EGYPTIAN DENTAL JOURNAL
www.eda-egypt.org

Vol. 69, 1501:1515, April, 2023

Print ISSN 0070-9484 • Online ISSN 2090-2360

Fixed Prosthodontics and Dental Materials

Submit Date : 02-03-2023 • Accept Date : 03-04-2023 • Available online: 10-04-2023 • DOI : 10.21608/edj.2023.196818.2465

EFFECT OF CROSS ARCH STABILIZATION ON THE RETENTION OF A UNILATERAL DISTAL EXTENSION PARTIAL DENTURE USING A RESILIENT EXTRACORONAL ATTACHMENT: (IN VITRO STUDY)

Simone Nabil Anwar Aboutar* , Maha Wagdy Elkerdawy **

and Ahmed Emad ELdin Fayyad**

ABSTRACT

Aim: The aim of this in-vitro study was to compare the retention of unilateral attachment retained removable partial denture with crossing the arch for stabilization versus not crossing the arch. Retention was measured using the Universal Testing machine.

Methods: Mandibular epoxy model was made simulating unilateral free end saddle case with missing right first molar and second molar. The right first and second premolars were prepared to receive surveyed crowns with attached patrices of "rk-1 uni" attachment. Two metal-framework designs were made with matrices of "rk-1 uni" attachment casted to it. The intervention group design was a unilateral partial denture without cross-arch stabilization. The control group design was a conventional partial denture with cross-arch stabilization using double Aker clasp on the dentate side. A ready-made hook was attached to the geometric center of the intervention group partial denture. In the control group, a metal bar with a ready-made hook was attached to the geometric center of the partial denture. The hooks were used to help in measuring the retention with the Universal Testing Machine, at a speed of 0.5 mm/min. Measurements were done initially, after 500, 1000, 1500 & 2000 insertion/removal cycles which simulate 2 years of use by the patient.

Results: Statistically significant difference was found between retention of both designs ($p<0.001$). The partial denture of the control group showed higher retention than the intervention group partial denture. Both groups lost retention over time. Retention increased again after 1500 cycles. After completion of 2000 cycles, the control group partial denture design showed higher retention than the intervention group partial denture design.

Conclusion: The unilateral partial denture design had less retention than the partial denture with cross-arch stabilization. It also lost more retention than the denture with cross-arch stabilization. Although both dentures had initial acceptable retention force above 5 N, yet the denture with cross-arch stabilization showed superior retention than the unilateral denture after 2000 cycles.

KEYWORDS: Extracoronal attachment, Retention, Cross-arch Stabilization, Distal Extension, Removable Partial Denture.

* Master's Degree Candidate, Department of Prosthodontics, Faculty of Dentistry, Cairo University.
** Professor, Department of Prosthodontics, Faculty of Dentistry, Cairo University.

INTRODUCTION

Partial edentulism remains till the day one of the most common challenges in dentistry. It is a condition which has a direct effect on the life quality of the patient. Loss of teeth affects patient's esthetics and speech, especially if there was loss in the anterior teeth, that may cause lisping during speaking and may have an adverse effect on the self-confidence of the patient. In addition to its direct impact on health, as it affects mastication, and may force the patient to follow a soft diet only to adapt to their condition [(1)].

Kennedy Class II, which represents unilateral distal extension cases, is of the trickiest cases to restore, and has always presented biomechanical challenges since they acquire their support from two different tissues. One of them is the periodontal ligament via the teeth, through the action of the rest seat, while the other is acquired from the mucosal tissues of the residual ridges. There is variation in behavior of the supporting structures when enduring occlusal forces. The abutment tooth shows little movement of about 0.1 mm only, whereas the compressibility of the mucosa may range between 0.4 and 4 mm with mean resilience of 1.3 mm. In other words, the mucosa allows free movement to the saddle almost 13 times more than that permitted by the tooth in its alveolus. There are also horizontal forces generated on the denture by occlusal contact during function as well as by the oral musculature that surrounds the denture. These forces act in a way that displace the denture both antero-posteriorly and laterally [(2-4)].

There are multiple treatment options for restoring these cases, starting with implants as a primary option in cases which present no obvious contraindications for the use of implants. Implants offer the privilege of fixed prosthesis, which is highly demanded by patients, but it remains an expensive option. The alternative is the use of removable prostheses [(5-7)].

Removable prosthesis that can be used in restoring distal extension cases, are either conventional clasp-retained dentures, or attachment-retained dentures. The latter is not used commonly due to lack of dentist's knowledge or lack of technician's skill. Despite that, it has a lot of advantages, such as superior esthetics due to absence of clasps as well as superior retention derived from the attachments [(8-11)].

One of the most important considerations in the design of dentures for restoring unilateral distal extension cases, is the need for crossing the arch and placing clasps on the dentate side, in what we call "cross-arch stabilization", which aids in stability of the denture and resisting horizontal and rotational forces and thus aid in the overall retention of the prosthesis. On the other hand, cross-arch stabilization adds to the discomfort of the patient and their overall resenting of the removable partial denture [(9, 12-13)].

Some attachments were claimed that they are sufficient in providing the retention and do not require crossing the arch as in the conventional design of removable partial dentures used to restore the unilateral distal extension cases, such as the "rk-1 uni" attachment used in this study. Therefore, this study aimed to assess the effectiveness of this treatment option in case of not crossing the arch for stabilization and whether the retention will be affected or not, in contrast to crossing the arch [(14)].

MATERIALS AND METHODS

Modification of Acrylic Mandibular Educational Model

An acrylic cast[*] of the mandible used for educational purposes was used, where the posterior molars of the right side were removed to mimic a unilateral free-end saddle state, and their spaces were closed with utility wax[**]. The last two standing abutments, the right first and second premolars have been prepared to receive surveyed PFM crowns

* Banna educational acrylic model, Egypt.

** Cavex set up regular wax, Holland BV.

(fig.1). As for the left side, occlusal rests were prepared on the mesial triangular fossa of the left second molar and on the distal triangular fossa of the left first molar.

Construction of the Silicone Mold:

The modified model was inserted in the metallic duplicating flask* and duplicated using silicone duplicating material**. The assembly was then left on the bench for 25 minutes until complete setting of the silicone. The silicone mold was then poured into hard stone type III*** to produce primary cast. The stone cast was modified by lowering the height of the edentulous area (fig.2-b) to accommodate for the height of the used rk-1 attachment. Another silicone mold for the finally adjusted primary cast was made with the same way previously mentioned (fig.2-c).

Construction of the Epoxy Mandibular Cast:

The final silicone mold was poured into clear epoxy resin material**** and left to completely polymerize and reach its final setting time in 24 hours. Then the produced epoxy resin cast was finished and polished (fig.3).

