Original Article

Retention Evaluation of Implant-Supported Mandibular Overdenture Using Two Different Attachment Systems: An in Vitro Study

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Abstract

Objective: The purpose of this in vitro study was to evaluate the retentive behavior of implant-supported overdenture using two different attachment systems (locator and milled bar-clip attachment system).

Methods: Six edentulous mandibular models were fabricated from cold-cure PMMA; the denture-bearing area of the acrylic resin model was covered by an approximately 1.5 mm thick silicone resilient liner to simulate mucosa. The Study models were divided into three groups: Model A (locator), Model B (milled bar-clip attachment system without extension), and Model C (milled bar-clip attachment system with 1cm extension). However, for each study model, a complete mandibular denture was constructed. Anterior, posterior, and central dislodging forces were measured by digital force gauge at the beginning of the study (Initial retention) and after 540 courses of consecutive pulling and inserting the prosthesis (final retention), which was to simulate six months of overdenture use assuming three daily removals and insertions for oral hygiene practice.

Results: There were statistically significant differences in retention between the group models, and milled bar-clips attachment systems revealed the highest retentive capacity. However, after six months of simulated use, there was a significant retention loss; retention of Model B recorded the highest percentage loss of 55.1%, while Model A recorded the most minor retention loss of 24%.

Conclusions: The bar and clip attachment system offered higher retentive values than the locator attachment system. However, the retention loss was correlated to the particular attachment system, and the bar–clip attachment systems had the highest percent of retention loss. In contrast, the locator attachments were associated with acceptable retention, simplicity, and minimal retention.

Keywords: *CAD/CAM, Implant supported overdenture, Locator, Milled bar.*

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Introduction

Implant-supported overdentures (ISODs) have expanded rapidly as a successful treatment modality to rehabilitate completely edentulous patients. It has been demonstrated that implant-supported overdentures have improved retention and stability compared to conventional dentures.[1] Also, implant-retained overdentures may reduce residual ridge resorption and improve chewing function, nutritional status, speech, and patient confidence.[2,3]

With implant-supported overdentures, different attachment systems are used to anchor the prostheses to the implants placed in the patient's mouth; various attachment systems are available for implant-supported overdentures, including bar, ball and socket, magnets, and locators.[4] However, the attachment selection depends upon the case's complexity, the angulation of the implants, the amount of retention needed, available vertical and horizontal prosthetic space, and jaw morphology.[5]

Attachments are small mechanical components incorporated to provide retention and support, one part connects to a root, tooth, or implant (male part) and another part to a prosthesis (female part), or the two components can be called 'matrix' and 'patrix', the patrix being the male component that is attached to a prosthesis or denture framework and the matrix being the female component.[6]

Furthermore, attachments are divided into two categories: non-splinted anchorage systems (such as the ball attachment, locator attachment, and OT equator) and splinted anchorage systems, such as the bar type, to provide retention force for implant-supported overdentures.[7]

The function of the prosthesis is influenced by the type of attachment system and the design of the implant overdentures; however, the overdentures must be carefully designed to achieve adequate stability, optimal form, contour, aesthetics, and comfort for the patient. Moreover, retention and stress distribution are the two crucial factors that the prognosis of the prosthesis depends on.[8]

The last decade has seen an increasing number of digital intraoral scanner devices to overcome difficulties associated with conventional techniques; hence, digital impressions with an intraoral scanner (IOS) and CAD/CAM technologies were developed for dental applications.[9] Scanning the edentulous arch for many IOS systems and dental cases can be challenging. It can be difficult for scanners to capture reliable data due to the lack of tooth structure and anatomy. However, if users execute the correct scan strategy with the intraoral scanners, they will be able to capture accurate scan data successfully.

Fortunately, advances in CAD/CAM technology have brought about production techniques that are faster and more precise, increasing the efficiency with which implant bars are fabricated and greatly improving predictability upon seating. The overall CAD/CAM process minimizes or eliminates repeat trials, and the high-grade alloys used to mill inclusive CAD/CAM bars result in a one-piece, lighter, stronger framework, increasing patient comfort and confidence.[10]

The digital designing process for the bar gives the flexibility to manipulate every dimension of the bar with a level of precision measured in microns, and this enables us to set the height of the bar and craft its shape for maximum strength, optimal comfort, and proper support for the acrylic build-up. So digital manufacturing technology Cr/Co bars serve to eliminate the guesswork associated with conventional casting techniques.

