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Periodic Retention Evaluation of Two Implants Retained Complete Mandibular Overdenture with Zirconia-PEEK Telescopic Attachments.

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Abstract:
Purpose: *This clinical study was conducted to periodically evaluate retention forces of two implants retained complete mandibular overdenture with Zirconia-PEEK telescopic attachment.*
Materials and methods: *Six completely edentulous patients of both sexes and average age of 60 years old were selected for this study. Each patient received two implants in the mandibular canine regions. Maxillary conventional complete dentures were constructed against mandibular overdentures for all patients. Zirconia-PEEK telescopic attachments were fabricated to retain the overdentures where primary crowns were made of zirconia and secondary ones were made of PEEK. Retention force of mandibular overdenture was measured at the time of insertion (T0), six months (T6) and twelve months later (T12).*
Results: *Retention values significantly decreased (p<.001) with advance of time. There was a significant decrease in retention values from time of overdenture insertion (T0) (21.62±1.50) to 6 months after overdenture use (20.30±1.26), (p=.002) and from (T0) to 12 months after overdenture use (20.13 ±1.27), (p=.001).*
Conclusion: *Despite the significant decrease of retention force with advance of time, PEEK may be considered a suitable material for secondary crowns fabrication against zirconia primary ones regarding the initial and maintained retention force values.*

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I. Introduction

Edentulism is considered a chronic disability; edentulous patients commonly experience problems with retention, stability, support, phonetics, and the related compromise in chewing ability with conventional complete dentures. The rehabilitation of completely edentulous arch with implant overdentures shows fewer complications, in comparison with conventional dentures[1].

Numerous attachment systems have been successfully used to retain implantoverdentures[2].Telescopic crowns are defined as a double crown or crown and sleeve coping (CSC) and consist of primary telescopic crown, permanently cemented to an abutment, and secondary telescopic crown, rigidly attached to the denture[3].They give good retention, stabilization and provide secondary splinting action due to the accurate relation between the inner and outer crowns and the rigid connection of outer crowns to the denture base [4].

New CAD-CAM materials are recently recommended for the construction of telescopic attachments. Zirconium dioxide (ZrO_2), commonly known as Zirconia, possesses excellent esthetics, biocompatibility, wear resistance, and superior mechanical properties than metals. It is recently recommended in the fabrication of double crowns [5].Emera[6]**,** concluded that all zirconia double crown attachment system could be considered as a biologically promising telescopic retainer for overdentures.

Poly-ether-ether-ketone (PEEK) represents a modification of the main thermoplastic high-performance polymer group poly-ether-aryl-ketone (PEAK).It has high thermal stability, high hardness, lower water absorption, chemical inertness, superior biocompatibility and solubility [7], moderate biofilm formation [8], and excellent mechanical properties[9,10].

In assessing retention load, Merk et al[11], reported that PEEK may be a suitable material for telescopic crowns construction when used on zirconia primary crowns. Reviewing the literature, very rare data is available about the clinical performance of zirconia-PEEK telescopic attachments. Consequently, this study was conducted to periodically evaluate retention forces of two implants retained complete mandibular overdenture with Zirconia-PEEK telescopic attachment.

II. Materials and Methods

Six healthy completely edentulous patients of both sexes and average age of 60 years were selected for this study. Inclusion criteria were adequate height and width of mandibular residual alveolar ridge as verified by cone beam CT, suitable restorative space, and normal maxilla-mandibular relationship (Angle's class I). Exclusion criteria were systemic diseases that interfere with surgical procedures, systemic diseases that affect metabolic activity of bone, history of chemotherapy or radiotherapy to the head and neck region and history ofparafunctional habits. This research protocol was approved by the Faculty Ethical Committee.

- **Pre-surgical procedures**:

- Conventional maxillary and mandibular dentures were constructed for each patient.
- Stereolithographic surgical guide template was constructed using dual scan technique as follows :(Fig 1,2).