Fig. (1): The educational model after modification and abutment preparation

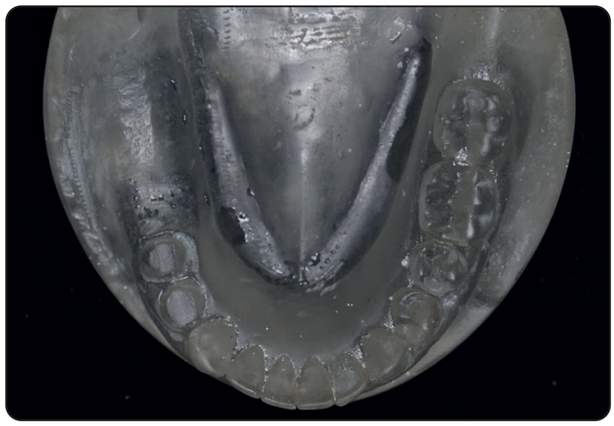

Fig. (3): Clear epoxy resin cast.

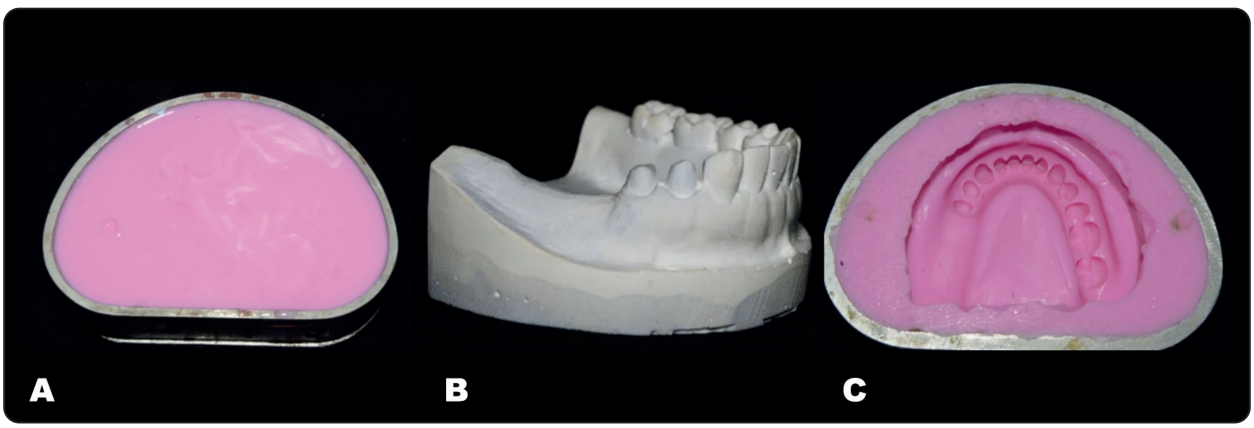

Fig. (2): (a) Silicone duplication in metal flask and cast totally submerged, (b) stone cast after ridge height adjustment, (c) final silicone mold for the adjusted primary cast.

* Metallic duplicating flask
** Replisil 22 N, duplicating addition silicone, Erlenweg, Germany.
*** Elite model dental stone, Zhermach, Germany.
**** Kemapoxy 150 resin, CMB, Giza, Egypt.

Fabrication of the Surveyed PFM Crowns with the Matrix Part of the rk-1 Attachment:

A two-stage impression of the epoxy resin model was done with addition silicone rubber impression material* and was poured into horseshoe stone cast with type IV extra hard stone**. After that, the abutments were sewed to produce removable dies, and ditching was done to the dies to accentuate the finish line. Wax pattern*** of the surveyed crowns of the prepared first and second premolars was then made, and lingual ledges were prepared with the help of a dental surveyor**** (fig.4).

The matrix part of the rk-1 attachment***** (fig.5) was aligned using the paralleling mandrel inserted in the dental surveyor, to ensure placement in a direction parallel to the path of insertion and removal of the prosthesis to be made and centered in the middle of the crest of the ridge which was stabilized with blue wax****** leaving 2mm space between the attachment and the ridge (fig.6).

Fig. (4): Wax pattern of the surveyed crowns with lingual ledges.

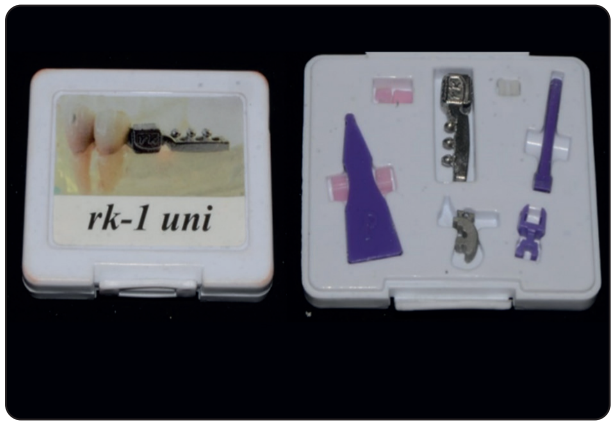

Fig. (5): The rk-1 uni attachment and its components.

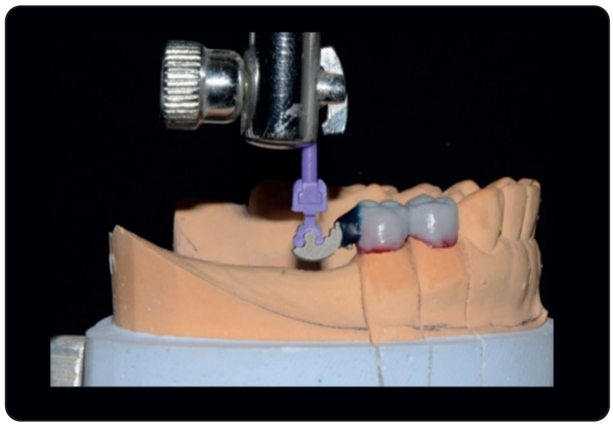

Fig. (6): Stabilizing the matrix part of the attachment with blue wax to the crowns' wax pattern.

The whole wax assembly, the splinted crowns together with the matrix, was sprued, flasked and invested with phosphate bonded investment material*******. Devesting of the crowns and sandblasting was done. Porcelain******** was then fired as buccal facings over the metal crowns of the lower right premolars. The splinted crowns were then cemented on the epoxy resin cast using glass ionomer cement********* (fig.7).

* Elite HD+, Zhermach, Germany.
** Shera Maximum 2000, Lemforde, Germany.
*** GEO Expert Functional Wax Grey, Renfert, Germany.
**** Surveyor B2, Bio-art, Brazil.
***** Rk-1, Kargi Saglik, Bursa, Turkey.
****** GEO Expert Functional Wax Blue, Renfert, Germany.
******* Bellavest SH, Bego, Bremen, Germany.
********Vita VM 13, Vita Zahnfabrik, Germany.
********* Medicem, Promedica Dental Material GmbH, Neumunster, Germany.