Hence, this in vitro study was performed to evaluate the retentive behavior of the implant-supported overdenture using two different attachment systems (locator and milled bar-clip attachment system) after 540 courses of consecutive pulling and inserting of the prosthesis, which was to replicate a six-month period of overdenture use, supposing three daily removals and insertions for oral hygiene practice.

Furthermore, to replicate the lower edentulous arch, a 1.5 mm thick layer of self-curing silicone soft liner was added; this may have had an additional impact on the retentive behavior of the attachment systems since the elasticity of the soft tissue may affect their retentive properties.[11]

According to Xia et al.,[12] a denture's retention, stability, and attachment are all crucial for optimum oral results; however, an ideal overdenture has attachment systems that offer enough retentive forces to offset dislodging forces.[13]

Materials and methods

Fabrication of study cast models

Three edentulous mandibular models (without ridge undercuts) were fabricated from cold-cure poly methyl methacrylate resin. The denture-bearing area of the acrylic resin model was covered by an approximately 1.5 mm thick silicone resilient liner (GC.co) to simulate edentulous mucosa.[14]

From the beginning of the procedure, the stone model (Goldstone. co) was fabricated from an edentulous mandibular mold called the first mold. Light cure acrylic plate (PMMA) was used to form a layer on the stone model to create a 1.5 mm space for the acrylic models to be filled with a resilient silicone liner later on. The dental stone was used for sealing the lightly cured acrylic plate on the stone cast to prevent leakage of duplicate silicone (Protechno.co) into underneath the base. After that, the stone cast, with a layer of light-cured acrylic plate was inserted inside a dental flask to allow easier pouring of the duplicate silicone material and form the second mold with 1.5mm space.

Next, the first mold was filled with the cold-cure poly methyl methacrylate resin (PD.co); after the acrylic model had set, the soft base primer was applied to the acrylic surface to stimulate the contact between the acrylic models and the resilient silicone liner. Later, the resilient silicone liner was inserted inside the second edentulous mandibular mold. Then the acrylic model was placed over the resilient silicone liner to form an acrylic model, as shown in detail in Figure 1.

Mandibular overdenture fabrication

An upper and lower stone cast was fabricated from the second maxillary and edentulous mandibular molds. A conventional technique was followed for the construction of four mandibular dentures and one maxillary denture; (one of the mandibular dentures was used as a surgical guide for standardization of implant placement, and the rest of the mandibular dentures were used as overdentures for the study models), while the maxillary denture was used as a guide for the arrangement of all mandibular dentures on the fully adjustable articulator.

Implant placement into the models

One of the mandibular dentures was used as a guided stent (surgical guide) to locate the position of the dental implants. Dental implant fixtures (Roott.co) 3.5 mm in diameter and 10.0 mm in length were placed inside the models.

The successive drills of the implant surgical kit were used to prepare implant housing, finishing with a drill of 3.2 mm in diameter. First, the pointer drill was used to locate the implant site, and then the pilot drill was used to reach the full length of the implant, after which the DSTEP1 and DSTEP2 drills were used to prepare the implant holes.

The implants were screwed into their prepared sites using a ratchet wrench till the torque reached higher than 35 N. Finally, the parallelism of the implants was checked using a dental cast surveyor.[15]

Grouping of the models

The two dental implants were placed in the left and right first premolar regions for each model and divided into three groups according to the different attachment systems: Model A (locator attachment), Model B (bar-clip attachment without extension) and Model C (bar-clip attachment with 1cm extension), as illustrated in Figure 2.

Placement of locator attachment

The locator attachment system of 2 mm height (Roott.co) was selected for our study models according to the thickness of the soft resilient liner. The placement of locator attachments was performed by the pick-up technique; first, the locator abutment was screwed onto each implant using a screwdriver and wrench to 30 N torques. After that, the nylon cap and the housing were snapped onto the locator abutments.

