The Effect of Two Different Fabrication Techniques on PEEK Telescopic Crowns to Retain Mandibular Implant Overdenture (In-Vitro Study)

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Abstract:

Objective: To evaluate the retention force between primary telescopic crowns milled from PEEK material and secondary telescopic crowns constructed from PEEK material with two different techniques (milled and pressed).

Material and method: Primary and secondary copings (N= 28, n= 14 per group) were fabricated using Polyetheretherketon (PEEK) material. Primary telescopic crowns were milled using CAD/CAM technology while secondary copings were made with two different techniques: (group 1(PM): which milled from PEEK using CAD/CAM technology; while group 2 (PG): which fabricated from PEEK granules with pressing technique). The retention forces were analyzed using the universal testing machine where secondary copings were pulled off by an upper chain with a speed of 50 mm/min.

Results: The milled PEEK secondary copings showed higher retention force values than the pressed ones.

Conclusions: Different fabrication techniques of telescopic crowns influence the retention forces between the primary and secondary copings.

Keywords: Implant retained mandibular overdenture, PEEK telescopic attachment, CAD/CAM technology.

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Introduction:

Due to a reduced load-bearing capacity and poor retention, edentulous patients frequently encounter functional and emotional issues with their conventional dentures (CD). The first line of treatment for such denture-related issues is placing dental implants to hold a detachable overdenture in place. (1)

Implant placement is recognized as a safe, dependable therapeutic method with high survival rates (>95%) for retaining an overdenture. Additionally, mandibular implant-retained overdentures (IOD) exhibit superior stability and retention than conventional dentures (CDs), boosting chewing capacity and bite power. (1)

In order to facilitate prosthesis retention, support, and stability during functional and parafunctional activities, the overdenture attachment system is employed. Attachments are regarded as the pillars of overdentures supported by implants. (2)

To attach implants to overdentures, a variety of commercially available attachment systems are used. A variety of attachment designs are offered by various vendors. There are four different types of attachment assemblies that are frequently used, depending on the type of attachment system. They are Stud, Bar and Clip, Magnetic and Telescopic attachments. (2)

Double crowns, sleeves, and crown coping (CSC) are other names for telescopic crowns. These crowns are composed of an abutment-tightly attached main or inner telescopic coping and a congruent, removable secondary or outer telescopic crown. These retainers provide good retention due to the frictional contact between the crown and sleeve. They also provide improved force distribution and help to preserve the tooth and alveolar bone by increasing the crown root ratio and axial transmission of occlusal stress. This is caused by how the outer crown and abutment are connected circumferentially. Based on the wall design, telescopic retainers can be classified as parallel sided crowns. Conical-shaped crowns that are tapered and crowns with extra attachments. (2)

Telescopic crown could be manufactured from multiple different materials, The most common dental materials used in the double crown-retained systems for removable dentures are titanium, non-precious metal alloys, precious metal alloys, zirconia, and high-density polymers [polyaryletherketone (PEEK) family] (3)

Polyether ether ketone (PEEK) is a semi crystalline linear polycyclic aromatic polymer. Although PEEK is a rigid material with greater thermal stability, low plaque affinity, one of the best biocompatibilities, and favorable physical, chemical, and mechanical properties, its grayish brown color prevents it from being used for anterior teeth's aesthetic restoration. (4)

PEEK can be processed in one of two ways: vacuum pressing or milling from blanks created using CAD/CAM software. Regarding pressing method, the market offers either granular form or industrially pre-pressed pellets. The process is comparable to the alloy cast process, which involves placing a heated muffle containing molten PEEK in a vacuum-pressing apparatus first. (5)

Precision milling of the inner and outer crowns has become increasingly widely used as a result of the development of computer-aided design (CAD) and computer-aided manufacturing (CAM) technology. As a result, new materials for primary and secondary crowns have been developed, such as zirconia ($ZrO2$), titanium, or high-strength resins like polyether ether ketone (PEEK). The cost of manufacturing and human labor associated with double-crown-retained RPDs, as well as the associated financial load on the patient, may be decreased by milling primary and secondary crowns from these materials. (6)

There are two additional methods of converting Polyetheretherketone (PEEK) material: pressing from granules or pressing from pellets with a specialized vacuum-pressing apparatus. These methods are in addition to milling PEEK material from blanks using CAD/CAM software. Prepressed forms of the raw material PEEK granules include blanks and pellets. (7)