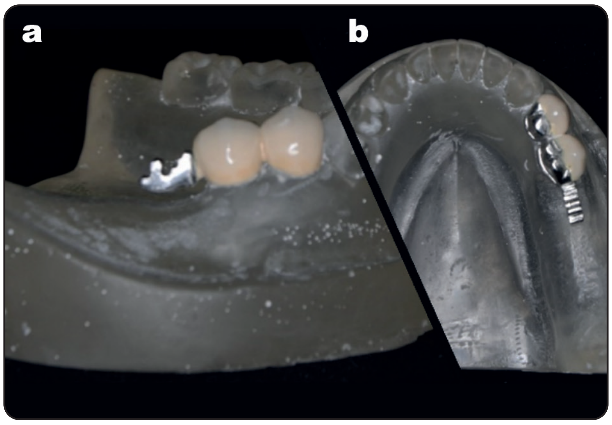

Fig. (7): Lateral (a) and occlusal (b) views of the cemented crowns with the matrix part of the rk-1 uni attachment.

Framework Fabrication:

An alginate impression* was made for the epoxy resin cast to which the crowns have been cemented. The impression was poured into hard stone**. On that stone cast, relief and block out of the undesirable undercuts, specially below the matrix of the rk-1 attachment, was made using block out wax*** (fig.8).

A silicone mold of the modified master cast was made and poured into phosphate bonded investment material**** to produce refractory cast, which after hardening was placed in an oven for half an hour. While the cast was still warm it was dipped into dipping wax*****. The whole procedure was repeated another time to produce another refractory cast (fig.9).

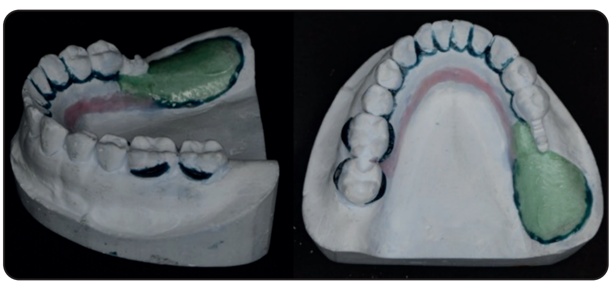

Fig. (8): Block out and relief done of master cast.

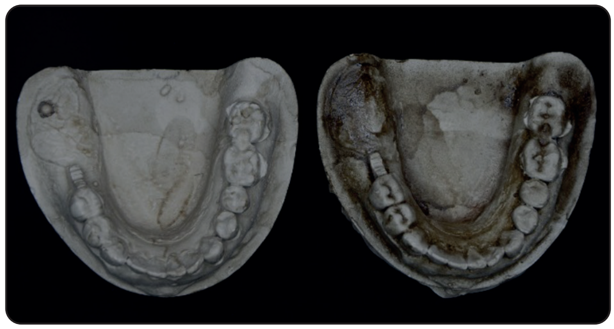

Fig. (9): The 2 refractory casts after dipping wax, ready for wax pattern fabrication.

On the refractory cast of the intervention group, wax pattern****** of the unilateral denture that doesn't cross the arch was made (fig.10-a) and the metal patrix of the rk-1 attachment was joined to the wax pattern, specifically related to the meshwork on the edentulous area, in its relative place to the matrix of the attachment, according to the manufacturer's instructions. The wax pattern extended as a plate from the meshwork and ended anteriorly at the right canine and was seated on the lingual ledges which have been designed on the surveyed crowns previously made.

On the refractory cast of the control group, wax pattern of the denture crossing the arch was made (fig. 10-b) and the metal patrix of the rk-1 attachment was attached to the wax pattern in its relative

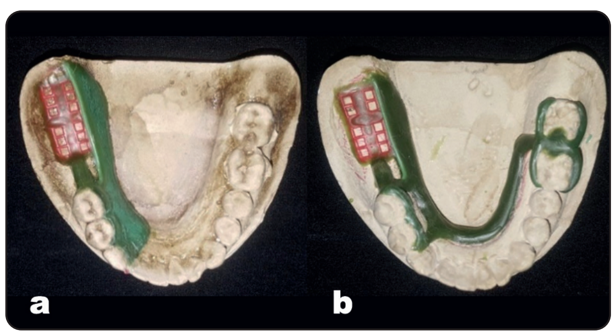

Fig. (10): (a) Wax pattern of the intervention group (not crossing the arch), (b) wax pattern of the control group (crossing the arch).

* Cavex CA 37, Holland BV.
** Elite model dental stone, Zhermach, Germany.
*** Bredent Biotec blocking out wax, Bredent, Senden, Germany.
**** Sheracast 2000, Shera, Germany.
***** Duro-Top dipping hardener, Bredent, Senden, Germany.
****** Bego modelling wax, Bego, Bremen, Germany.

place to the matrix of the attachment, relevant to the manufacturer's instructions as in the first refractory cast. In this design, the major connector has been a lingual bar, which extended from the meshwork on the free-end saddle at the right side and crossed the arch up to the left molars. From the major connector, arised 2 minor connectors, that were connected together coronally as an extended bracing clasp, resting on the lingual ledges that have been prepared on the surveyed crowns. The major connector on the left side, terminated by a minor connector arising between the left first and second molars, ending by a double Aker clasp on the left first and second molars.

The two wax patterns were sprued, flasked and invested with phosphate bonded investment material*. Wax elimination and casting into cobalt chromium** was done. Devesting, finishing and polishing of the frameworks was done. Final waxing up, flasking, acrylic packing of the frameworks was completed. The dentures were removed from the flasks and then finished and polished (figure 11).

The final dentures were checked on the epoxy master cast, then nylon caps of the rk-1 attachments were inserted in their position in the patrices of the attachments using plastic positioner tool (fig.12).

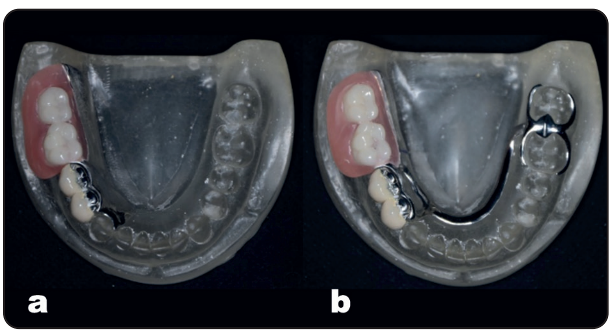

Fig. (11): Final completed dentures (a) intervention group, (b) control group.

