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RETENTION LOAD AND VOLUME LOSS OF TELESCOPIC PEEK CROWNS WITH DIFFERENT TAPER ANGLES AND THICKNESS: IN VITRO STUDY

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ABSTRACT

Objective: The aim of this study was to investigate the Retention force and Volume Loss of CAD/CAM-fabricated polyetheretherketone (PEEK) telescopic crowns which with different Tapers and Thicknesses. **Material and methods:** Peek primary crowns (N = 5) were CAD/CAM milled and provided with secondary crowns CAD/CAM-fabricated PEEK secondary crowns (group N = 5). The universal testing machine was used to determine the retentive force and volume loss at values at baseline and after 3, 6, 9, and 12 months. Data were analyzed by using Statistical Package for Social Sciences P value <0.05(*) was considered a significant difference & P-value <0.001(**) was considered a highly significant difference. **Results:** Maximum Retentive Load results were analyzed by using mean and standard deviation. repeated measure ANOVA test is used to compare duration in each group in which there is a highly significant difference between durations, also One Way ANOVA test is used to compare groups in each period, while there is no significant difference between groups in each duration. PEEK; secondary crowns exhibit stable retentive force values over 12 months of use showing no signs of deterioration while the retentive force values of electroformed secondary crowns increase over time. **Conclusions:** Clinical relevance PEEK might be a suitable alternative to proven metallic materials for the fabrication of secondary crowns.

KEYWORDS: CAD/CAM Double crowns. Polyetheretherketone (PEEK); Retentive force; Implant prosthetics.

INTRODUCTION

The use of dental implants to support the restoration of missing teeth has a long and varied history because tooth loss is common and can be caused by disease or trauma. When; teeth are lost, the masticatory function is reduced. The use of dental implants to support the replacement of lost teeth has a long and complex history because tooth loss is quite prevalent and can occur due to disease and trauma (1-5).

A telescopic denture is "an overdenture which is a dental prosthesis that covers and is partially supported by natural teeth, natural tooth roots, and, or dental implants" (1). The; phrase telescopic denture refers to the type of prosthesis that includes a double crown system as retainers or attachments.

Double-crown attachments comprise two crowns; the primary crown (inner crown), which is firmly attached to the tooth or implant, and a precisely matching outer secondary crown is incorporated in

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the denture connected to the denture[2]. Classical; double crown systems' retention effect is based on the mechanical concepts of friction or wedging.

Because of the benefits of adequately incorporating Double crowns, they efficiently transfer the occlusal forces along the longitudinal axis of the abutment tooth or implant abutment. Additionally; they offer direction, and defense against movements that could dislocate the denture[2]. In addition to providing distribution of force on the abutments, high patient comfort and favorable long-term survival rates have been reported with the preservation of periodontal health; Further benefits are favorable long-term survival rates and achievement of good esthetics, have been documented [3,4].

Gold, titanium, titanium alloys, cobalt-chromium alloys, zirconium-based ceramics, and polymers are used to make crowns [5-7]. These; are materials with different hardness and friction coefficient [8]. A telescoping crown's parts may be made of the same or various materials [9].

Polyetheretherketone (PEEK), is a thermoplastic high-performance polymer that has a melting point of about 343° C. This; the material is an intriguing candidate for use in dentistry due to the investigated physical qualities [10] , abrasion resistance [11] , high hardness, and low water absorption and solubility [12]. There; are three methods in this field for converting PEEK material: milling from blanks using CAD/CAM software, pressing from granules, or pressing from pellets using a specialized vacuum-pressing apparatus. Pressed; forms of the raw material PEEK granules include blanks and bullets.

Additionally, it is simple to create a stable retentive force by adjusting various design features following each condition. This minimizes working time and decreases technical errors and sensitivity[13,14]. Also; it enables simple design modifications before manufacturing [15,16] and the chance of constructing primary crowns from a variety of materials, including tooth-colored materials like zirconia and PEEK, which are more aesthetically pleasing and cause less thermal irritation and hypersensitivity to vital teeth than metal alloys [17,18].