In addition, sufficient clearance was provided for the corresponding site for locator abutments on the mandibular dentures since the entire set of complete dentures used the same arrangement, and the position of dental implants was similar for all the models.

Once it was verified that there was adequate clearance at the inner surface of the dentures, with the dentures seated in a passive fashion and not making any contact with the locators, the cold cure acrylic resin was mixed and applied to the inner surface of the denture, and the dentures were seated on the study models. Once the acrylic resin had set, the denture was removed from the study model and the excess acrylic was removed from the inner side of the denture.

Fabrication of the bar attachment

A. Scanning the study cast models

Our main objective in using IOS (MEDIT i700) was to obtain the standard tessellation language file (STL file) of the model to be executed in computer-aided design software (Exocad GMBH Dental CAD) for digital designing of the bar.[16]

The manufacturer's instructions for IOS were followed to scan the study models; the initial step was scanning the mandible without scan bodies (Figure 3 A). The scanning process started from the right retromolar pad region and then continued along the crest of the alveolar ridge to the left retromolar pad region. Once the arch had been scanned, it would provide a stable foundation for the scanned data. Next, the buccal and lingual vestibules were scanned and the scan bodies were then screwed onto the study models to start the second step of the scanning process, using the same path as in the previous step. During the process the scan bodies were recognized by the scanner as the implant library had previously been introduced to the scanner software.

B. Designing and milling the Bar

After the designed file had been approved, the file could be executed by the milling software. That software runs a preliminary routine that nests the virtual bar within a digital blank and maps out the proper toolpath. A physical chrome cobalt blank was then attached to a milling fixture and placed within the highly precise 5 Axis mill.

When the milling process was completed, the bar underwent a proprietary treatment process to ensure maximum flexural strength. The screws holding the bar within the block were cut and removed, followed by a final hand polish. The bar underwent a final inspection and was fitted onto the study cast models to ensure a passive fit with no rocking and no gaps. (Figure 3 C)

C. Clip attachment

Bar-clip attachment systems basically consist of a clip that snaps over to hold the prosthesis in its place. The clip compartment of (Rhein83.co) consists of two parts: the clip attachment (yellow part) and the plastic housing (blue part). The plastic housing is converted to a metal housing, inside which the clip is fitted and inserted into the prosthesis. The milled bar was screwed on the study models, and then the clip compartments snapped into their places on the bars; next, a dental wax was used to block all undercuts on the study models.[16]

In addition, sufficient spaces for the corresponding sites of the bars and clips were prepared on the inner side of the complete dentures in a passive manner.

The cold cure acrylic resin was mixed and applied to the inner surface of the dentures and the dentures were then seated on the study models. Once the acrylic resin had set, the dentures were removed from the study models, the clips and their metal housing were picked up with the dentures, and the excess acrylic was removed.

Retention evaluation process

First, four U-shaped stainless steel wire loops (Ø 0.9 mm) with retentive tags were attached via cold cure acrylic resin to the lingual side of the denture’s polished surface (canines and second molars). Next, the U-shaped loops on both sides of the denture were connected with stainless steel wire (Ø 0.5 mm), and the two loops on the left and right canines were connected to create an anterior centrally looped wire to measure the anterior retention value. Stainless steel wire was then used to connect the two loops on the left and right second molars to create a posterior centrally looped wire to measure posterior retention value and two diagonal wires that met at a crossing point were used to measure the central retention value.[17,18] (Figure 4 A, B)

Second, three holes were drilled into the base of the study cast models in line with the anterior, posterior, and centrally looped wires, respectively. Each hole met the hook of the digital testing machine, and the study models according to anterior, central, and posterior looped wires interchangeably, and using these holes the model would be screwed to the stand of the testing machine to be stabilized firmly during the experiment. Artificial saliva (Wyvern medical Ltd) was applied before retention evaluation to help resemble the natural oral environment, and additional artificial saliva was used between every ten insertions and removal to maintain the moisture of the surface. (Figure 4 C, D)