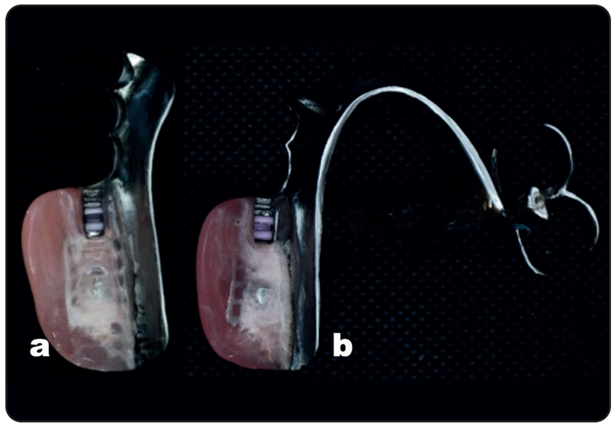

Fig. (12): Nylon cap inserted in the (a) unilateral denture of the intervention group, (b)cross-arch denture of the control group (b).

Metal Bar Construction and Hooks for Outcome Assessment:

In the control group, wax wire*** was used to construct a metal bar, connecting both sides of the metal framework. To place the hook for measurement of the outcome, it had to be placed in the geometric center of the prosthesis. Thus, the bar extended from the center of the free end saddle side, that is below the lower first molar, up to the center of the metal framework of the cross-arch side, below the minor connector arm (fig.13).

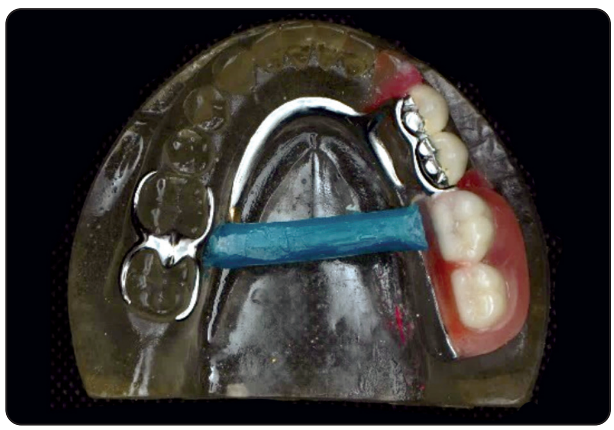

Fig. (13): Wax wire used for constructing the metal bar.

* Wirovest, Bego, Bremen, Germany.
** Brealloy F400, Bredent, Senden, Germany.
*** Beading wax wire, Bego, Bremen, Germany.

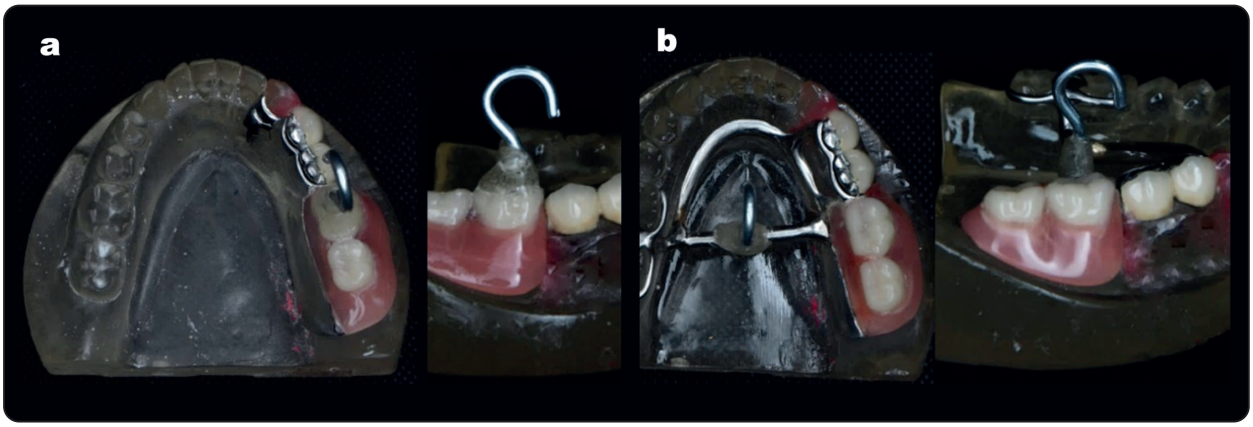

Fig. (14): (a) the attached hook centralized on the unilateral denture, (intervention group), (b) the casted and soldered metal bar with the attached hook centralized on the cross-arch denture (control group).

The wax arm was then flasked, invested and casted into cobalt chromium arm*. The arm was then devested, finished and polished and finally soldered in place to the metal framework of the denture of the control group. Then, a ready-made hook was attached to the center of the metal bar in a direction parallel to the path of insertion and removal of the metal-framework, using clear self-cure acrylic resin** (fig.14).

Whereas, in the intervention group, the ready-made hook was attached to the geometric center of the unilateral metal framework, which was midway between both ends of the prosthesis, and lied exactly at the center of the first molar, using clear self-cure acrylic resin (fig. 14).

Outcome measurement

In order to measure the outcome, Universal testing machine*** was used to calculate the force required to dislodge the partial dentures from the model. The outcome was measured in Newtons. The machine is controlled by a software**** on a computer, which allows data collection and analysis.

To measure the retention in each group, the denture was seated in place on the epoxy cast which was locked tightly on the machine table via tightening screw. A hook from the machine attached to the load cell was inserted loosely into the hook attached to the denture (fig.15).

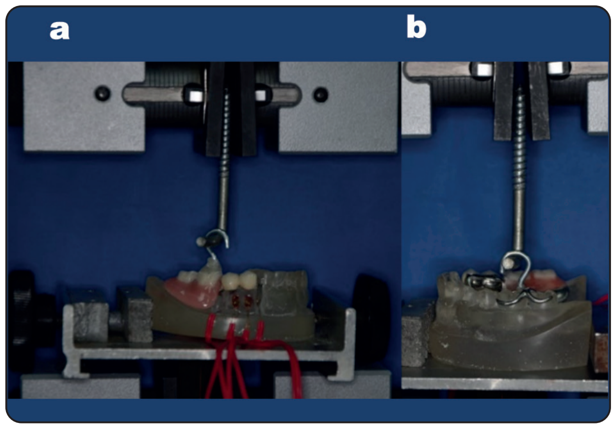

Fig. (15): (a) Hook from the universal testing machine engaging in the hook attached to the intervention group denture, (b) and the control group denture.