PEEK is a high-performance thermoplastic resin with advantageous physicochemical features with a long history of medicinal use[19]. From; the family of polyaryletherketone, polyetheretherketone (PEEK) has been introduced as a thermoplastic and semi-crystalline polymeric material [10]. Which characteristics include low water solubility, high thermal and chemical stability, high-temperature resistance, and high biocompatibility. It also has excellent mechanical properties. PEEK exhibits chemical inertness, a highly polished surface, a low plaque affinity, a low specific weight, and the capacity to build lighter, aesthetically pleasing metal-free RPDs due to its high hardness and low water absorption and solubility[12,20].

Therefore, PEEK is an exciting alternative to traditional alloy and ceramic dental materials that have attracted attention and are increasingly being used in fixed and removable prosthetics. For; dental applications, PEEK can be processed using computer-assisted design and computer-assisted manufacturing (CAD/CAM) technology from industrially manufactured blanks or by heat pressing from pellets or ingots. Processing; PEEK restorations using CAD-CAM produce restorations with superior and more reproducible mechanical properties [21-23].

PEEK is, therefore, an intriguing substitute for conventional alloy and ceramic dental materials that have gained attention and are being utilized more frequently in fixed and removable prosthetics. PEEK; can be processed for dental applications by heat pressing from pellets or ingots or using computer-aided design and computer-assisted manufacturing (CADCAM) technologies from industrially produced blanks. Using; CAD-CAM to process PEEK restorations results in restorations with better and more repeatable mechanical characteristics [21-23].

Using CAD/CAM, it is also possible to design every component individually, including the implant, retainer, and milled denture. Consequently; utilizing CAD/CAM is favorable and particularly beneficial in implant-supported telescopic dentures(15).

For these purposes, PEEK material is already successfully used in daily clinical practice by numerous dentists. However; there are few investigations on the PEEK double crown systems' retention force, whether; the retention force and volume loss of PEEK double crown systems are impacted by the thickness and taper of the PEEK double crowns.

According to Kotthaus et al., there is currently no information on the wear behavior of PEKK utilized in a telescoping crown system (24).

Therefore, this study aimed to evaluate the retention forces and volume loss of double crown systems of PEEK crowns, which were manufactured by different thicknesses with two different tapers during the Insertion-Removal test. Retentive force; values were measured before, during, and after The test which, was repeated 360, 720, 1080, and 1440 cycles to clinically simulate the 3,6, 9, and 12 months of Insertion-Removal condition, The null hypotheses that were examined were:-

The tested null hypotheses were that

1. The number of Insertion-Removal tests shows no impact on the retention force values or volume loss.
2. The thickness of secondary crowns from PEEK shows no impact on the retention force values.
3. Different tapers also show no impact on the retention force values.

MATERIALS AND METHODS

In the present study, the telescopic crowns used have differed concerning the following two characteristics:

A. The thickness of secondary crowns is 1mm, 2mm

B. Degree in taper

The taper of the primary crowns was set at 2°, 6°.

The experimental design, therefore, resulted — based on A and B— in 4 different test groups with five specimens each. To; avoid any operator impact all samples were made by one qualified person.

Study Design

A total of 20 implant abutments will be designed and fabricated in two-piece implants by using different designs in 4 groups (n = 5).

Group 1: Primary crown tapering angle2°

A secondary crown thickness of 1mm will be used.

Group 2: Primary crown tapering angle 6°

A secondary crown thickness of 1mm will be used.

Group 3: Primary crown tapering angle2°

A secondary crown thickness of 2mm will be used.

Group 4: Primary crown tapering angle6°

A secondary crown thickness of 2 mm will be used.

Fabrication of the primary crowns

Each implant's abutment was scanned by (Zirkonzahn The South Tyrol-based company Zirkonzahn Italy). The primary crowns were designed by the Exocad software (Exocad DentalCAD, exocad GmbH, Darmstadt, Germany) with a height of 6 mm and a deep chamfer finish line preparation, primary crowns with different convergence taper of 2° and 6°. Primary crowns; were milled from one PEEK resin blank (JUVORA™ Dental Disc, United Kingdom), using (a VHF milling machine, in Germany).