1-The mandibular denture was prepared for the cone beam CT scan by attaching guttapercha, radiopaque markers, to act as reference points.

2-Each patient was exposed to cone beam CT scan wearing his/her denture while biting in centric relation.

3-The two scans were merged to obtain software 3D image. The bone height and thickness were measured for accurate planning of implant location, diameter and angulation. Universal surgical kit with successive diameter drill sleeves with horizontal indicators was supplied with the stent.

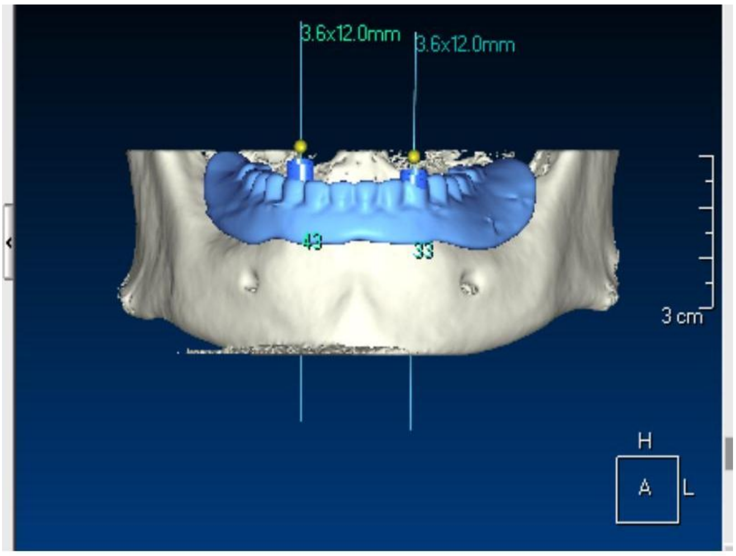

Fig 1: Cone beam CT scan while the patient was wearing the denture.

Fig 2: Stereolithographic surgical guide template

- **Surgical and prosthetic procedures:**

For each patient, intraoral fixation of the surgical guide template was done and two implants (Dentium Superline, Dentium , Co. Ltd., Korea) (3.5mm diameter and 12 mm height) were inserted in the mandibular canine area bilaterally. After 3 months of oseointegration period, covering screws were exposed and replaced by healing abutments for more two weeks.

Mandibular acrylic resin custom tray was constructed with two holes corresponding to each implant site. Zinc oxide eugenol-free impression was done for recording residual alveolar ridges. Two long transfer copings were secured to the implants and splinted with light cured flowable composite. Light body rubber base material (Speedex, Coltene/WhaledentInc, Cuyahoga Falls, OH, USA) was injected to record the peri-implant soft tissues (Fig. 3). Implant analogues were fixed to the transfer coping and impression was poured (Fig. 4).

Fig 3: Final impression with the attached implant analogues.

Fig 4: Poured master cast with the attached implant abutments.

- **Attachment construction:**

A-Primary telescopic crown construction:

The model containing the two implants abutments was scanned to gain 3D virtual image for designing a resilient telescopic attachment using CAD/CAM technology. The same parameters for designing primary copings were maintained for all groups concerning 5mm height (2mm gingival height was paralleled and the occlusal 3mm was occlusaly tapered 4^{o}) (fig 5). The computer numeric control (CNC) data were transmitted to a milling machine and connected to the CAD system (Sheraeco_scan3 Germany) to mill primary copings from semi-sintered zirconia (Zirconia Katan)