The loose position of the measuring hook was recorded by the machine as the zero position or the starting position. The machine was started via the software recording the force required to dislodge the denture from the epoxy cast at a speed of 0.5mm/min. As the load increased, the hook of the testing

* Brealloy F400, Bredent, Senden, Germany.
** Cold cure special tray material, Acrostone, Egypt.
*** Lloyd LR5K Plus Testing Machine, AMETEK Lloyd Instruments Ltd, United Kingdom.
**** Bluehill Universal testing software, Instron, Norwood, Massachusetts, United States.

machine was moving upward until complete dislodgement of the denture. The process was repeated 10 times to record 10 readings for each denture.

For each group, the partial denture was manually inserted and removed 500 times simulating 6 months of use by the patient. New readings were taken for each partial denture in the same way previously mentioned, 10 readings for each denture. Another 500 insertion and removal cycles were manually made, and new readings were recorded by the universal testing machine simulating the use after 12 months. After that, another 500 cycles with new readings to simulate 18 months use and finally 500 cycles were as well made and new readings were recorded to finally simulate 24 months of use by the patient for each denture. All these data were collected and statistically analyzed.

The mean and standard deviation values were calculated for each group in each test. Data were explored for normality using Kolmogorov-Smirnov and Shapiro-Wilk tests, data showed parametric (normal) distribution.

Two-way ANOVA was used to test the effect of interaction between different variables. Repeated measure ANOVA test was used to compare between more than two groups in related samples. Paired sample t-test was used to compare between two groups in related samples. Independent sample t-test was used to compare between two groups in non-related samples.

The significance level was set at $P \leq 0.05$. Statistical analysis was performed with IBM® SPSS® Statistics Version 20 for Windows.

RESULTS

A- Two-way ANOVA:

Data in table (1) shows the results of Two-way ANOVA analysis for the effect of different variables. The results showed that groups had a statistically significant effect. Also, subgroups had a statistically significant effect. The interaction between the two variables had a statistically significant effect.

B- Retention between the two groups:

i. Initial retention:

There was a statistically significant difference between (Unilateral denture) group where the mean retention was (5.26 N ±0.02) and (Cross-arch denture) group where the mean retention was (8.78 N ± 0.04), where (p<0.001), as shown in (table 2) and (figure 16).

ii. After 500 cycles:

There was a statistically significant difference between (Unilateral denture) group where the mean

Table (1): Results of Two-way ANOVA for the effect of different variables.

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	150.639	9	16.738	18722.999	.000
Intercept	527.850	1	527.850	590461.931	.000
Groups	47.105	1	47.105	52692.837	.000
Subgroups	88.955	4	22.239	24876.657	.000
Groups * Subgroups	14.578	4	3.645	4076.882	.000
Error	.018	20	.001		
Total	678.506	30			
Corrected Total	150.656	29			

df: degrees of freedom = (n-1), * Significant at $P \leq 0.05$

retention was (2.87 N ± 0.02) and (Cross-arch denture) group where the mean retention was (7.25 N ± 0.06), where (p<0.001), as shown in (table 2) and (figure 16).

iii. After 1000 cycles:

There was a statistically significant difference between (Unilateral denture) group where the mean retention was (1.71 N ± 0.02) and (Cross-arch denture) group where the mean retention was (2.87 N ± 0.01), where (p<0.001), as shown in (table 2) and (figure 16).

iv. After 1500 cycles:

There was a statistically significant difference between (Unilateral denture) group where the mean retention was (2.29 N ± 0.01) and (Cross-arch denture) group where the mean retention was (2.98 N ± 0.01), where (p<0.001), as shown in (table 2) and (figure 16).

v. After 2000 cycles:

There was a statistically significant difference between (Unilateral denture) group where the mean retention was (2.58 N ± 0.01) and (Cross-arch denture) group where the mean retention was (5.36 N ± 0.04), where (p<0.001), as shown in (table 2) and (figure 16).

C- Retention within groups

I. Unilateral denture: ***(table 2 & figure 16)***

There was a statistically significant difference between (Initial retention), (After 500 cycles), (After 1000 cycles), (After 1500 cycles) and (After 2000 cycles) where (p<0.001).

A statistically significant difference was found between (Initial retention), which was the highest retention force measured, with a mean of (5.26 N ± 0.02) and each of (After 500 cycles), (After 1000 cycles), (After 1500 cycles) and (After 2000 cycles) where (p<0.001).

Also, a statistically significant difference was found (After 500 cycles), where the mean retention force was (2.87 N ± 0.02), and each of (After 1000 cycles), (After 1500 cycles) and (After 2000 cycles) where a significant decrease was obvious (p<0.001).

Also, a statistically significant difference was found between (After 1000 cycles), where the mean retention force was (1.71 N ± 0.02) and each of (After 1500 cycles) and (After 2000 cycles) where the decrease in retention force continued (p<0.001).

A statistically significant difference was found between (After 1500 cycles) and (After 2000 cycles) where the mean retention forces were (2.29 N ± 0.01) and (2.58 N ± 0.01) respectively, where a significant increase is noted (p<0.001).

II. Cross-arch denture: (table 2 & figure 16)

There was a statistically significant difference between (Initial retention), (After 500 cycles), (After 1000 cycles), (After 1500 cycles) and (After 200 cycles) groups where (p<0.001).

A statistically significant difference was found between (Initial retention), which was the highest retention force measured, with a mean of (8.78 N ± 0.04) and each of (After 500 cycles), (After 1000 cycles), (After 1500 cycles) and (After 2000 cycles) groups where (p<0.001).

Also, a statistically significant difference was found between (After 500 cycles), where the mean retention force was (7.25 N ± 0.06), and each of (After 1000 cycles), (After 1500 cycles) and (After 2000 cycles) groups where a decrease in retention force was obvious (p<0.001).

Also, a statistically significant difference was found between (After 1000 cycles), where the mean retention force was (2.87 N ± 0.01) and each of (After 1500 cycles) and (After 2000 cycles) groups where the decrease in retention force continues significantly (p<0.001).

A statistically significant difference was found between (After 1500 cycles) and (After 2000 cycles) where the mean retention forces were (2.98 N ± 0.01) and (5.36 N ± 0.04) respectively, where a significant increase in retention is noted (p<0.001)

TABLE (2): The mean, standard deviation (SD) values of Retention of different groups.