Each abutment was primed by ((MKZ Primer; bredent GmbH & Co KG MKZ Primer, bredent, Germany) is used for conditioning titanium abutment alloys, then the Primary crowns were adhesively cemented on the Ti alloy abutments using a self-adhesive resin cement according to the manufacturer's instruction (Voco cement, Germany). Afterward, all primary crowns were polished with a silicone polisher (Whip mix pumice), brushes (4 40 ×), and a polishing paste.

Fabrication of the secondary crowns

Each primary crown was individually scanned (Zirkonzahn, The South Tyrol-based company Zirkonzahn Italy,) and the secondary crowns were designed by CAD software (exocad GmbH, Darmstadt, Germany)) with a hole on the occlusal surface. To specify the restoration direction of the secondary crown for later the retention pull out tests to attach to the hook by CAD software (exocad) with different thickness 1, 2 mm.

Measurement Insertion-Removal test,

- Volume loss
- Measurement of retentive force

Insertion-Removal test

The testing machine (Model 3345; Instron Instruments Ltd., USA) was adjusted to allow the crown placement to its predetermined terminal position and its subsequent removal from the abutment, thus simulating the placement and removal of a RPD at a crosshead speed of 50 mm/min. The test; was repeated 360, 720, 1080, and 1440 cycles to clinically simulate the 3,6, 9, and 12 months Insertion-Removal condition, according to previous studies (Fig. 2-a).

Topographic features methodology

The optical methods usually satisfy the need for quantitative characterization of surface topography without contact [(25).] Specimens; were photographed using a USB Digital microscope (because of easier access, affordability, and reduced time) with a built-in camera (U500X Capture Digital Microscope, Guangdong, China) connected with a compatible personal computer using a fixed magnification of 120X. By; using a USB Digital microscope which a built-in camera, each specimen was photographed. The surface of each primary coping was analyzed, and this was done at baseline, after 360, 720, 1080, and 1440 insertion removal cycles.

Technique; the images were taken with the following image acquisition system;

- Digital camera (U500x Digital Microscope, Guangdong, China) with 3 Mega Pixels of the resolution, placed vertically at a distance of 2.5 cm from the samples. The angle between the axis of the lens and the sources of illumination is approximately 90°.

Illumination was achieved with 8 LED lamps (Adjustable by Control Wheel), with a color index close to 95 %.

The images were taken at maximum resolution (2272 · 1704 pixels) and connected with an IBM-compatible personal computer using a fixed magnification of 120X. The images were recorded with a resolution of 1280 × 1024 pixels per image.

Digital microscope images were cropped to 350 x 400 pixels using Microsoft office picture manager to specify/standardize the area of measurement. The cropped images were analyzed using WSxM software (Ver 5 develop 4.1, Nanotec, Electronica, SL) (Horcas I, Fernandez R, Gomez JM, Colchero J, Gomez-Herrero J, and Baro AM, Review of Scientific Instruments. 2007; 78; 013705). Within; the WSxM software, all limits, sizes, frames, and measured parameters are expressed in pixels. Thus; system calibration was performed to convert the pixels into absolute real-world units. Comparing; an object of known size (a ruler in this study) with a scale generated by the software was done for Calibration.