MATERIALS AND METHODS:

- For this study, 14 sponge models of edentulous mandibular arches were used. Each model had two dummy implants placed bilaterally on the lateral/canine region utilizing a sequential drilling technique. (Fig:1-2)

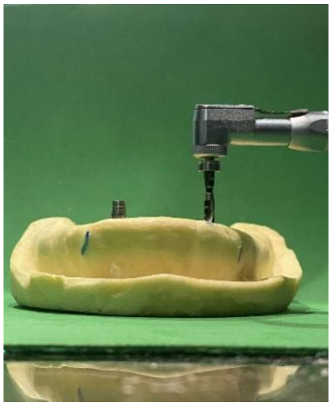

Figure 1: drilling procedure

Figure 2: checking parallelism between implants.

- Non-engaging Ti-base abutments were attached to each dummy implant, and the Ti-bases were then treated with a specific spray in preparation for extra-oral scanning. (Fig: 3)

Figure 3: Ti-base attached to dummy implants.

- Using the Exocad software, the models were scanned using an extra-oral scanner (DScan 5) to produce a 3D image that was utilized for designing the resilient telescopic crowns. (Fig: 4)
- For all groups, the same principal crown design specifications of 1.1 thickness and 5 mm height (3 mm gingival height was paralleled and the occlusal 2 mm was 2° occlusally tapered) were maintained. (Fig: 5)

Figure 4: Model scanning with Extra-oral scanners.

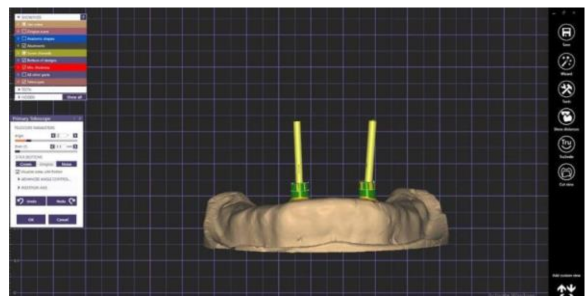

Figure 5: design of Primary telescopic crowns by Exocad software

- CAM technology was used to fabricate primary crowns from PEEK blanks (breCAM BioHPP, bredent) using milling machine (IMES iCore 350i, imes-icore GmbH, Eiterfeld, Germany).
- The fitting surfaces of primary copings and Ti-bases were sandblasted using 110 um aluminum oxide particles (BEGO sandblaster, BEGO Bremer GMBH, Germany) under pressures of 2 to 3 bars. The

fitting surface of copings was coated with PEEK primer (Visio Link, Bredent, Germany) for PEEK crowns, which was then light cured for 90 seconds. The Ti-bases were coated with metal primer (MKZ-primer, Bredent, Germany) for 30 seconds.

- Utilizing dual-cure adhesive resin cement (SuperCem, Self-adhesive resin cement, South Korea), primary crowns were attached to the Ti-base abutments. (Fig: 6)

Figure 6: Primary telescopic crowns attached to the Ti-bases.

- The primary copings were scanned utilizing extra-oral scanners to create the secondary copings based on their 3D representation. Primary and secondary copings were separated by occlusal space (0.3 mm), which was designed as a parallel wall with a minimum wall thickness of 0.5 mm. A hole shaped like a roof ridge was drilled into the secondary crown's occlusal surface in preparation for eventual retention force tests. (Fig: 7)
- The models were divided into the following categories depending on the method used to create the secondary crowns:

1st group: in which the secondary copings were constructed from PEEK material by milling technique.

2nd group: in which the secondary copings were constructed from PEEK material by pressing technique.

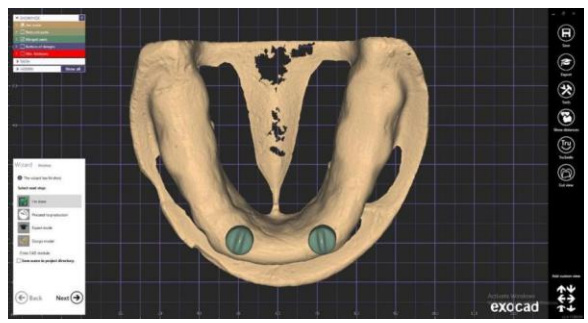

Figure 7: design of secondary coping by Exocad software

- Milling technique was used to fabricate secondary copings from PEEK blanks in one group and from wax (breCAM.wax, bredent) in the other group.
- The waxed crowns were invested and then burned out leaving a mold of crown which was used to fabricate the secondary coping from PEEK material (BioHPP Granulat) by pressing technique.