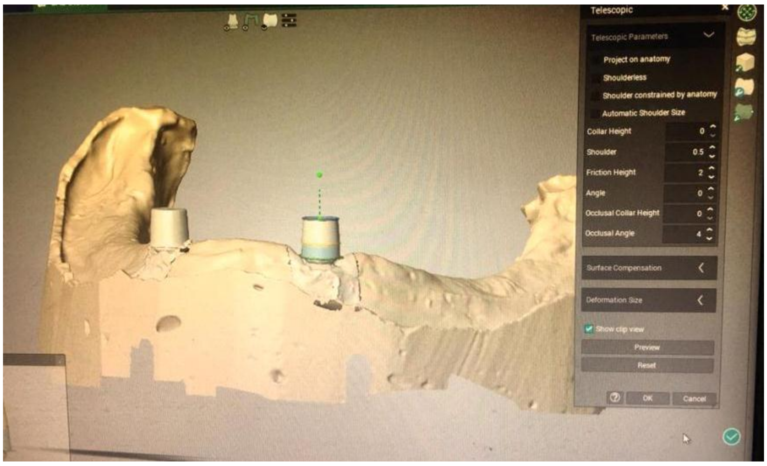

Fig 5: Final software design of primary crowns.

B-Secondary telescopic crown construction:

Scanning of primary copings was done after trying them intraoral for designing the secondary copings on their 3D image .Parameters used for designing secondary copings were parallel wall with minimal wall thickness of 0.5 mm and an occlusal space (0.3mm) was preserved between the primary and secondary copings (Fig 6).Projections were added to secondary copings design to enhance their mechanical retention to the overdenture fitting surfaceaccording to **Emera**[6] (Fig 7)**.** Data were finally transferred to the CAM program for milling of the secondary crowns from PEEK (ceramic filled Bio HPP).

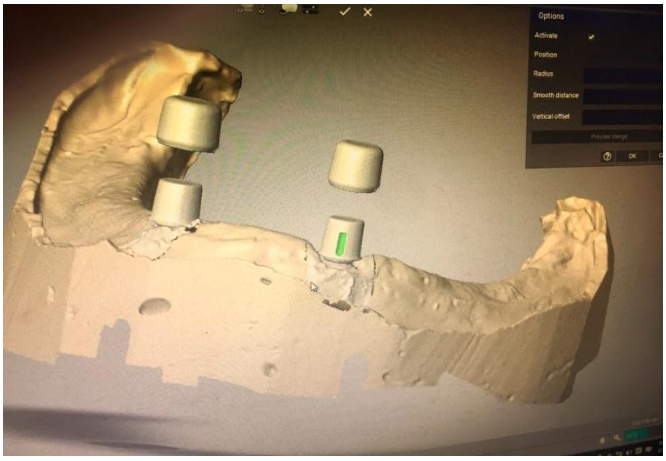

Fig 6: Final software design of secondary crowns.

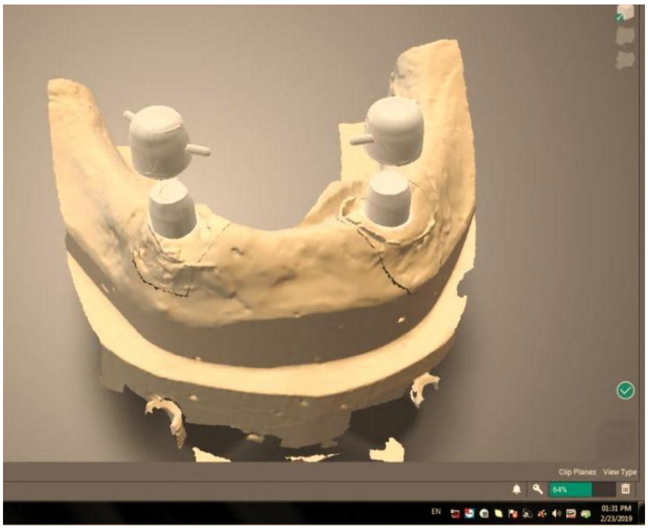

Fig 7: Final software design of secondary crowns with the attached projections.

- **Fabrication of mandibular overdentures:**

Duplication was done to the model while the secondary telescopic crowns were secured over the primary ones on each abutment. Duplication of the conventional mandibular denture polished and occlusal surfaces was done using a silicone index (Coltoflax; ColteneAG, Altstatten, Switzerland). Identical acrylic teeth were positioned in their respective places in the mold. The index was repositioned against the duplicate stone model. The mold cavity was filled with molten base plate wax followed by flasking procedures.