Variables	Retention				
	Unilateral denture		Cross-arch denture		p-value
	Mean	SD	Mean	SD	
Initial retention	5.26	0.02	8.78	0.04	**<0.001***
After 500 cycles	2.87	0.02	7.25	0.06	**<0.001***
After 1000 cycles	1.71	0.02	2.87	0.01	**<0.001***
After 1500 cycles	2.29	0.01	2.98	0.01	**<0.001***
After 2000 cycles	2.58	0.01	5.36	0.04	**<0.001***
p-value	**<0.001***		**<0.001***		

; significant (p<0.05) ns; non-significant (p>0.05)

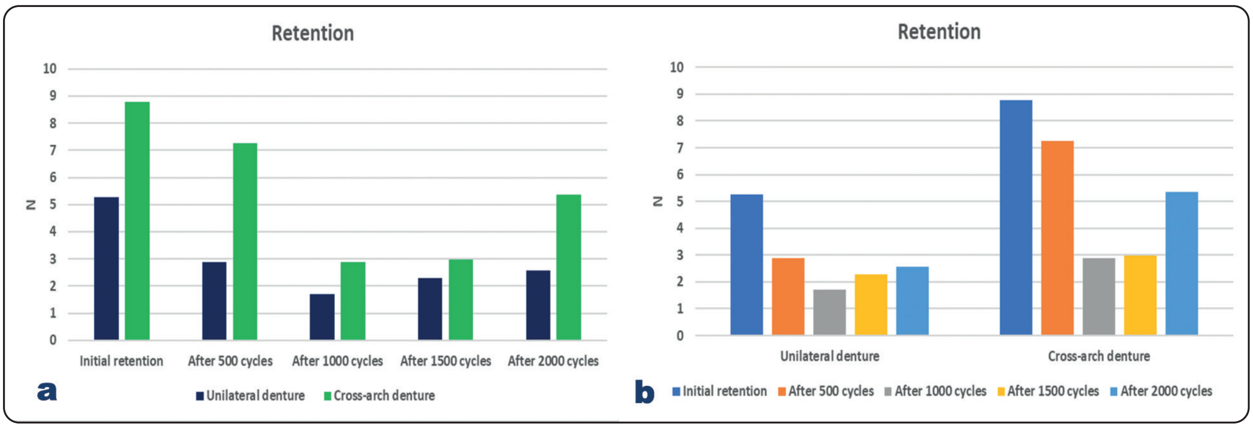

Fig.16: Bar chart representing retention of different groups.

DISCUSSION

This study was designed as an in-vitro study, to overcome limitations of measuring retention in-vivo, due to the difficulty of performing pure vertical force intraorally. In addition, in-vitro study for retention measurement, allows standardizing the tested conditions such as the direction and magnitude of the dislodging force. However, in-vitro studies lack circumstances existing in the oral environment as humidity, variation of temperature, load of mastication as well as presence of saliva. It doesn't take into consideration as well presence of parafunctional habits that could be present and vary from one patient to another [15,16].

In this study, a mandibular model was chosen since partial edentulism is more prevalent in the mandible than in the maxilla as stated in the literature. Prabhu N et al., related the reason behind the higher incidence of edentulism in the mandible to the fact that mandibular teeth erupt earlier in the oral cavity than maxillary teeth and are thus more prone to caries and extraction. In addition, Kennedy Class I and II are more prevalent in the mandible. Besides the challenges present in restoring Kennedy class II cases due to retention and support problem, an American study found out an escalating need of Kennedy class II RPDs among the past 30 years, unlike other Kennedy classes. Mandibular Kennedy class II cases comprise about 24.3 % in a study made in 2012 [17-19].

Duplication of casts was done using addition duplication silicone and was chosen over the agar-agar hydrocolloid material. This choice was related to the fact that processing time for the duplication addition silicone is much less than time required for preparing the agar-agar material. In addition, it was found that addition silicone produced no linear dimensional changes in the duplicated material due to absence of byproducts such as alcohol and water. Whereas, duplicated materials produced from the reversible hydrocolloid agar-agar, show significant linear dimensional change, owing to the great water content proportion leading to syneresis phenomenon. On the other hand, both materials produce fine surface details of the duplicated materials [20-23].

The model used here for the final measurements of results was made from epoxy resin material, which has comparable modulus of elasticity to the bone, which is approximately 20 GPa [24].

One of the drawbacks of using extra-coronal attachments is the massive torque it exerts on the most distal abutment. This leads to a necessity to splint abutments to reduce stresses and torquing action on them. It was found that reducing the number of splinted teeth from two to one caused a significant increase in micro-strains by 52% [25-27].

The frameworks were made on refractory casts that were made from phosphate bonded investment, that were left for half an hour in an oven for complete hardening, and while still hot were dipped in dipping wax to make them smooth and dense and enhance the adhesion of the wax patterns to the casts' surfaces. When designing frameworks for unilateral distal extension cases, it must be taken into consideration that these cases act as class I lever, where the free end saddle functions as the effort arm whereas the cross-arch stabilization acts as the resistance arm. Thereby, of the most common designs used in this case is an embrasure clasp extending between first and second molars on the dentate side, except if there is excessive soft tissue undercut requiring excessive block out in the second molar region, it will require the movement of the embrasure clasp more anteriorly between the second premolar and first molar. A recent study as well has shown that absence of a major connector led to increase in stresses on abutment teeth in unilateral distal extension RPDs that do not cross the arch [28,29].

The bracing arm and plate incorporated in the design act to counteract the harmful lateral forces at the attachment, thereby decrease the wear of the attachment [30-32].

A metal bar was constructed in the control group to which a ready-made hook was attached for measurements. The metal bar was attached to the bilateral partial denture framework between the first mandibular molars for outcome assessment. The area of connection was selected as the first molar is the main bearer of occlusal load in mandibular dental arch. In the intervention group, the hook was also placed at the first molar area for the measurements [33].

Dislodgement of the dentures was performed using the universal testing machine parallel to the path of insertion and removal of the attachment part of the dentures, after locking the epoxy cast tightly on the machine table, to secure it in position without any movement. This machine replicates the vertical dislodgement of the denture from the mouth and is approved as a reliable and valid instrument in testing peak load forces in-vitro. The crosshead speed was adjusted at 0.5 mm/min. Insertion and removal cycles of both dentures were done manually 2000 times and measurements were taken following each 500 cycles, mimicking 6 months of use for each 500 cycles, this was based on the assumption that a denture is removed 3 times a day approximately for cleaning [34-38].

One of the main challenges when restoring Kennedy class II cases is the retention. After the introduction of unilateral extra-coronal attachments, it was assumed that they can eliminate the need for crossing the arch in the RPD design, which will reduce the bulk of the prosthesis and thus be more comfortable to the patient. This study examined the impact of two designs on the retention of RPDs used in Kennedy Class II restoration. A unilateral design, depending mainly in retention on the used attachment, the rk-1 uni, and a conventional design crossing the arch and embracing the dentate side with a double Aker clasp, in addition to the rk-1 uni attachment on the free-end saddle side.

The results displayed statistically significant difference between retention in both designs. Where the cross-arch design, exhibited higher retention force, with an average of 8.78 N compared to the unilateral design, which exhibited mean retention force of 5.26 N as initial retention. Both designs showed values higher than 5N, which is the minimum retention force needed for stabilizing a prosthesis to be considered effective for clinical use [38-40].