Therefore, a 3D image was created of the surface profile of the specimens. Three; 3D images were collected for each sample, in the occlusal area, and on the sides of the site 10 μm × 10 μm. This area

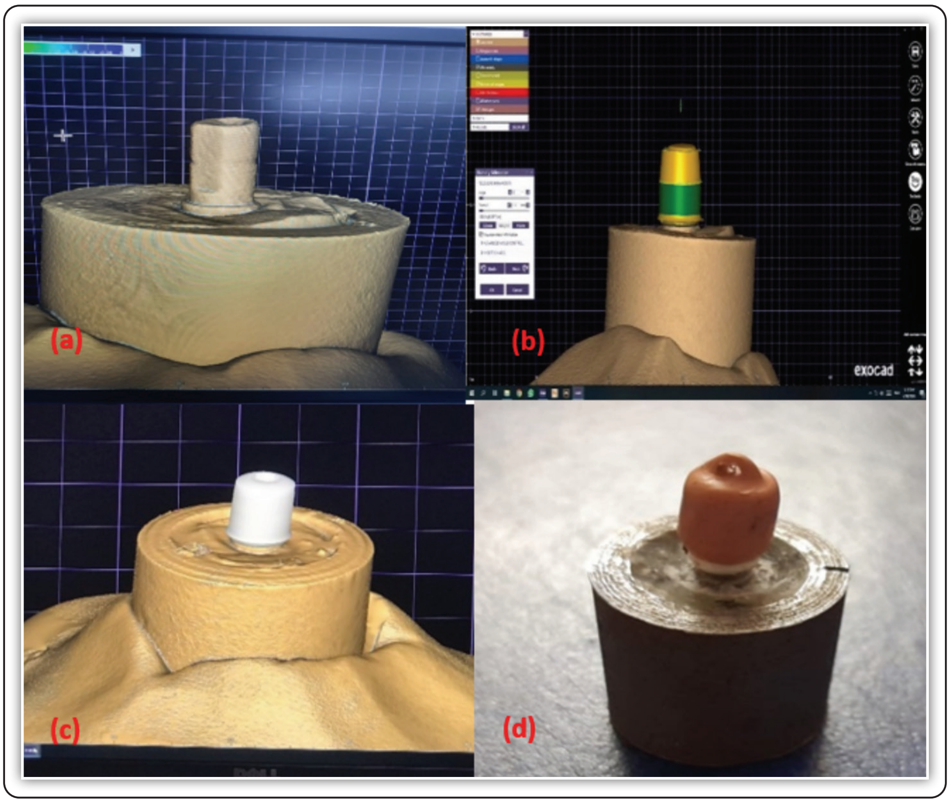

FIG (1) (a) Scanned abutment (b) the primary crown was designed (c) scanned primary crown (d) The secondary crown with a hole for the hook for the retentive test

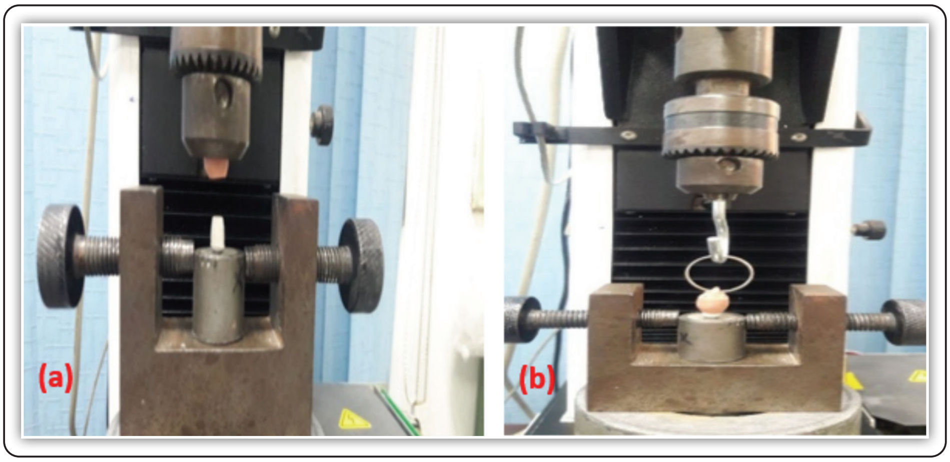

FIG (2) (a) Testing machine for Insertion-Removal test (b) Secondary crown with a hook on its primary crown during the pull-off tests.

was chosen based on the dimension of the typical bacteria expected to adhere to the restoration surface in vivo [26]. WSxM software was used to determine volumetric changes expressed in (µm3), which can be assumed as a reliable index of surface wear [27].