- In the lost wax technique, the waxed crowns were embedded in a muffle according to the manufacturer's instructions. After 25 min, the muffle and the press plunger were placed in a preheated furnace at 850°C for 60 min, then allowed to cool down till it reached 400°C for another 60 min. Subsequently, the pre-heated muffle was filled with PEEK granules, and kept in the preheating oven for 20 min at 400°C. Then, the crowns were pressed at a pressure of 4.5 bar in a special vacuum-pressing device.
- After cooling, the crowns were divested using 110 um alumina particles, then they were polished manually.

Retention force evaluation:

The models with the primary crowns were placed in a universal testing machine. The secondary crowns were placed on their respective primary crowns in their final position using artificial saliva, then they were held by a hook, allowing the whole system to self-align. The secondary copings were pulled off by an upper chain with a speed of 50 mm/min. Then retention force values were calculated.

Statistical analysis:

Statistical analysis was performed with SPSS 16 ® (Statistical Package for Scientific Studies), Graph pad prism & windows excel and presented as mean and mean difference, and standard deviation in 1 table and 1 graph. Exploration of the given data was performed using Shapiro-Wilk test and Kolmogorov-Smirnov test for normality which revealed that data originated from normal data. Accordingly, comparison between 2 different groups was performed by Independent t test. The significance level was set at $p \leq 0.05$.

Results:

Comparison between both groups was performed by using Independent t test which revealed that group I (23.78 ± 5.64) was significantly higher than group II (19.44 ± 5.49) with (4.34) mean difference as P= 0.049*. (Table 1) (Fig: 8)

Table (1): Mean and standard deviation of retention in both groups and comparison between them using independent t test:

	M	SD	Difference (Independent t test)				
			MD	SEM	95% CI		P value
					L	U	
Group I	23.78	5.64	4.34	2.104	-8.66	-0.016	0.04*
Group II	19.44	5.49					

M: mean SD: standard deviation MD: mean difference SEM: standard error mean
CI: confidence interval L: lower arm U: upper arm
**Significant difference as P<0.05.*

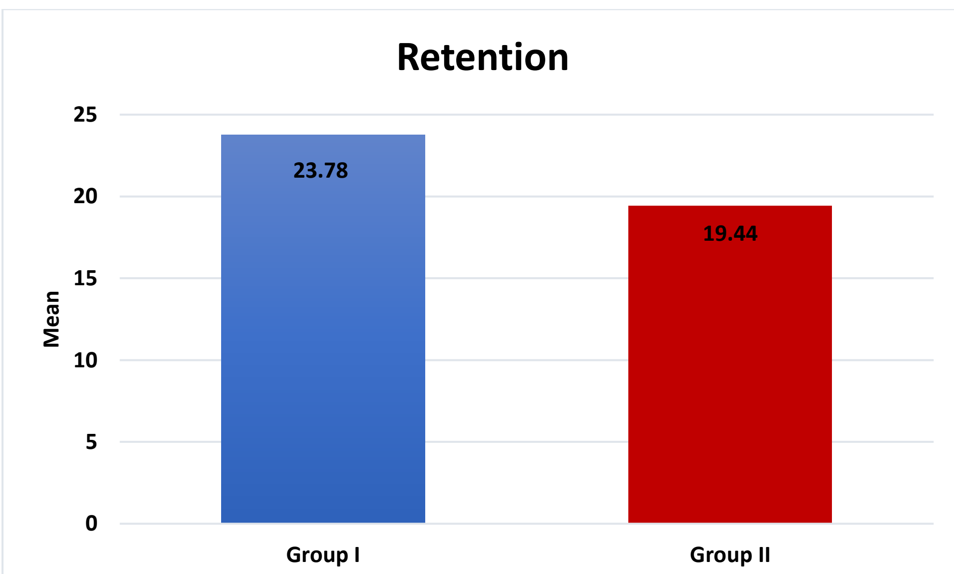

Figure (8): Bar chart representing retention of both groups.