There was noticeable reduction in retention force for the unilateral RPD design after 500 cycles, retention force was found to be 2.87N only, which represents 54.5 % only of the initial retention. Whereas the decrease in the cross-arch RPD design after 500 cycles resulted in retention force of 7.25N, which is about 82.5% of the initial retention. After 1000 cycles, retention force of the unilateral design continued to descend until reaching 1.71N, which represents 32.5% of the initial retentive force. The cross-arch RPD design, showed significant decrease after 1000 cycles, to reach a retention force of 2.87N which represents 32.6% of the initial retention of this design. Therefore, after 1000 cycles which represents a year of use in our study, both designs reached approximately 32% of their initial retention force at the time of insertion, with the cross-arch design having superior retention above the unilateral design. This gradual loss in retention of attachments coincides with the findings in literature attributed to wear phenomenon. Wear of attachments, specifically nylon caps of attachments is the main cause behind the decrease of retentive force of the attachment, affecting its clinical predictability and its performance, and thus may affect the patient acceptance of the prosthesis. Other causes of retention loss in attachments may be due to surface changes, plastic deformation or even fracture in attachment components due to functional or parafunctional loads [37,38,41-43].

After 1500 cycles, an increase in the retention force of both designs was noticed, to reach 2.29N in the unilateral RPD design and 2.98 in the cross-arch RPD design. This increase continued after 2000 cycles to reach 2.58N in the unilateral RPD design which represents 49% of the initial retention at the time of insertion, and 5.36N in the cross-arch RPD design which represents 61% of the initial retention at the time of insertion. This increase in the retention force was mentioned as well in previous studies in the literature, it was attributed to the increase in roughness of the retentive parts. The increase in roughness or wear of the retention components, leads to increase in the forces required for joining and separation of the attachment system, therefore causing this temporary increase in the retentive force. The same wear phenomenon, or in other words, the abrasion is the reason behind the loss of the retentive force on the long run [37,44-48].

The alternative increase and decrease in the retention force behavior of attachments, was discussed in literature and resulted in dividing the retention force behavior into two periods namely the run-in period and the functional period. The run-in period is characterized by unstable behavior of the attachments in which marked increase followed by subsequent decrease in the retention force occurs. On the other hand, the functional period is characterized by more stable pattern of the retention force of the attachment [46].

There are few limitations in this study, since the retention force here was measured only in the axial direction, and rotational forces were not taken into consideration, but these para-axial forces are not evitable inside the patient's mouth. Also, no saliva simulation was used, this would definitely affect the results, due to its direct effect on the wear of attachments which affects retention. Finally, in-vitro studies never mimic the actual conditions of the patient's mouth.

CONCLUSION

Within the limitations of this study, it could be concluded that initial retention in unilateral distal extension RPD retained by resilient extra-coronal attachment which crosses the arch is higher than unilateral distal extension RPD design, but both designs offered acceptable initial retention. Both designs decrease in retention over time, but the loss of retention is higher in the unilateral design than the cross-arch design. The retention force after 2000 cycles, which represents 2 years of use, is higher in the cross-arch design RPD than the unilateral design.

REFERENCES

1. Emami, E., de Souza, R. F., Kabawat, M., & Feine, J. S. (2013): The impact of edentulism on oral and general health. International journal of dentistry, 2013, 498305.
2. Dhingra, K. (2012): Oral rehabilitation considerations for partially edentulous periodontal patients. Journal of Prosthodontics: Implant, Esthetic and Reconstructive Dentistry, 21(6), 494-513.
3. Ben-Ur, Z., Helft, M., & Serebro, L. (1983): Planning the clasp system for a distal extension removable partial denture. Quintessence of dental technology, 7(1), 15-18.
4. Davenport, J. C., Basker, R. M., Heath, J. R., Ralph, J. P., Glantz, P. O., & Hammond, P. (2001): Bracing and reciprocation. British Dental Journal, 190(1), 10–14.
5. Pjetursson, B. E., Tan, K., Lang, N. P., Bragger, U., Egger, M., & Zwahlen, M. (2004): A systematic review of the survival and complication rates of fixed partial dentures (FPDs) after an observation period of at least 5 years. I. Implant-supported FPDs. Clinical Oral Implants Research, 15(6), 625–642.
6. Ohkubo, C., Kobayashi, M., Suzuki, Y., & Hosoi, T. (2008): Effect of implant support on distal-extension removable partial dentures: in vivo assessment. The International Journal of Oral & Maxillofacial Implants, 23(6), 1095–1101.
7. Turkyilmaz, I. (2009): Use of distal implants to support and increase retention of a removable partial denture: A case report. Journal of the Canadian Dental Association, 75(9), 655–658.
8. Davenport, J. C., Basker, R. M., Heath, J. R., Ralph, J. P., & Glantz, P.-O. (2000): Retention. British Dental Journal, 189(12), 646–657.
9. Carr, A.B., & Brown, D.T., (2016). McCracken's Removable Partial Prosthodontics, (13th ed.), St. Louis, Missouri.
10. Angadi, P. B., Aras, M., Williams, C., Nagaral, S., & Angadi, P. (2012): Precision attachments; applications and limitations. J Evol Med Dent Sci, 1(6), 1113-1121.
11. Burns, D. R., & Ward, J. E. (1990): A review of attachments for removable partial denture design: Part 2. Treatment planning and attachment selection. The International Journal of Prosthodontics, 3(2), 169–174.
12. Scott, B. J., & Maillou, P. (2003): The distal extension base denture. Dental Update, 30(3), 139–144.
13. Ferro, K. J., Morgano, S. M., Driscoll, C. F., Freilich, M. A., Guckes, A. D., Knoernschild, K. L., ... & Twain, M. (2017). The glossary of prosthodontic terms.
14. Uludag, B., Gonuldas, F., Tokar, E., & Sahin, V. (2015): A Technique for Retrofitting a Metal Ceramic Crown to an Attachment-Retained Removable Partial Denture: A Clinical Report. Journal of Prosthodontics, 24(2), 164–167.
15. Rutkunas, V., Mizutani, H., & Takahashi, H. (2007): Influence of attachment wear on retention of mandibular overdenture. Journal of Oral Rehabilitation, 34(1), 41–51.
16. Rodrigues, R. C. S., Faria, A. C. L., Macedo, A. P., Sartori, I. A. D. M., De Mattos, M. D. G. C., & Ribeiro, R. F. (2009): An in vitro study of non-axial forces upon the retention of an O-ring attachment. Clinical oral implants research, 20(12), 1314-1319.
17. Charyeva, O. O., Altynbekov, K. D., & Nysanova, B. Z. (2012): Kennedy classification and treatment options: a study of partially edentulous patients being treated in a specialized prosthetic clinic. Journal of Prosthodontics: Implant, Esthetic and Reconstructive Dentistry, 21(3), 177-180.