Finally, retention was evaluated by a digital force gauge that is used to record maximum dislodging forces.[18-22] The digital force gauge was attached to the upper portion of the stand, and the model was screwed to the stand base. The device's hook was attached to the anterior, posterior, and central looped wires to measure the overdentures’ anterior, posterior, and central retentions. The handle of the digital force gauge stand was slowly rotated clockwise until the overdenture was dislodged. The peak retention value was recorded automatically in Newton (N) as a retention value. (Figure 4 E)

This process was repeated ten times for each region, and the mean of every ten peak dislodging values was calculated and defined as the initial anterior, posterior, and central retention values, respectively. For recording the final retention, the same procedure was repeated for all models after 540 times of consecutive pulling and inserting of the overdentures to simulate six months of overdenture use, assuming three daily removals and insertions for oral hygiene practice.

Statistical analysis

SPSS (ver. 27.0) software (IBM Inc.) was used for statistical analysis. The normality of data was checked using the Shapiro-Wilk test. Accordingly, parametric tests were used. One-way ANOVA testing was applied for determining the difference between the means of the Models, and a Paired sample t-test was applied for determining the difference between initial and secondary retention value, where the significance alpha level was set at $p<0.05$.

Results

The initial retention

The initial (anterior, posterior, and central) retention values between the models showed statistically significant differences, Model C had the highest initial anterior, posterior, and central retention values of (75.11 N, 57.23 N, and 85.14 N), respectively. In contrast, Model A had the lowest initial (anterior, posterior, and central) retention values of (23.08 N, 13.51 N, and 25.52 N), respectively (Table 1).

As shown in Table 1, Model A (locator attachment) exhibited the higher central retention values of (25.52 N) when compared to anterior and posterior retention values of (23.08 N, 13.51 N), respectively, within the same model.

Additionally, in contrast, Model C (bar-clip attachment system with 1cm extension) recorded higher central retention values of (85.14 N), followed by anterior and posterior retention values of (75.11 N, 57.23 N), respectively.

However, for Model B (bar-clip attachment system without extension) the anterior retention value of (51.91N) was higher than its subsequent central and posterior retention values of (35.5 N, 23.04 N).

The final retention values

The final (anterior, posterior, and central retention) values recorded by the models showed statistically significant differences. Model C had the highest final (anterior, posterior, and central) retention values (37.97 N, 26.81 N, and 43.2 N, respectively).

In contrast, Model A had the lowest average final (anterior and posterior) retention values (20.28 N and 7.28 N, respectively), but Model B had the lowest final central retention value of (15.21 N) (Table 2).

Furthermore, Model A revealed statistically significant difference between the initial and final retention values at ($P < 0.000$), as there was a significant decrease in the amount of the anterior, posterior, and central retention values. Moreover, it recorded the overall highest loss of retention value, with a posterior retention value of (46.11%), followed by a central retention value of (13.79%), and an anterior retention value of (12.13%); the overall mean for these retention losses for Model A was calculated as 24% (Table 3).

In Model B, there was a statistically significant difference between the initial and final retention values at ($P > 0.000$) because the amount of anterior, posterior, and central retention values decreased significantly. However, the posterior retention loss was recorded as a 58.42% loss of its initial retention value, followed by the central retention value with 57.15% loss, and anterior retention recorded the lowest loss of retention value (49.59%); the overall mean for these retention losses was calculated as 55.1% (Table 3).

Model C revealed a statistically significant difference between the initial and final retention value at ($P < 0.000$) as there was a significant decrease in the amount of the anterior, posterior, and central retention values of Model C. The overall highest loss of retention value for Model C was seen with the posterior retention value (53. 15%), followed by the anterior retention value (49.45%), while the central retention value recorded the lowest loss (49.26%); the overall mean of these retention losses was calculated as 50.6% (Table 3).

Table 1: Comparison of the initial retention values (in Newton).