- **Pick up of secondary crowns procedures:**

Primary copings were cemented to the implants abutments (Fig 8).Venting holes were prepared through the lingual flanges of mandibular overdentures. Secondary crowns were positioned over primary ones in the correct path of insertion then were picked up to the overdentures fitting surfaces using an autopolymerized acrylic resin (Fig 9). The excess material of auto-polymerized acrylic resin was removed using diamond bur.

Fig 8: Cemented primary copings to the implants abutments

Fig 9: Picked up secondary crowns in the overdenture fitting surface.

- **Retention measurements:**

The retentive values of mandibular overdenture were measured using the device developed by Hussein and Elsyad[9]at the following intervals:
(A) At the time ofoverdenture insertion. (T0)
(B) Six months after overdenture insertion. (T1)
(C) Twelve months after overdenture insertion. (T2)

Measuring device:

Force meter device was used to measure the retention of the mandibular overdenture in Newton. Measurement of retention was recorded in vertical direction perpendicular to the patient's occlusal plan.

Four hooks were attached at the buccal flange at the canine and first molar areas using auto-polymerized acrylic resin at the same height (Fig 10). The mandibular overdenture was completely seated in the patient's mouth. The patient was asked to rest his chin on the chin support of the device keeping the mandibular occlusal plane parallel to the floor (Fig 11). The hooks would engage intra-orally to the fork of the force meter at the pull end. The force gauge was used to measure the pull force needed to dislodge the mandibular overdenture from its place. Five readings were recorded and the mean was calculated.

Fig 10: Attached four hooks to the buccal flange of the overdenture.

Fig 11: The patient rested his chin on the chin support of the device.

III. Statistical Analysis

Shapiro Wilk test was used to detect the normal distribution of data. The data was parametric and normally distributed. One-way repeated measures ANOVA was applied to test possible differences in retention force between times of measurement (T0, T6 and T12). *P* values for multiple comparisons were adjusted for simultaneous hypothesis testing according to the Bonferroni method of multiple comparisons. The overall threshold value for significance (α) was set at .050.The data were analyzed using SPSS® software version 22 (SPSS Inc., Chicago, IL, USA).

IV. Results

- There was a significant difference in retention values (N) between observation times ($p<.001$)
- Retentive values significantly decreased ($p<.001$) with advance of time
- There was a significant decrease in retention values from time of overdenture insertion (21.62±1.50) to 6 months after overdenture use (20.30±1.26), ($p=.002$)
- There was a significant decrease in retention values from time of overdenture insertion (21.62±1.50) to 12 months after overdenture use (20.13 ±1.27), ($p=.001$)
- Also, there was a significant decrease in retention values from 6 months after overdenture insertion (20.30±1.26) to 12 months after overdenture use (20.13 ±1.27), ($p=.004$) as shown in table 1 and Fig 12,13.

