EGYPTIAN DENTAL JOURNAL
www.eda-egypt.org
VOL. 68, 3421:3430, OCTOBER, 2022
PRINT ISSN 0070-9484 • ONLINE ISSN 2090-2360
FIXED PROSTHODONTICS AND DENTAL MATERIALS
Submit Date : 01-06-2022 • Accept Date : 06-07-2022 • Available online: 01-10-2022 • DOI : 10.21608/edj.2022.141917.2127

COMPARING CHANGES OF RETENTION BETWEEN MILLED ZIRCONIA AND POLYETHERETHERKETON (PEEK) FRAMEWORK ON TELESCOPIC IMPLANT RETAINED OVERDENTURE: AN INVITRO STUDY

Nora M. Sheta* *and* Nouran Abdel Nabi*

ABSTRACT

Introduction: Telescopic retainers would provide excellent retention due to the frictional fit between the primary and secondary coping. The aim of this invitro study was to compare the changes of retention between milled zirconia and PEEK framework for a telescopic implant retained overdenture after being subjected to 12500 and 37500 cycle.

Materials and methods: An epoxy resin model of a completely edentulous mandible received four implants installed in the intra-foraminal area. Four custom-made titanium abutments were the primary coping. The secondary coping was a framework that was made of milled zirconia (Group I) and milled polyetheretherketon (PEEK) (group II). Three frameworks in each group, were picked up in a metal prosthetic part. The metal prosthetic part was designed to measure retention using the universal testing machine at base line then subjected to chewing cycles of 12,500 cycles and 37,500 using the chewing simulator then retention was evaluated again.

Results In both groups there was a significant decrease in retention from base line and after being subjected to 12500 cycle and 37500 cycles. Group I recorded higher statistically significant retention values at base line, after 12500 cycle and after 37500 (8.473±2.368) (4.148±0.844) ($p=0.024$). Group I showed a greater change in retention from base line to 12500 cycle and from baseline to 37500 cycles which wasn't significant. Comparison between the groups was done using Paired t-test. P-value was insignificant > 0.05.

Conclusion : The milled zirconia framework used as a secondary coping showed higher retention values compared to the milled PEEK framework .

* Assistant Professor of Prosthodontic Department, Faculty of Dentistry, Cairo university

INTRODUCTION

The recommended number of implant to retain mandibular overdenture still remains controversial. Two implants installed in the mandible are considered as the standard of care[1,2]. While implant supported by four implants-retained overdentures offers an alternative treatment that proved to be reliable and further improved phonetics, hygiene, and esthetic and was of economic advantages[3].

Several attachments have been used to retain implant overdenture. Telescopic retainers were introduced in 1896 to maximize denture retention. It was proved to be a reliable treatment option. Telescopic retainer consists of an inner or primary telescopic coping, permanently cemented to an abutment and a detachable outer or secondary telescopic coping which is rigidly connected to a detachable prosthesis. This gives the telescope a secondary splinting action[4]. Telescopic retainers would provide excellent retention, better force distribution and axial transfer of stresses which would decrease the torque to the underlying abutments[5,6]. The friction retention between the telescopic copings depends on the design and material of copings.

The materials most commonly used for telescopic retainers include gold alloys, chrome cobalt metal alloys, titanium, and zirconia. Nowadays, it can be fabricated by several methods such as conventional one-piece castings, casting and laser welding, casting and spark erosion, copy milling, and computer-aided design/computer-aided manufacturing (CAD/CAM). The CAD/CAM technology will result in high precision, passive seating of restoration and fast construction.Zirconia (ZrO2) is a ceramic material that showed high biocompatibility, excellent mechanical strength, and wear resistance[7]. Polyetheretherketone (PEEK) was reported to be a suitable material for the telescopic retainers[8].

The retention of the prosthesis played an important role in improvement of patient satisfaction and quality of life[9,10]. Assessment of Denture retention, was performed using either subjective or objective methods[11]. The subjective methods usually includes professional operator questionnaire, but it proved to be unreliable, while the objective methods involve the construction of devices based on physical and mechanical principles as levers, pulleys, springs, dynamometers and strain gauges.

The aim of this in vitro study was to compare the changes in retention between two different frameworks the milled zirconia and Polyetheretherketon (PEEK) implant supported mandibular overdenture after being subjected to 12500 and 37500 chewing cycles.