18. Manimaran, P., Kumar, C. D., Saisadan, D., Abirami, M., Kumar, N., & Mani, J. (2017): Partial Edentulousness in a Rural Population Based on Kennedy's Classification: Epidemiological Study. Journal of Pharmacy & Bioallied Sciences, 9(Suppl 1), S34–S36.
19. Chamoko, J., & Khan, S. (2019): Outcomes of mandibular Kennedy Class I and II prosthetic rehabilitation-An observational study. South African Dental Journal, 74(10), 549-555.
20. Margetis, P. M., & Hansen, W. C. (1957): Changes in agar-agar type duplicating material and agar-agar on heating and storage. The Journal of the American Dental Association, 54(6), 737–745.
21. Hembree, J. H., & Nunez, L. J. (1974): Effect of moisture on polyether impression materials. The Journal of the American Dental Association, 89(5), 1134–1136.
22. RW, P. (1997): Skinner's Science of dental materials 9th ed, Philadephia.
23. Jain, S., Mattoo, K. A., & Arora, A. (2016): Comparative evaluation of linear dimensional accuracy and surface detail reproduction of duplicating materials-An in vitro study. International Journal of Research in Dentistry, 5(6), 1–11.
24. Dahab, I. A., El-Gendy, A. A., & Eltorky, I. R. (2015): In vitro stress analysis study of different prosthetic options using single posterior implant for management of mandibular unilateral distal extension saddle. Tanta Dental Journal, 12(1), 7-15.
25. Berg, T., & Caputo, A. A. (1992): Comparison of load transfer by maxillary distal extension removable partial dentures with a spring-loaded plunger attachment and I-bar retainer. The Journal of prosthetic dentistry, 68(3), 492-499.
26. Berg, T., & Caputo, A. A. (1993): Maxillary distal-extension removable partial denture abutments with reduced periodontal support. The Journal of prosthetic dentistry, 70(3), 245-250.
27. El Charkawi, H. G., & El Wakad, M. T. (1996): Effect of splinting on load distribution of extracoronal attachment with distal extension prosthesis in vitro. The Journal of prosthetic dentistry, 76(3), 315-320.
28. Carr, A. B., & Brown, D.T., (2005a). McCracken's Removable Partial Prosthodontics, (11th ed., p. 30), C.V.Mosby.
29. Aras, M. A., & Mascarenhas, K. (2009): Designing options for mandibular unilateral distal extension removalble partial dentures. Journal of Indian Prosthodontic Society, 9(4).
30. HW, P. (1979): Precision attachments in dentistry. 3rd ed., p. 217-300, St Luis: CV Mosby Co.
31. Carr, A. B., & Brown, D.T., (2005b). McCracken's Removable Partial Prosthodontics, (11th ed., p. 112–126), C.V.Mosby.
32. AlmEldeen, H. I. (2017): The effect of reciprocal arm on the supporting structures of the abutments in cases retained by unilateral attachment. Egyptian Dental Journal, 63(1-January (Fixed Prosthodontics, Dental Materials, Conservative Dentistry & Endodontics)), 933-939.
33. Kumagai, H., Suzuki, T., Hamada, T., Sondang, P., Fujitani, M., & Nikawa, H. (1999): Occlusal force distribution on the dental arch during various levels of clenching. Journal of Oral Rehabilitation, 26(12), 932-935.
34. Williams, B. H., Ochiai, K. T., Hojo, S., Nishimura, R., & Caputo, A. A. (2001): Retention of maxillary implant overdenture bars of different designs. The Journal of prosthetic dentistry, 86(6), 603-607.
35. Rutkunas, V., & Mizutani, H. (2004): Retentive and stabilizing properties of stud and magnetic attachments retaining mandibular overdenture. an in vitro study. Stomatol Baltic Dent Maxillofac J, 6(3), 85-90.
36. Fromentin, O., Lassauzay, C., Abi Nader, S., Feine, J., & de Albuquerque Junior, R. F. (2010): Testing the retention of attachments for implant overdentures–validation of an original force measurement system. Journal of oral rehabilitation, 37(1), 54-62.
37. Mahross, H. Z., & Baroudi, K. (2015): Evaluation of retention and wear behavior for different designs of precision attachments. OHDM, 14(4), 244-249.
38. Reda, K. M., El-Torky, I. R., & El-Gendy, M. N. (2016): In vitro retention force measurement for three different attachment systems for implant-retained overdenture. Journal of Indian Prosthodontist Society, 16(4), 380–385.
39. Botega, D. M., Mesquita, M. F., Henriques, G. E. P., & Vaz, L. G. (2004): Retention force and fatigue strength of overdenture attachment systems. Journal of oral rehabilitation, 31(9), 884-889.
40. Da Fontoura Frasca, L. C., Mattia, P. R. C., Botega, D. M., & Rivaldo, E. G. (2014): Evaluation of retention

forces and resistance to fatigue of attachment systems for overdentures: plastic and metal components. Implant dentistry, 23(4), 451-455.

41. Fontijn-Tekamp, F. A., Slagter, A. P., Van Der Bilt, A., Van'T Hof, M. A., Witter, D. J., Kalk, W. J. J. A., & Jansen, J. A. (2000): Biting and chewing in overdentures, full dentures, and natural dentitions. Journal of dental research, 79(7), 1519-1524.

42. Van der Bilt, A., Van Kampen, F. M., & Cune, M. S. (2006): Masticatory function with mandibular implant-supported overdentures fitted with different attachment types. European Journal of Oral Sciences, 114(3), 191–196.

43. Swain, M. V. (2009): Attachment systems for mandibular two-implant overdentures: a review of in vitro investigations on retention and wear features. Int J Prosthodont, 22(5), 429-0.

44. 44. Breeding, L. C., Dixon, D. L., & Schmitt, S. (1996): The effect of simulated function on the retention of bar-clip retained removable prostheses. The Journal of prosthetic dentistry, 75(5), 570-573.

45. Petropoulos, V. C., Smith, W., & Kousvelari, E. (1997): Comparison of retention and release periods for implant overdenture attachments. The International Journal of Oral & Maxillofacial Implants, 12(2), 176–185.

46. Besimo, C. E., & Guarneri, A. (2003): In vitro retention force changes of prefabricated attachments for overdentures. Journal of oral rehabilitation, 30(7), 671-678.

47. Naert, I., Alsaadi, G., & Quirynen, M. (2004): Prosthetic aspects and patient satisfaction with two-implant-retained mandibular overdentures: a 10-year randomized clinical study. The International Journal of Prosthodontics, 17(4), 401–410.

48. Wolf, K., Ludwig, K., Hartfil, H., & Kern, M. (2009): Analysis of retention and wear of ball attachments. Quintessence International, 40(5), 405–412.