Retention test

These tests were performed using Bluehill® Lite from Instron Instruments.

Each crown with its implant abutment was fixed to the lower fixed compartment of a materials testing machine (Model 3345; Instron Instruments Ltd., USA) with a loadcell of 5 kN. Data was acquired using computer software (Bluehill Lite; Instron Instruments). The; sample was attached through a centrally positioned 0.07 mm diameter wire loop to facilitate the aligning with the machine's loading axis and proper load distribution. A; tensile load with pull-out a mode of force by the wire that was attached to the upper compartment of the materials testing machine at a crosshead speed of 5 mm/min. Newton; was used to record the load required to dislodge the sample (Fig. 2 -b).

The maximum resistance value during removal of the secondary crown was considered the retentive force. The Retentive force; was measured five times, and the mean of these five values was calculated.

Statistical analysis

Statistical analyses were performed by using Statistical Package for Social Sciences (IBM SPSS Statistics version 26). Numerical; variables are expressed by descriptive statistics as mean and standard deviation. Repeated; measure ANOVA test is used to compare durations in each group for Volume Loss (um3) and Maximum Retentive Load (N). Since One Way ANOVA test is used to compare groups in each duration for RMSE (um), Roughness Average (um), Volume Loss (um3,) and Maximum Retentive Load (N). P value <0.05(*) was considered significant difference & P-value <0.001(**) was considered highly significant difference.

RESULTS

Volume Loss results

Descriptive statistics describe the Volume Loss results using mean, and S.D. Repeated measure ANOVA test is used to compare duration in each group and there is no significant difference between durations, since One Way ANOVA test is used to compare groups in each duration, while there is no significant between groups (Table 1) & (Figure 3).

TABLE (1) Comparison between the four groups

Volume Loss (um3)						
Groups	3 Months	6 Months	9 Months	12 Months	F	p-value
	Mean ±S.D	Mean ±S.D	Mean ±S.D	Mean ±S.D		
Group 1	4.23±1.34	3.67±1.38	3.57±0.49	3.89±0.27	0.698	0.587
Group 2	4.78±1.38	4.58±0.28	3.82±0.93	4.13±0.51	0.715	0.542
Group 3	4.39±0.78	5.11±0.89	3.16±0.40	4.99±0.84	4.522	0.144
Group 4	2.21±0.68	4.63±1.16	4.62±0.46	4.76±0.17	11.409	0.052
F	3.331	1.039	3.912	2.971	-------	--------
p-value	0.077	0.426	0.050	0.097	-------	--------

There is a significant at P-value< 0.05 (*), and highly significant at P-value< 0.001 (**).

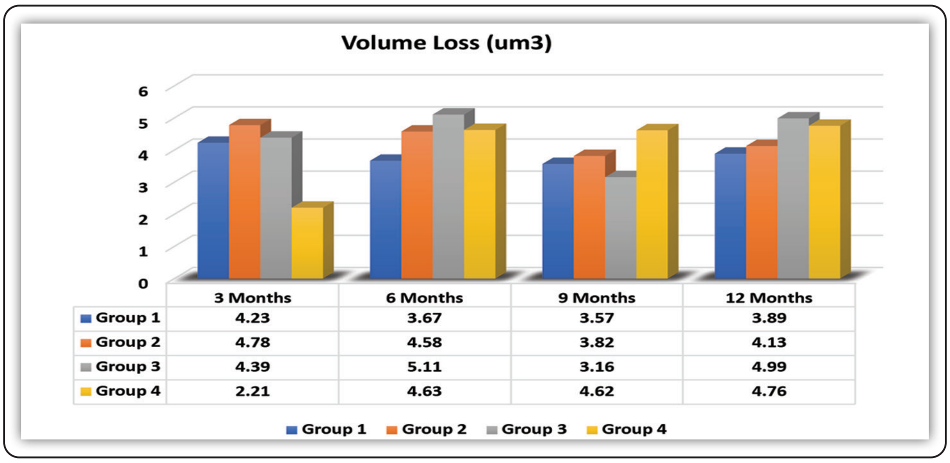

FIG (3) Volume Loss (um3)

Maximum Retentive Load results

Descriptive statistic describes the Maximum Retentive Load results using mean and, S.D. Repeated measure ANOVA test is used to compare duration in each group which there is a highly significant difference between durations in groups 1, 2, and 4, also One Way ANOVA test is used to compare groups in each duration, as there is no significant difference between all groups at each baseline, 3 and 6 months while there is a significant difference after 9 and 12 months (Table 2) & (Figure 4).