Materials and methods

Sample Size Calculation:

In a previous study the response within each subject group was normally distributed with standard deviation 3.26. If the true difference in the experimental and control means is 6, we will need to study 6 experimental subjects and 6 control subjects to be able to reject the null hypothesis that the population means of the experimental and control groups are equal with probability (power) 0.8. The Type I error probability associated with this test of this null hypothesis is 0.05[12].

Construction of epoxy resin model and implant installation

Epoxy resin acrylic model[1] represent mandibular completely edentulous arch was used in this study. A trial denture base was constructed using self-cure acrylic resin over the epoxy model. Setting up of teeth following the principals of teeth set up was followed. A wide diameter fissure bur was used to drill for implant installation in the epoxy resin model .The four intera-frominal implant* with diameter 3.5 mm and length 10 mm were installed using a

* Implant Direct Sybron Manufacturing LLC. Thousand Oaks, USA.

surveyor[3]. Soft mix of acrylic resin was placed within corresponding four holes during implant placement[*].

Abutments (primary coping) design and preparation

The Medit Identica Hybrid 3D dental scanner[**] was used to scan the epoxy resin model using scan bodies[***]. The design and preparation of the abutment which present the primary coping were selected from software library The custom-made titanium cylinder abutments by Implant Direct were pre-milled with taper 2 degrees done in the laboratory and then was designed on software for enough clearance [****]. A defined chamfer finish line was present in all abutments .After milling of the designed abutments, finishing of the abutments was carried out to obtain a smooth surface. All abutments (primary coping) were checked for parallelism and all of the same clinical height of 6mm. The abutments were screwed to the four installed implants in the model using a torque ratchet at 30N/cm.

Framework with the secondary coping design and construction

The study was divided into 2 groups: Group I received the milled zirconia framework and Group II received the milled PEEK framework and was designed using Exocad software [*****] **(Fig. 1).**

Six frameworks for each group, were constructed to be splinted and covering all the abutment surfaces which present the telescopic secondary coping: group I The Zirconia framework was milled by VHF milling machine [******] using Zirconia block by Dentaurum (**Fig 2 a**), and group II the PEEK framework was milled by VHF milling machine using PEEK block by Dentaurum (**Fig 2 b**). All frameworks were checked for proper seating using alternate figure pressure technique and also, the fit checker spray was used for proper seating of the frameworks .Areas that exhibit metal showing were adjusted and the high spots were removed until passive seating of the framework was achieved.

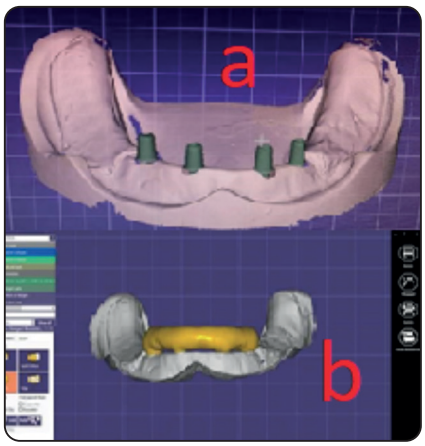

Fig. (1): Designing the abutment (a)and (b) framework

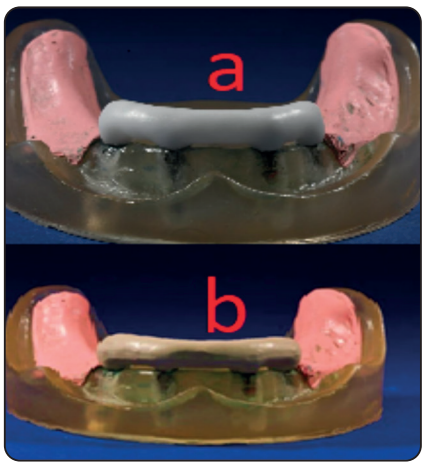

Fig. (2): The milled zirconia (a) and (b) Peek framework

Metal prosthetic part construction

Three layers of base plate wax were applied over the framework, and extend to cover all the four abutments. The applied wax was of adequate with (10 mm in width) to accommodate 3 nuts on

* Ney Surveyor, Dentsply, York, PA.