Position	Model	N	Mean	SD	p-value
Initial anterior retention	Model A	10	23.08	0.14757	0.000
	Model B	10	51.91	0.21318	
	Model C	10	75.11	0.30714	
Initial posterior retention	Model A	10	13.51	0.32128	0.000
	Model B	10	23.04	0.29889	
	Model C	10	57.23	0.44981	
Initial central retention	Model A	10	25.52	0.37059	0.000
	Model B	10	35.5	0.44222	
	Model C	10	85.14	0.25906	

N: sample size; SD: standard deviation; P-value is significant at 5% level

Table 2: Comparison of the final retention values (in Newton).

position	Model	N	Mean	SD	p-value
Final anterior retention	Model A	10	20.28	0.16193	0
	Model B	10	26.17	0.16364	
	Model C	10	37.97	0.42439	
Final posterior retention	Model A	10	7.28	0.13984	0
	Model B	10	9.58	0.15492	
	Model C	10	26.81	0.28848	
Final central retention	Model A	10	22	0.34319	0
	Model B	10	15.21	0.24244	
	Model C	10	43.2	0.27487	

Table 3: Comparison of initial and final retention values of study models at anterior, posterior and central retention positions.

Model	Position of retention	N	initial		final		percentage of retention loss		p-value
			Mean	SD	Mean	SD	%	Mean %	
Model A Locator attachment	anterior	10	23.08	0.15	20.28	0.16	12.13	24	0
	posterior	10	13.51	0.32	7.28	0.14	46.11		0
	central	10	25.52	0.37	22	0.34	13.79		0
Model B Bar-clip attachment without extension	anterior	10	51.91	0.21	26.17	0.16	49.59	55.1	0
	posterior	10	23.04	0.3	9.58	0.15	58.42		0
	central	10	35.5	0.44	15.21	0.24	57.15		0
Model C Bar-clip attachment with 1cm extension	anterior	10	75.11	0.31	37.97	0.42	49.45	50.6	0
	posterior	10	57.23	0.45	26.81	0.29	53.15		0
	central	10	85.14	0.26	43.2	0.27	49.26		0