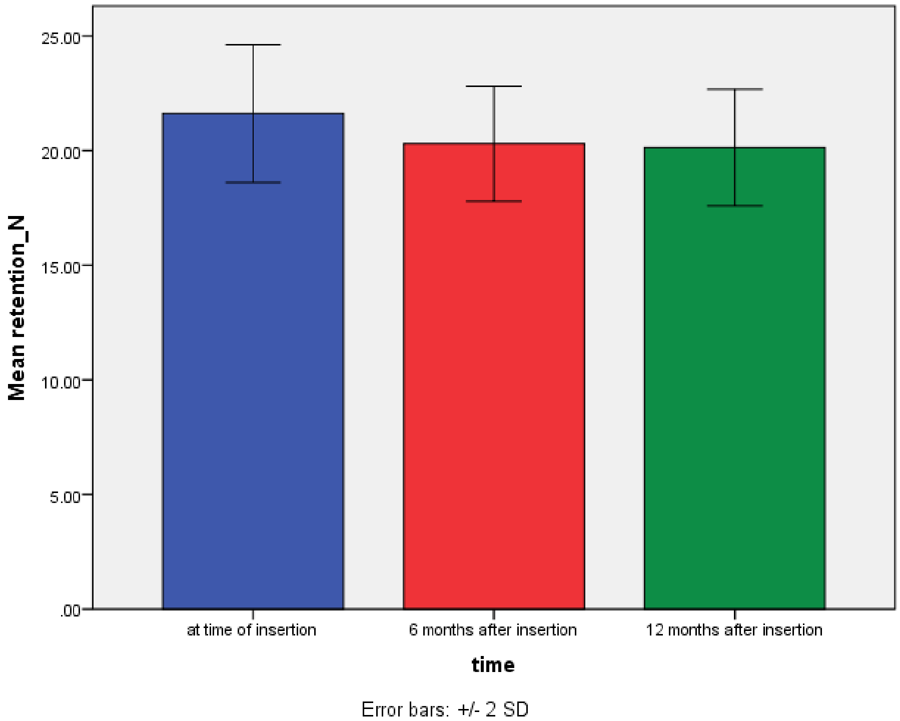

Fig 12: Mean retentive values in N at different observation times

Table 1:Mean and standard deviation of retentive values in N at different observation times

Time of measurement	X±SD	Bonferrnoni multiple comparison(p value)		
		T0-T6	T0-T12	T6-T12
At time of overdenture insertion (T0)	21.62±1.50	.002*	.001*	.004*
6 months after overdentureuse (T6)	20.30±1.26			
12 months after overdentureuse (T12)	20.13 ±1.27			
Df	1			
F	1448.465			
Repeated measures ANOVA (P value)	<.001*			

X; mean, DS; standard deviation, * p is significant at 5% level

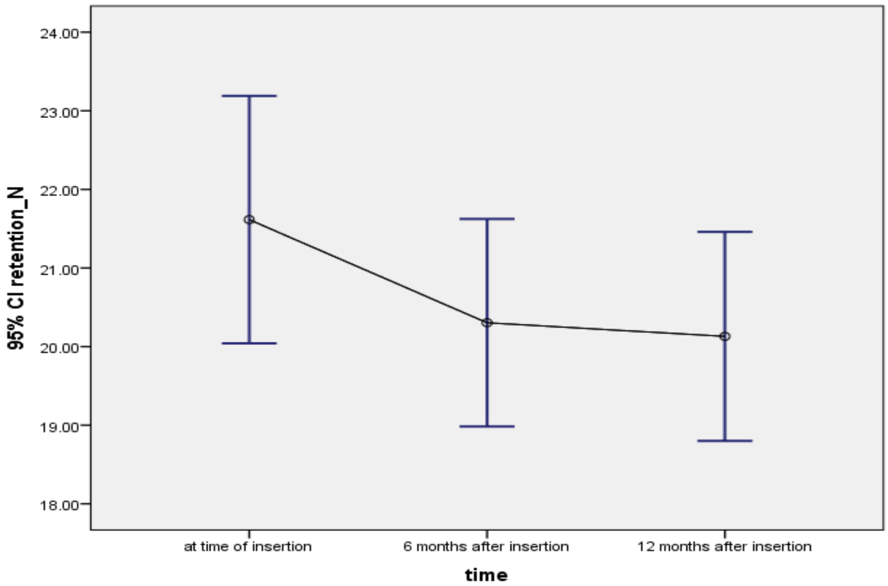

Fig 13: Change in mean of retentive values over time. Error bar representing 95% confidence interval for mean of retentive values at different observation times

V. Discussion

Providing a prosthetic treatment with a satisfactory retention is one of the greatest challenges facing clinicians. Capability of maintaining retention of an attachment system is essential for clinical performance and predictability of the prosthesis and for maintaining patient satisfaction[13]. Previous studies have shown that the retention force of double crown attachments depends on angle of occlusal convergence, abutment height, precision of fit, and material of fabrication [14-17].