** Medit Identica Hybrid 3D dental scanner. Seoul, Korea.

*** Implant direct Dentistry Legacy scan Adapter

**** VHF Milling machine K5. Ammerbuch, Deutschland.

***** Dynamic and innovative dental CAD/CAM Software Company.

****** VHF dental milling machine, Germany.

the occlusal surface that would further be used to attach the 3 screws that will be used for measuring This space of the base plate wax would be later used to create sufficient space for the pickup of each framework retention using orthodontic wires. This model was then duplicated into an investment model for casting of the metal prosthetic part.

The metal prosthetic part was being waxed up using the investment model. The occlusal surface had a horse shoe shape with adequate width for the 3 nuts. At the lingual surface near to the floor of the mouth , there were 3 lingual triangular shaped extensions present at the two terminal abutments bilaterally and one in the midline. The prosthetic part would maximally extend to cover the terminal implants bilaterally. The waxed up part was sprued, invested and casted over the metallic nuts.

After the prosthetic part was casted finished and polished, it was seated over the epoxy model, the lingual area of the cast was indexed using a large acrylic bur. A thick mix of stone plaster was placed on the lingual area of the model, to create a stone index. This stone index will be flushed with the three triangular shaped extensions that are located on the lingual surface of the model **(Fig 3).**

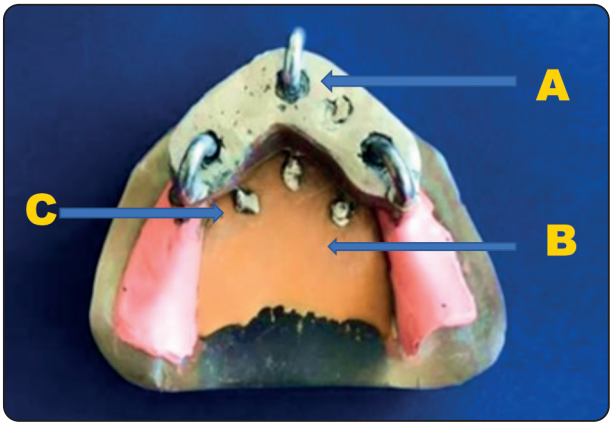

Fig. 3: Metal prosthetic part (A) , and the stone index(B) (C) 3 the lingual triangle shaped extension area of the cast.

Pick up of the framework

Each framework was checked for proper seating over the primary abutments, then trial seating of the metal prosthetic part was carried out to ensure proper placement of the framework. The lingual triangular shaped extension rests had to securely be seated in their defined position in the lingual stone index. The metal prosthetic part was removed and a soft mix of self-cured acrylic resin was placed inside the fitting surface. The metal prosthetic part was then seated over the framework with the lingual triangular shaped extensions properly placed over the stone index After complete setting of the self-cure acrylic resin, the metal prosthetic part was removed and checked for proper pick up of the frameworks. This was carried out for all frameworks.

Baseline retention measurement

After pick up of each framework, the metal prosthetic part was seated over the epoxy model and were subjected to tensile forces using universal testing machine* to record the retention at the baseline in Newton (N). The epoxy resin model was attached to the lower compartment of the universal testing machine by the aid of a hole made in the epoxy model to be fixed to the cast holder by a tightening screw while the upper compartment of the universal testing machine was attached to the metal prosthetic part over the framework. The metal prosthetic part was suspended from the upper movable compartment of the testing machine by triple orthodontic wire loop of height 12 cm and width 0.7 mm through custom-made 3 hooks fixed to metal pickup. The orthodontic wires were joined together and then fixed into the center of the upper compartment of the universal testing machine through a Jacobs chuck. The device was subjected to a slowly increasing vertical load (1mm/min) until total dislodgment of the prosthetic part from their initial position (**Fig 4**).

* Lloyd LR5K An AMETEK Company, USA

Fig. (4): Recording of retention using the universal testing machine

Chewing simulation

The chewing simulator used in this study was the multimodal ROBOTA * chewing simulator integrated with thermo-cyclic protocol operated on servo-motor. ROBOTA chewing simulator consists of four chambers that simulate the horizontal movements of 10mm and vertical movements of 3mm simultaneously in the thermodynamic condition. The rising and forward speeds were 90mm/s while the descending and backward speeds were 40mm/s. the cycle frequency was 1.6 Hz with torque 2.4 Nm and the weight per sample was 3 kg. These cycles were performed in wet environment of artificial saliva simulating the saliva of oral condition.