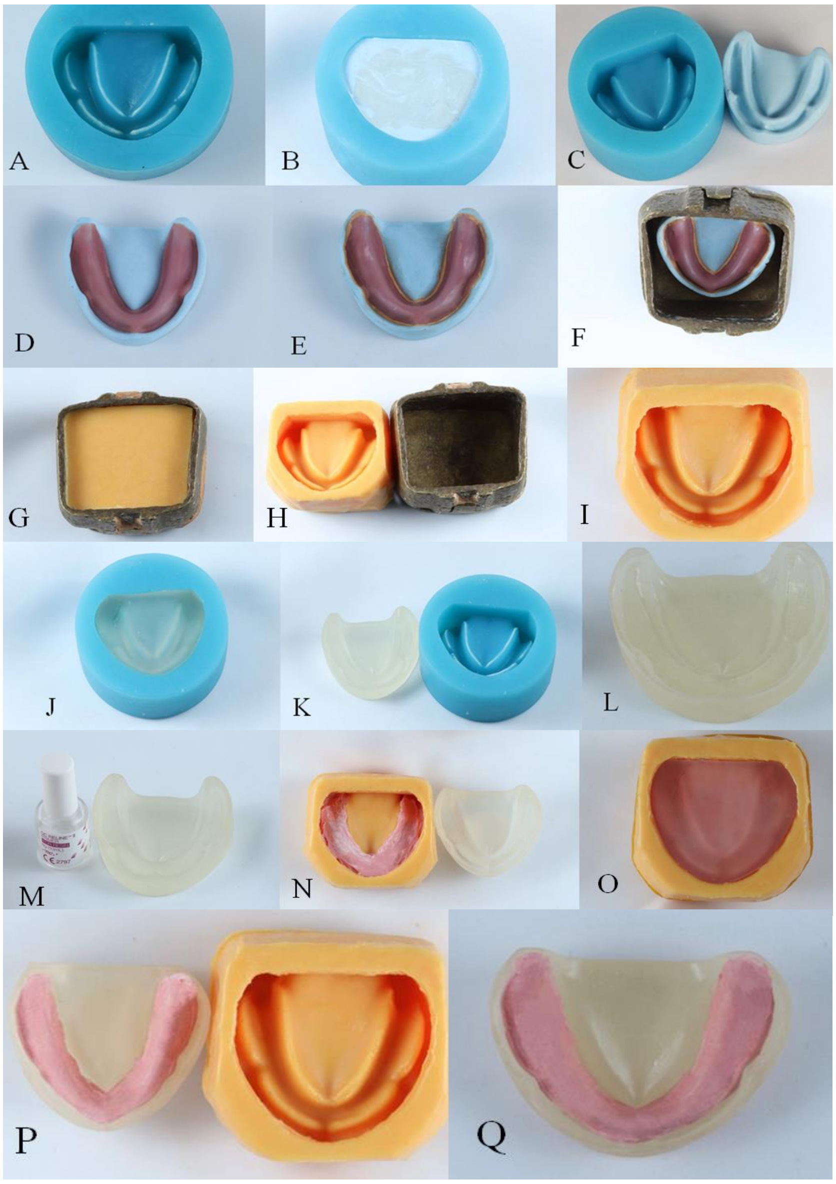

Figure 1: Fabrication of study model A: Mandibular edentulous mold (the first mold). B: Stone was poured into the mandibular mold. C: Construction of mandibular model in a dental stone. D: Mandibular base light cure PMMA. E: The borders of the base were sealed with dental stone to prevent leakage of the duplicate silicone under the base. F: The stone cast was placed in a conventional dental flask to take on the shape of the flask. G: Duplicate silicone was poured into the dental flask. H: Removal of the second mold from the flask. I: Second edentulous mandibular mold with 1.5mm space. J: Pouring the cold-cure PMMA into the first mold. K: Taking out the acrylic model. L: The acrylic model. M: Applying the soft base primer. N: Resilient silicone liner was applied into the second mandibular edentulous mold. O: Placement of acrylic model on the first mandibular mold. P: Removal of the acrylic model with silicone resilient liner. Q: Study model with silicone resilient liner.

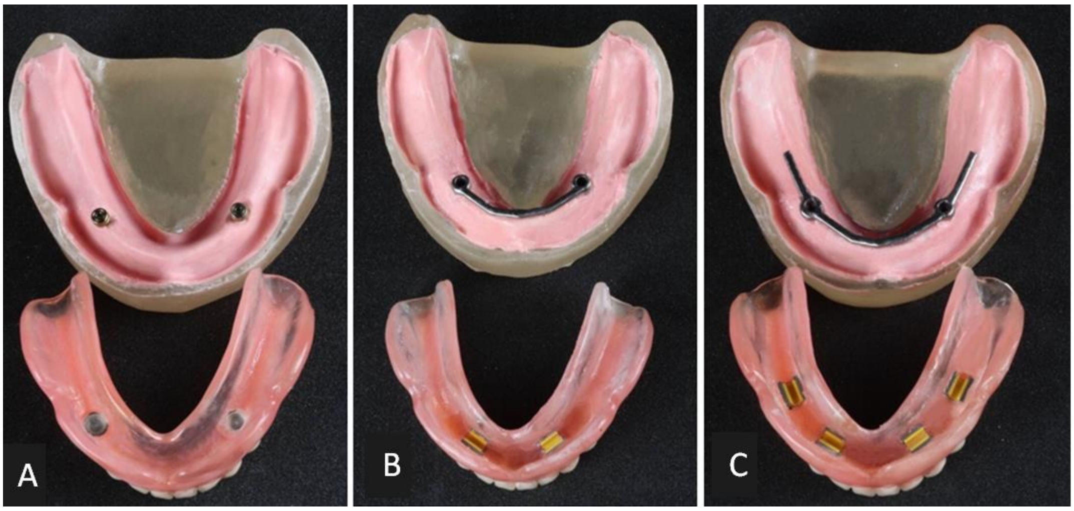

Figure 2: Two implant supported study models with their corresponding overdentures and attachment systems. A: Locator attachment, B: Bar-clip attachment systems without extension, C: Bar-clip attachment systems with 1 cm extension.