TABLE (2) Comparison between the four groups

Maximum Retentive Load (N)							
Groups	Baseline	3 Months	6 Months	9 Months	12 Months	F	p-value
	Mean ±S.D	Mean ±S.D	Mean ±S.D	Mean ±S.D	Mean±S.D		
Group 1	22.62±3.87	18.94±1.20	15.74±1.33	9.80±1.35	9.39±0.72	36.991	0.000**
Group 2	19.61±0.87	17.63±1.45	14.49±2.09	8.75±1.67	8.94±1.33	46.153	0.000**
Group 3	24.88±4.93	18.71±1.14	16.01±1.27	11.70±0.69	11.16±0.71	27.585	0.004*
Group 4	19.37±2.31	16.84±1.23	13.65±1.59	9.28±0.72	8.53±0.88	64.175	0.000**
F	2.179	3.217	2.371	5.906	7.526	-------	--------
p-value	0.130	0.051	0.109	0.007*	0.002*	-------	--------

There is a significant at P-value< 0.05 (*), and highly significant at P-value< 0.001 (**).

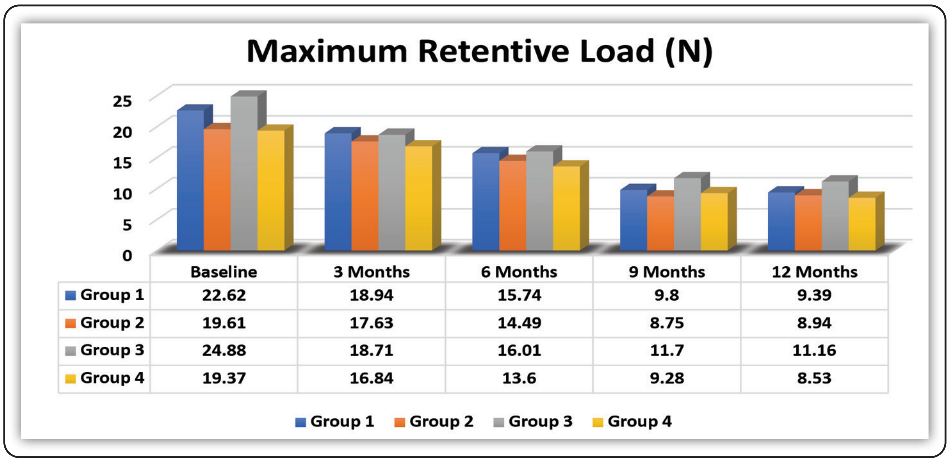

FIG (3) Volume Loss (um3)

DISCUSSION

PEEK might be an appropriate material for primary crowns regardless of the taper. This; might be explained by the fact that PEEK is a soft, ductile malleable material that yields and adapts well and efficiently, leading to an excellent marginal fit [19. 28].

The telescopic crowns in removable partial dentures experience changes in surface structure throughout use due to frictional wear, which causes a loss of retention force [29, 30]. Additionally; it has several disadvantages, such as the technique sensitivity of telescoping crowns since it necessitates precise manufacturing techniques to provide fit between the secondary and primary crown [31]. Moreover, there is a quick loss of retention due to constant contact of double peak crowns, which causes cumulative wear and excessive force on the supporting structures and increasing deterioration, so it is only used with strongly supported abutments[32].

The taper of telescopic crowns is one of many elements that affect the retentive force of telescopic crowns. Previous studies showed that retention load decreased as taper was increased with a 6° spread[14, 32, 33].