One of the prosthetic options in combining the use of PEEK restorations with zirconia is the load cushioning capacity[19]. It was proven that the use of hard and wear resistant material for primary crowns against a less hard material for secondary crowns may be advantageous. Minimum changes will occur in the primary crown, which is designed according to the treatment plan of the dentist, and the adaptation between both crowns will be achieved by the changes in the secondary crown[18].

It is clear that different CAD/CAM materials behave very differently when placed in function opposing one another [18].moreover, very limited data is available about the clinical performance of double crown attachments made of zirconia primary crown in combination to PEEK secondary crowns. Consequently, this invivo study was conducted to evaluate the periodic retention of these recently recommended attachments. Initial retention force was evaluated at time of overdenture insertion (T0) and periodically after six months (T6) and twelve months (T12) of overdenture use.

Retention force of different attachment systems was evaluated and it was reported that retention strengths ranged between 5N and 8N may be sufficient for implant-retained overdentures during long-term function[20]. A prospective crossover clinical study evaluated the correlation between patient satisfaction and retention force values and determined that approximately 10 N of retention force was effective[21]. Results of the present study showed that, the minimum recorded initial retention force was 21.62 N. This value is larger than the minimum retention values reported in the literature for mandibular overdentures to achieve sufficient patient satisfaction [22, 23.The] lowest retention force value that was recorded after twelve months of overdenture use (T12) was 20.13 N which also still a satisfactory retention value.

Aga et al[24], invitro study evaluated the retention forces of resilient telescopic attachments made of cobalt chromium alloy with tiny amount of circumferential play and occlusal space between the primary and secondary crowns. They recorded 19.01 N as a mean value of initial retention forces which is a comparable value to the recorded one in the present study. However, the recorded mean retention forces after repeated insertions and removals to simulate six months of function was 4.9 N which is much less than the recorded value in the present study (20.30 N).

Recorded retention values of the present study were also higher than that of a previous clinical study of Bayer et al[25], which tested double crowns that were fabricated from high-gold-content type IV alloys with a slight conical angle of 1-2°. The measurement was performed 4-6 weeks (baseline), 6 months, and 18 months later. The recorded median retention forces were 12.9 N , 10.4 N,and11.1N respectively. This finding revealed that combining zirconia and PEEK materials in telescopic attachment fabrication can provide adequate retention forces that grantee patient satisfaction.

The invitro study of Schubertet al[23], evaluated the retention forces of CAD-CAM fabricated PEEK secondary crowns on zirconia primary crowns over a period of artificial aging representing 10 years of clinical function and compared them to electroformed secondary crowns made from pure gold. The results revealed that the artificial aging had significant influence on the retentive force of the electroformed primary crowns by means of an increase of their retention force. The PEEK secondary crowns presented stable retention force values over the time of simulation. They concluded that CAD-CAM fabricated secondary crowns made from PEEK are able to provide sufficient and stable retention force values and could offer an efficient and appropriate alternative to electroformed secondary crowns. However, they recommended further clinical investigations on the long-term behavior and survival rates under clinical conditions.

Dillschneider et al[26],also reported slightly increasing retention force values for electroformed secondary crowns on zirconia primary crowns during artificial aging, but did not comment on possible causes. Meanwhile, Schubertet al[23], suggested that the phenomenon of increasing values could be attributed to the high ductility of the pure gold. As a result, the electroformed secondary crowns gradually adapt better to the primary ones and the gap sizes decrease. However, this observed increase in retention force values of the electroformed secondary crowns after aging was in contrast to the results of other studies, which mostly exhibit decreasing retentive forces [27, 15]or no significant changes [13,28].