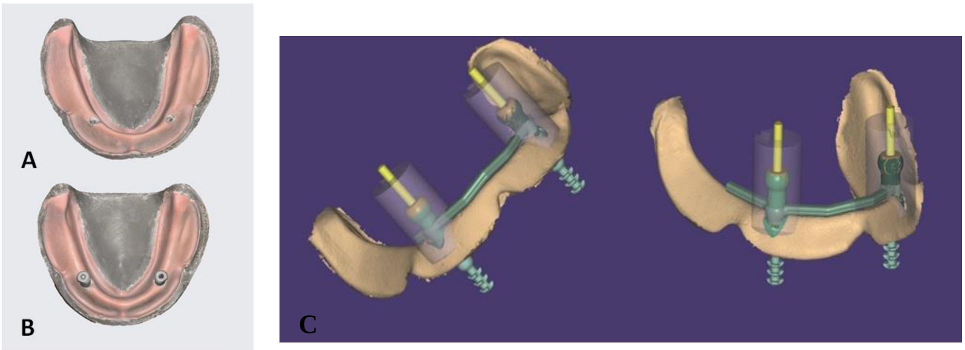

Figure 3: STL file of the study models A: impression scan without scan bodies, B: impression scan with IOSs, C: design of the bar-clip attachment with 1 cm extension at two different views showing the digital bar, the implant alignments, and the digital analogues.

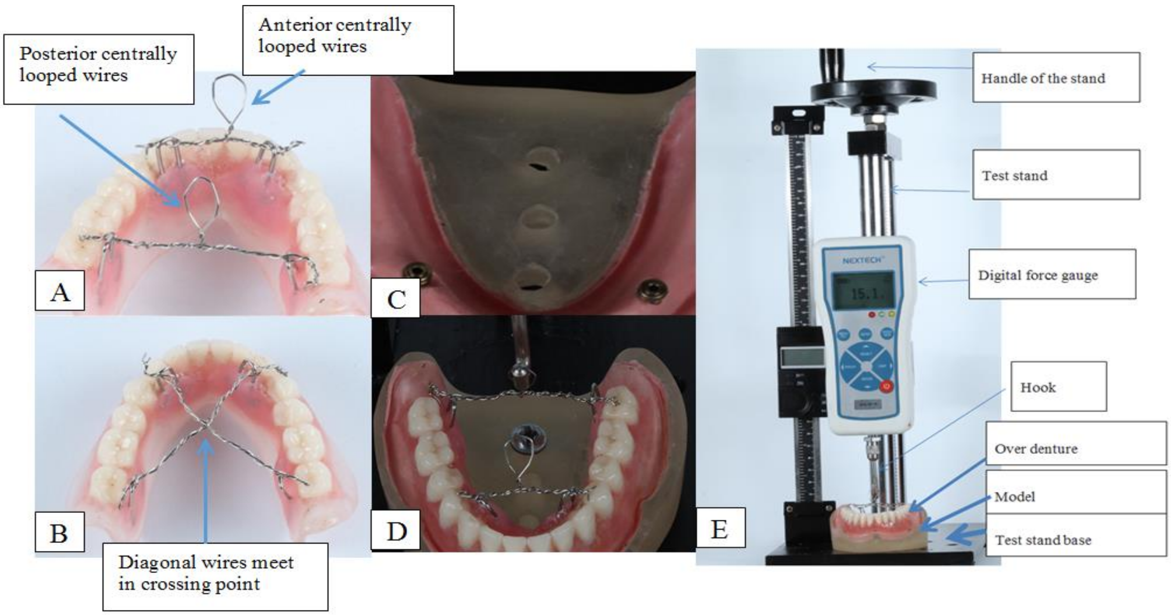

Figure 4: Retention evaluation process A: Anterior and posterior centrally looped wires,.B: Two diagonal wires meet at a crossing point to form a centrally looped wire. C: Three holes were drilled in the base of acrylic model. D: Posterior hole meeting the hook of the digital testing machine for testing the posterior retention value using the posterior centrally looped wire. E: The digital force gauge with the model attached to the test stand base.