Each framework of the two groups were then placed on the corresponding abutment and fixed to Jakobe's chuck of the upper part of machine through inverted t-shaped auto-polymerizing acrylic resin ** centrally positioned horizontal bar to facilitate the aligning with the loading axis of machine and proper load distribution. The prosthetic part had enough width occlusally to accommodate the width of the inverted t-shaped acrylic resin

The chewing simulator has four chambers allowing the vertical and horizontal movements simultaneously. The epoxy model with the framework was mounted in Teflon housing in the lower cast holder of the chewing simulator

The test conditions were maintained at room temperature (20±2°C) and wet condition (artificial saliva***). To analyze the data obtained during the simulation test, a weight of 3 kg, comparable to 29.4 N of chewing force was exerted. The test was repeated 12500 and 37500 times to clinically simulate the one and three months chewing condition respectively, according to previous studies[13]. This test was performed for each framework in each group (Group I, and II). After being subjected to the chewing cycles, retention will be measured afterwards using the universal testing machine in the same manner as baseline retention.

The framework of each group will be removed from the metal prosthetic part by a thin acrylic bur to remove all of the soft acrylic resin, after being subjected to the different chewing cycles. Then the new framework of each group will be picked up to be ready for recording the retention before and after being subjected to different chewing cycles.

All data were presented as mean &standard deviation. Data were presented 2 tables & 2 graphs. Statistical analysis was performed with SPSS 16 (Statistical Package for Scientific Studies), Graph pad prism & windows excel. Exploration of the given data was performed using Shapiro-Wilk test and Kolmogorov-Smirnov test for normality which revealed that the significant level (P-value)

* Model ACH-09075DC-T, AD-Tech Technology CO., LTD., Germany.

** Caulk, Dentsply.

*** Glandosane, No. 9235461109, cell pharm, Bad Vilbel, Germany

was insignificant as P-value > 0.05. Comparison between the groups was done them using Paired t-test. Also, percent of change was also calculated using the following formula: Percent of change = (Amount of change \ original amount) ×100.

RESULTS

In both groups there was a significant decrease in retention from base line and after being subjected to 12500 cycle and 37500 cycles. In group I (Zirconia group) there was a statistically significant decrease at base line (13.502±1.407) after 12500 cycle (equivalent to 1 month-follow up) (8.699±0.821) (p<0.0001). Retention values also decreased when subjected to 37500 (equivalent 3 month follow up) but was not significant. While for group II (PEEK) there was a statistically significant decrease in retention at base line (8.130±0.885), after 12500 cycle (equivalent 1 month follow up) (5.667±0.886), and after 37500 (equivalent 3 month follow up) (4.148 ±0.844) (p<0.0001) **(Table 1, Fig5)**.

When comparing between both groups, group I (Zirconia) recorded higher statistically significant retention values than group II (PEEK) at base line (13.502±1.407), (8.130± 0.885) (P=0.01), after 12500 cycle (equivalent 1 month) (8.699±0.821) (5.667±0.886) (p=0.05), and after 37500 (equivalent 3 month) (8.473±2.368) (4.148±0.844) (p=0.024) **(Table 2, Fig 6).**

Group I (Zirconia) showed a statistically significant greater change in retention from base line to 12500 cycle (1 month follow up) (4.803±0.414) (2.464±0.001) (p=0.02). While from 12500 cycle (equivalent 1 month follow up) to 37500 cycle (equivalent 3 month follow up) group II (PEEK) showed a greater change in retention than group I which wasn't significant. The greatest retention change was recorded by group I (Zirconia) from baseline to 37500 cycles (equivalent 3 month follow up) (5.029±0.961) when compared to group II (PEEK) (3.982±0.47) which wasn't significant (p=0.47) **(Table 2, Fig 6)**.

TABLE (1): Mean retention for group I (Zirconia Telescopic retainer) and group II (PEEK) and comparison between them using Paired t-test.

	Group I Zirconia Telescopic retainer		Group II PEEK		P value (Paired T-test)
	M	**SD**	**M**	**SD**	
Baseline	13.502 [a]	1.407	8.130[a]	0.885	0.001*
12500 cycles (1 months)	8.699 [b]	0.821	5.667[b]	0.886	0.005*
37500 cycles (3 months)	8.473 [b]	2.368	4.148[c]	0.844	0.024*
P value (One Way ANOVA test)	<0.0001*		<0.0001*		

M; mean SD: standard deviation P; probability level (significant < 0.05).