In particular, it has been reported that the retentive force is reliant on the occlusal taper of primary crowns, and the smaller the taper, the higher the retentive force [29]. This phenomenon is thought to be due to the wedge effect caused by the settling of the secondary crown, which affects the retentive force.

Nakagawa et al[30], investigated the effect of taper on retention force of double crowns made of a zirconia/alumina nanocomposite stabilized with cerium oxide (Ce-TZP/A). The studied taper angles were 2°, 4°, and 6°. They concluded that the taper had a significant effect on retentive force and settling. Where 4° taper was the most appropriate for retention force production. At 2° taper and 4° taper, the settling of the secondary crown exhibited the wedge effect and brought about retentive force. This conclusion may explain the high retention forces recorded in the present study where the angle of occlusal tapering of zirconia primary crown was 4°.

Turp et al [31], evaluated retention and surface changes of telescopic attachments made of gold alloy primary crown- electroformed gold secondary crowns (AA), zirconia primary crown - electroformed gold secondary crowns (ZA) and zirconia primary crown-casted non-precious alloy secondary crowns (ZC) with different conus angles .The recorded mean initial retention forces of AA group, ZA group, and ZC groups of 4° taper angle were 31.74 N, 12.73 N, and 25.46N respectively, while the mean final retentions forces were 25.29N, 19.44N , and 32.32N respectively which are a comparable values to the recorded ones in the present study. They observed no wear in zirconia primary crowns except for the ZC group and thus concluded that, a more predictable and less excursive retention force can be obtained using a hard primary crown material like zirconia. The scanning electron microscope images also indicated that wear occurred only in the secondary crowns in the ZA groups, whereas wear occurred in both crowns of AA groups. This may indicate that when the hardness of primary and secondary crown materials are close to each other, as in the AA group, plastic deformation caused by wear and cold-fusing can occur in both crowns.

Invitro study of Merk et al[11], investigated the retention load (RL) between ZrO2 primary crowns made with three different tapers (0◦, 1◦, and 2◦)and secondary poly-ether-ether-ketone (PEEK) crowns. They concluded that the taper has an impact on the retention load. Former studies reported that retention load decreases with the increase of the taper [31]. In contrast, this pattern could not be observed in the study of Merk et al [11]. They explained that by the low flexural modulus of PEEK material (4 GP) that could lead to a growing wedging of primary and secondary crowns in tapered groups, whereas almost no wedging occurs in 0◦ double crowns due to the parallelism and their chamfer with a final stop. These facts reflected in lower retention load values of the 1◦ taper compared with the 2◦ taper in the milled group.

Despite the minimal decrease of recorded retention forces in the present study at the different follow up periods, statistically significant difference was observed between initial retention forces (T0) and those recorded after six months and twelve months later. This may be attributed to changes in surface topography and wear of opposing surfaces of the inner and outer copings. It was concluded that the frictional wear occurs during function represents a common problem of the double crown retention concept that often reduces the patient's satisfaction [28,32].

Emera et al [33], evaluated the changes in surface topography of all PEEK, all zirconia and zirconia-PEEK telescopic attachments after simulating six months of overdenture use. They reported that combining PEEK and Zro2 materials for telescopic attachment construction was associated with more changes in surface topography (mainly in secondary crowns) in comparison to all PEEK and all zirconia telescopic attachments. This result was explained by the difference in the two materials physical properties where PEEK has a low modulus of elasticity (4 GPa) compared to zirconia (210 GPa), thus PEEK restorations absorb occlusal loads and undergo wear.

It was documented that, when deformative changes occur in the primary crown, the retainer long-term behavior will be affected[31].Moreover, the exceptional advantage of double crowns digital construction is that in case of retention loss or damage of secondary crowns, reproduction of any part of the system can be done, any number of times, based on the stored data[23].

VI. Conclusion

Despite the significant decrease of retention force with advance of time, PEEK may be considered a suitable material for secondary crowns fabrication against zirconia primary ones regarding the initial and maintained retention force values.

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