significance of the measured values is additionally limited from a statistical point of view. Further studies focusing on the fit between primary and secondary crowns in relation to changed CAD-CAM parameters and retention behavior are necessary to verify the results obtained in the present study. Long-term results, however, are still necessary.

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