Means with the same superscript letters were insignificantly different as P > 0.05

Means with different superscript letters were significantly different as P < 0.05*significant difference

TABLE (2): Changes in retention for group I (Zirconia Telescopic retainer) and group II (PEEK) and comparison between them using Paired t-test.

	Group I Zirconia Telescopic retainer		Group II PEEK		P value (Paired T-test
	MD	**SD**	**MD**	**SD**	
Baseline \ 12500 cycles (1 months)	4.803 [a]	0.414	2.464[a]	0.001	0.02*
12500 cycles (1 months) \ 37500 cycles (3 months)	0.226 [b]	0.11	1.519[b]	0.042	0.31
Baseline \ 37500 cycles (3 months)	5.029 [a]	0.961	3.982[c]	0.041	0.47
% of change	-37.21%		-48.98%		
P value (One Way ANOVA test)	<0.0001*		<0.0001*		

MD; mean difference ***SD: standard deviation*** ***P; probability level (significant < 0.05).***

Means with different superscript letters were significantly different as P < 0.05

****significant difference***

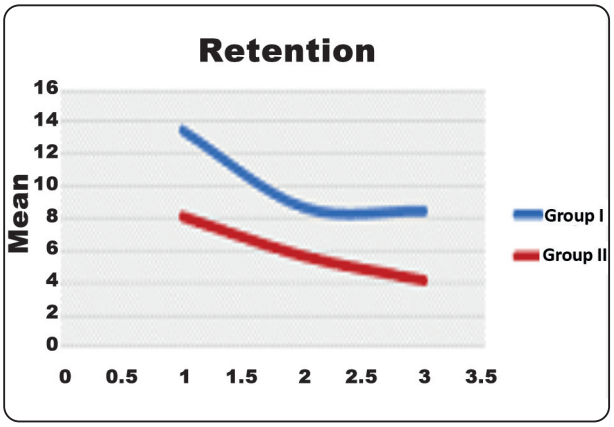

Fig. (5): Line chart showing comparison between Group I & II regarding mean of retention at baseline, 12500 cycles (1 month) & 37500 cycles (3 months).

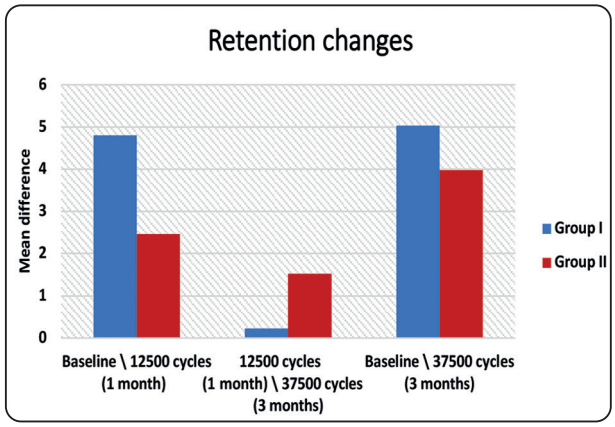

Fig. (6) bar chart showing comparison between Groups I & group II regarding mean difference of retention changes at different intervals

DISCUSSION

Improving the Retention of any prosthesis is considered to be an important factor that would improve patient satisfaction and clinical performance[7]. Several studies concluded that the retention of the telescopic retainer (double crown) would depend upon; height of the primary coping, the material selected and design of the primary and secondary coping, and the degree of occlusal convergence used[14-17]. This was the reason that in this invitro study the main aim was to compare the changes in retention between the milled zirconia and PEEK frameworks that were considered as secondary copings for a telescopic mandibular implant supported overdenture after being subjected

to 12500 (equivalent 1 month follow up) and 37500 (equivalent 3 month follow up).

In the present invitro study many variables were being standardized as one epoxy model was used in addition to that the primary copings and the metal prosthetic part used were similar in both groups, only different materials of the secondary coping were used in both groups. The PEEK framework was milled rather than pressed because pressed PEEK would experience greater potential errors as unpredictable expansion coefficient of the investment, pre-heating process and contraction of the material during the cooling which will affect the fit of the copings[8]. The metal prosthetic part used in the present invitro study was used to accommodate the secondary coping. It was designed to accommodate three nuts that would be used to record retention by using orthodontic wires. The stone index fabricated would also ensure proper pick up of both frameworks in the metal prosthetic part.