Discussion:

The current study compared the retention force between primary telescopic crowns constructed from PEEK with milling technique and secondary copings constructed from (PEEK) with 2 different techniques; first were milled by CAD/CAM and second were pressed, that was evaluated using the universal testing machine.

In this study, a conventional taper angle of 2 was used to enable prosthesis insertion, give a slight degree of resilience, and prevent excessive implant loading. The reason for choosing 2° degree was that Ohkawa et al. observed that retention was rapidly lost when the taper angle of telescopic crowns surpassed 2°. (8)

The majority of studies assessing retention forces of implant overdenture attachments were conducted in laboratory settings in order to apply pure vertical dislodging forces and prevent non-axial dislodging of the dentures if retention was assessed clinically. Due to the existence of the opposing jaw in clinical settings, it is challenging to apply dislodging forces perpendicular to the occlusal plane from the center of the dentures. As a result, non-axial dislodging frequently happened, which doesn't reflect retention forces but rather stability forces. (9)

One of the most popular teeth used for anchoring telescoping dentures is the canine. As a result, in this study, we chose to fabricate telescoping crowns using an artificial canine. (10)

Polyether ether ketone (PEEK) material was used to make telescopic crowns because it is a semi-crystalline engineering thermoplastic, exhibits exceptional chemical resistance, superior mechanical strength and dimensional stability, and good property retention at long-term high temperatures. PEEK polymer has a melting point around 341°C (646°F) and can survive longer periods under harsh conditions at 260°C (480°F). The good comprehensive performance of PEEK makes it possible to replace conventional materials like metals and ceramics in some applications, enhancing the product comprehensive performance and reducing the product weight.(11)

PEEK material comes in two different forms: granules and pellets. Granulated PEEK is the form of PEEK that is most frequently used and has demonstrated qualities like great heat resistance, flame retardancy, melting point over 700º F, outstanding chemical resistances, excellent electrical properties, high mechanical strength, and impact resistance. Based on the stated characteristics, PEEK granular material (BioHPP Granulat) (PEEK, 20% weight titanium oxide) was employed.

CAD/CAM technology is characterized by its high precision and is currently utilized to mill and create telescopic crowns. Furthermore, the adoption of CAD/CAM techniques, which avoid errors related to casting technology, has been credited with an increase in efficiency. (5)

In this study, a universal testing machine was used to measure the retention force between the primary and secondary coping of telescopic crowns. Retention forces have been investigated under moist conditions in previous studies of telescopic crowns to generate hydraulic adhesion between primary and secondary crowns. Previous studies have employed both distilled water and artificial saliva to create a moist environment. (12, 13)

In this investigation, the assessment of retention force was carried out at speed of 50 mm/min as Ohkawa et al. examined multiple speed values of 0.05, 2.5, 5, 10, 100 cm/min with the important outcome that there was no significant difference between retention forces at each speed. As a result, we chose to utilize a speed of 50 mm/min, which represented a mean value of clinical relevance, which can be commonly used under most technical settings. (8)

This study found that group 1 (milled PEEK blanks) displayed better retention values than group 2 (pressed PEEK granules), which is consistent with recent studies that found milled telescopic crowns had higher retention forces than those made using the lost wax technique. (13,14)

This finding could be attributed to the fact that the pressed PEEK as a technique is similar to the conventional lost wax technique, which entails more complicated procedures and has more possibility for error, particularly, the dimensional changes of the material that affect the telescopic fitting. (15)

Another reason could be due to the softer nature inherited in the pressed PEEK which increases its resiliency in comparison to milled PEEK. It was found that the flexibility and mechanical performance of the final PEEK product depend on the perform shape of the PEEK (blanks, pellets, or granules). According to a recent study, PEEK pressed from the granular form is softer and has a lower modulus of elasticity than PEEK blanks because industrially, the granular form does not undergo prepressing, whereas PEEK blanks and pellets are extruded from PEEK granules, which is the raw material for both the blanks and pellets. This increases their mechanical properties in comparison to the granular form. [(15)]

Conclusion:

With the limitation of this study, it was concluded that milled PEEK secondary telescopic crowns showed better retention force values than pressed ones. However, long-term investigations are still needed.

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