Telescopic crowns that are more susceptible to dislodging are frequently seen in clinical practice. Long-term; use reduces the retentive factors, which is why. According; to Yoshikawa et al., it is necessary to preserve the retentive force for a long time. Also; the influence of repeated insertion and removal cycles on settling was also examined. Although; several variables, like the primary crown's height or taper, might influence retentive force [32].

Therefore, the present study examined the impact of repeated insertion and removal cycles on the retentive force, based on an assumption of long-term use of telescopic crowns.

Ohkawa et al.,[33] studied retentive forces of several types of conus telescopic crowns. After 10,000 cycles of insertion and separation. They noted a reduction in retentive forces. These; retentive force measurements differ slightly from the ones made in this investigation. This; discrepancy is believed to have been caused by the material and removal device utilized being different.

According to Güngör et al., [32] the retention values reduced as the conus angle rises (2°, 4°, and 6°), with the 2°angle having the highest retention. This; is consistent with our results.

Additionally, most publications state that retention declines as the conus angle rises, and the obtained results corroborate the findings of the present study [33]. Therefore; the conus angle of telescopic crowns should not be tapered more than 2° for long-term use.

As Dillschneider et al., (34) mentioned previously, the range of 2° seems to be insufficient to confirm former statistical relationships of taper and retention loads even for the PEEK material; however, the maximum 2° taper considered in this study is recommended for long-term use.

The maximum 2° taper examined in this work is advised for long-term usage. Although Dillschneider et al., (34) previously stated that the range of 2° appears to be insufficient to support prior statistical connections of taper and retention loads even for the PEEK material.

At all observed cycles, telescopic crowns with a smaller tapered angle had a higher retentive force than those with a larger angle. This; is consistent with several other investigations (32,33). More specifically; a 2° taper was superior to a 6° taper in terms of retentive force following multiple insertions and removals, not just the initial retentive force. This; finding implies that, even after extended usage, telescopic crowns with a smaller taper can demonstrate more retentive force than those with a larger taper.

It is believed that wear between the primary and secondary crowns and the disappearance of the wedge effect is to blame for decreases in the retentive force of telescopic crowns, which can be problematic in clinical practice. Given; this it's crucial to think about the substance employed. In a prior study Nakagawa et al., (14) found that as the load applied to the secondary crown increased, so did the initial retentive force and settling of telescopic crowns. In; the current study a similar trend was seen at both tapers. In; light of this it is recommended that the taper be more prominent in individuals with a high bite force and more minor in patients with a weak bite force.

The present study had some limitations. First; off since this was an in vitro study, clinical trials are still required to corroborate the findings. Furthermore; using several telescopic crowns may have distinct impacts on the retentive force; the current study only assessed the retention of a single telescopic crown.

According to the present study's findings, taper changes can be used to modify retentive forces. It's; crucial to assess a patient's biting force during mastication and then choose the proper taper if you want to guarantee that telescopic crowns maintain the necessary retentive force throughout time.

Clinicians face a significant issue regarding the primary and secondary telescopic crowns being worn. While; primary crowns on teeth must be removed and may damage the remaining tooth structure, replacing secondary crowns on teeth is very simple. Therefore; one of the fundamental requirements for double-crown systems is to choose a wear-resistant material, particularly for the primary crown.

CONCLUSIONS

It can be concluded that all four primary crown materials tested with a high-performance polymer PEKK as the secondary crown reached acceptable forces for overdenture retention throughout 1440 cycles. This; is equivalent to a clinical wear period of 12 months. As; there are no long-term observational and clinical data for this material, further studies are needed.

Within the limitations of this study caused by the small sample and short evaluation period, PEEK secondary copings is recommended. Wear; induced loss of RF (Retention forces) in all evaluated groups. However; the material used exhibited significant influence.

Nevertheless, further investigations of these aspects require intraoral follow-up studies, in terms of retention force evaluation combined with monitoring of the patient level of satisfaction.

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