Retention was measured using the universal testing machine which is considered as a reliable and valuable tool to record retention in invitro studies[18]. The orthododontic wires were standardized to be of the same length diameter and were positioned anteriorly and posteriorly to simulate the forces excreted in a clinical situation during insertion and removal[19].

The ROBOTA chewing stimulator is considered as a reliable tool to replicate the masticatory forces and simulate the three-dimensional movement of the mandible[20]. One month and three months cycles were carried out in a wet environment using artificial saliva to simulate the oral condition. As **You et al., 2011** concluded that there was no difference between the use of distilled water and artificial saliva[21]. According to **Bayer et al., 2011,** the use of a lubricant is necessary to stimulate clinical conditions during wear simulation testing because it affects retention force[22]. It was concluded that the absence of saliva changes the frictional wear and therefore changes the retentive force values. Moreover, it was stated that the presence of saliva affects the retentive force of telescopic attachments[22].

Retention values showed a decrease from base line to 12500 (equivalent 1 month follow up) and 37500 (equivalent 3 month follow up) this finding comes in agreement with several studies that reported in telescopic overdenture that frictional wear that takes place between the primary and secondary coping would be responsible for the loss of retention[22,23].

When comparing the retention values between the two groups after being subjected to 12500 (equivalent 1 month follow up) and 37500 (equivalent 3 month follow up) group I (Zirconia group) showed a greater retention when compared to the PEEK group through-out all of the chewing cycles. This can be explained by the different physical properties of the two materials, PEEK has a low modulus of elasticity (4 GPa) compared to ZrO2 (210 GPa). The milled zirconia framework would depend upon the frictional fit and wedging with the primary coping[24], while the milled PEEK framework would mainly depend upon the hydraulic adhesion. The friction and the wedging action would be mainly be the reason for the greater retention values of the milled zirconia framework when compared to the milled PEEK framework.

While when comparing the changes in retention the zirconia group also showed greater changes in retention from base line to 12500 cycle , and from base line to 37500 cycles . The low elastic modulus and the ductility of PEEK would result in good marginal fit.[12]. The good adaptation and marginal fit would result initially in greater retention through hydraulic adhesion which is influenced by the viscosity of the applied saliva, as well as the chamfer design[14,22]. That would explain why the PEEK framework showed a smaller decrease in retention when compared to the zirconia framework after subjected to the 12500 and 37500 cycles.

CONCLUSION

The milled zirconia framework used as a secondary coping against the titanium abutment as primary coping showed higher retention values compared to the milled PEEK framework . Despite the fact the milled zirconia framework showed a greater change in retention when subjected to 12500 cycle (equivalent 1 month) and 37500 (equivalent 3 month).