Discussion

Initial retention values may indicate clinical predictability and performance and facilitate patient acceptance of the prostheses. In this current study, the initial retention values of all types of attachments were above the accepted effective retentive force for overdentures, recording a minimum of 13.51 N for Model A of posterior dislodging forces. According to Scherer et al.[23], 5-8 N is considered an optimum retentive force to stabilize overdentures during the long-term function to achieve reasonable patient satisfaction.

Statistically significant differences were observed among the different attachment systems. Model C had the highest average initial anterior, posterior, and central retention values, while the locator attachment had the lowest mean retention values. This result was in line with an in vitro study conducted by Ebeary et al.[24] which reported that the bar attachment showed a higher retentive force value, with a mean of 78.02N, compared to the locator attachment's mean of 40.57N. The difference between those values compared to our study's values relates to the different implant positions and manufacturing variations.

The higher retention values of bar-clip attachment system with 1cm extension compared to bar-clip attachment system without extensions were related to the distal extension of the bar attachment system, resulting in increases in the surface area and the number of clip attachments. Furthermore, many studies explained that distal extension of bar attachments would increase retention, while Elsyad et al.[25] concluded that the milled bar with distal extension presented higher retention values.

Moreover, this result was in line with Ebiary et al.,[24] who concluded that the bar-clip attachment system achieved superior initial retentive force, followed by the locator system.

Retentive forces appear to affect long-term success and patient satisfaction with the prosthesis. In many studies, the bar and clip attachments maintained the highest retention, but the longevity of the attachment system is always open to debate.

Regarding the retention of the attachments in this study, a decrease in the peak dislodgment force was observed between the initial measurement and after the 540 consecutive times of pulling and insertions, regardless of the attachment design. Although, the retention loss was evident in both attachment systems, Model C (Bar and clip attachments with 1cm extension) consistently maintained the highest retention value over the locator system.

However, the locator attachments exhibited the lowest percentage of reduction in retentive values compared to the other attachment designs by 24%, while the bar-clip attachment without extensions showed the greatest percentage loss at 55.1%.

This finding is in agreement with Elsyad et al., [11] who found that the bar attachment had the highest retention, followed by the locator, and the study documented a significant difference in the bar attachment's retention loss between groups of 60.99% for posterior retentive values. In addition, Nassar et al.[16] discussed that the wear of retentive clips over bar attachments has been documented to directly influence the retention of overdentures, and attachment wear occurs as a result of friction between retentive attachment surfaces at consecutive pulls and insertions.

However, after 540 consecutive pulls and insertions to simulate six months of oral use, the retentive values were still larger than the minimal range reported (5-7N) for long-term function and patient satisfaction.[23]

In the present study, the bar attachments had a higher retaining force value than locator attachments; although they require additional laboratory and clinical fabrication procedures; therefore, they are initially more costly, hard to fix, and need high interarch space.[26]

On the other hand, locator systems are relatively easy to fabricate and demonstrated clinically superior results when compared with ball and bar attachments relative to prosthodontic complications and hygiene.[8] Elsayed et al.[11] found that locator attachments are preferable to bar attachments for sustaining overdentures because locator attachments demonstrated high retention and stability after wearing simulation, with limited retention loss.

However, the behavior of actual attachments and their difference in resiliency may affect the dislodging forces;[23] hence, further studies should assess the attachments using different materials and with longer stimulated periods of function. In addition, in vivo studies are needed as one of the main factors of retention loss is the change induced on the components of the attachment systems as a result of wear. The factors associated with the clinical wear of attachments include masticatory forces, parafunction, temperature and composition of saliva, and products used.

Conclusion

Within the limitations of this study, the study concludes that:

- The bar and clip attachment system offered higher retentive values than the locator attachment system.

- The retention capacities of both the attachment systems in the present study were above the minimum values recommended after six months of simulated pulling and insertions.

- The retention loss is correlated to the particular attachment system regardless of its design, each having different retentive capacities, and the bar–clip attachment systems had the highest percentage of retention loss. However, the choice of attachment system needs to be based on the clinical situation, patient's desire, and cost factors; the prosthodontist should then make an informed decision on the appropriate type of attachment system that provides the amount of retention needed.

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