REFERENCES

1. Feine JS, Carlsson GE, Awad MA, et al. The McGill Consensus Statement on Overdentures. Montreal, Quebec, Canada,. Int J Prosthodont. 2002;15:413–414.
2. British Society for the Study of Prosthetic Dentistry. The York consensus statement on implant-supported overdentures. Eur J Prosthodont Restorative Dent 2009; 17:164–165.
3. Mau, J., Behneke, A., Behneke, N., Fritzemeier, C. U., Gomez-Roman, G., d'Hoedt, B. & Yong, M. Randomized multicenter comparison of 2 IMZ and 4 TPS screw implants supporting bar-retained overdentures in 425 edentulous mandibles. International Journal of Oral & Maxillofacial Implants 2003, 18(6), 835-847.
4. Verma R, Joda T, Brägger U, Wittneben JG. A Systematic Review of the Clinical Performance of Tooth-Retained and Implant-Retained Double Crown Prostheses with a Follow-Up of ≥3 Years. J Prosthodont. 2013;22(1):2-12.
5. Langer A. Telescope retainer for removable partial dentures. J Prosthet Dent.1981a; 45:37
6. Langer A. Tooth supported telescopic restorations. J Prosthet Dent.1981 b; 44:515
7. Weigl P, Hahn L, Lauer HC. Advanced biomaterials used for a new telescopic retainer for removable dentures. J Biomed Mater Res 2000;53:320-36.
8. Stock V, Wagner C, Merk S, Roos M, Schmidlin PR, Eichberger M, et al. Retention force of differently fabricated telescopic PEEK crowns with different tapers. Dent Mater J 2016;35:594 600.
9. Yamaga E, Sato Y, a Minakuchi S, A structural equation model relating oral condition, denture quality, chewing ability, satisfaction, and oral health-related quality of life in complete denture wearers.J Dent 2013;41(8), 710–717.
10. Cerutti-Kopplin D, Emami E. Hilgert JB, Hugo FN, Rivaldo E, Padilha DM. Predictors of satisfaction with dentures in a cohort of individuals wearing old dentures: functional quality or patient-reported measures? J. Prosthodont 2017; 26, (3), 196–200.
11. Kulak, Y., Özcan, M., & Arikan, A. Subjective assessment by patients of the efficiency of two denture adhesive pastes. Journal of Prosthodontics: Implant, Esthetic and Reconstructive Dentistry 2005, 14(4), 248-252.
12. Emarah, A. Metal versus poly ether-ether Ketone secondary copings for rigid telescopic retained implant supported mandibular over dentures. Evaluation of clinical retention forces. Egyptian Dental Journal 2000, 66(3-July (Fixed Prosthodontics, Removable Prosthodontics and Dental Materials)), 1769-1778.
13. Nawafleh, N., Hatamleh, M., Elshiyab, S., Mack, F. Lithium Disilicate Restorations Fatigue Testing Parameters: A Systematic Review. Journal of Prosthodontics 2016, 25:116–126.
14. Beuer F, Edelhoff D, Gernet W, Naumann M. Parameters affecting retentive force of electroformed double crown systems. Clin Oral Investig 2010; 14:129-35.
15. Engels J, Schubert O, Güth JF, Hoffmann M, Jauernig C, Erdelt K, et al. Wear behavior of different double crown systems. Clin Oral Investig 2013; 17:503-10.
16. Güngör MA, Artunç C, Sonugelen M. Parameter's affecting retentive force of conus crowns. J Oral Rehabil 2004; 31:271-7.
17. Wagner C, Stock V, Merk S, Schmidlin PR, Roos M, Eichberger M, et al. Retention load of telescopic crowns with different taper angles between cobalt-chromium and polyetheretherketone made with three different manufacturing processes examined by pull off test. J Prosthodont 2018; 27:162 8.
18. Arora, S., & Mittal, S. Comparative Evaluation Of Alteration In Retention Force Values Of Different Attachment Systems For Implant Overdenture Over Various Time Intervals: An In Vitro Study. International Journal for Innovative Research in Science & Technology 2017, 4, 71-76.
19. Scherer, M. D. Comparison of Retention and Stability of Implant-Retained Overdentures Based upon Implant Location, Number, and Distribution (Doctoral dissertation, The Ohio State University). The International journal of oral & maxillofacial implants 2012, 25(4), 156-171.

20. Conserva, E., Menini, M., Tealdo, T., Bevilacqua, M., Pera, F., Ravera, G., & Pera, P. Robotic chewing simulator for dental materials testing on a sensor-equipped implant setup. The International journal of prosthodontics 2008, 21(6), 501–508.

21. You, W., Masri, R., Romberg, E., Driscoll, C. F., & You, T. The effect of denture cleansing solutions on the retention of pink locator attachments after multiple pulls: an in vitro study. Journal of Prosthodontics: Implant, Esthetic and Reconstructive Dentistry 2011, 20(6), 464-469.

22. Bayer S, Kraus D, Keilig L, Gölz L, Stark H, Enkling N. Wear of double crown systems: Electroplated vs. casted female part. J Appl Oral Sci 2012;20:384-91.

23. Majcher A, Leśniewska Kochanek A, Mierzwińska Nastalska E. A method and a device for the evaluation of the retention of telescopic dental crowns. J Mech Behav Biomed Mater 2017;69:362-7.

24. Abdelrehim, A., Abdelhakim, A. A., ElDakkak, S. M., & Gepreel, M. A. A comparative study to evaluate the retention of conventional and CAD/CAM fabricated bar attachment implant supported assembly (in vitro study). Alexandria Dental Journal 2020, 45(1), 75-79.