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RESEARCH AND EDUCATION

Effects of interimplant distance and cyclic dislodgement on retention of LOCATOR and ball attachments: An in vitro study

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ABSTRACT

Statement of problem. Evaluation of the long-term retentive behavior of overdenture attachments is necessary for successful treatment. Interimplant distance (IID) could affect the retention of these attachments.

Purpose. The purpose of this in vitro study was to assess the effects of IID and cyclic dislodgement on the retention of LOCATOR and ball attachments.

Material and methods. Ball and LOCATOR attachments were connected to corresponding implant analogs. Metal housings were connected to each attachment. Thirty-six pairs of acrylic resin blocks were fabricated for 3 IIDs (19, 23, and 29 mm) and 2 attachments (n=6). Each pair consisted of 2 attachment assemblies parallel to each other with a specified IID. Overall, 1440 dislodgement cycles were applied by using a universal testing machine, and the maximum dislodging force was recorded after 0, 120, 360, 720, and 1440 cycles. Dislodging force data were analyzed by using repeated-measures 3-way analysis of variance, with the number of cycles as the within-subject factor for each specimen. Bonferroni-corrected Student *t* tests were used to resolve effects that were statistically significant. Moreover, dislodging force data were fit into an exponential decay model to determine the extent and rate of force decay for each attachment and IID studied.

Results. The initial retention of LOCATOR attachments was significantly higher than that of ball attachments with IIDs of 23 and 29 mm, but no significant difference was noted with the 19-mm IID. After 1440 cycles, the retention was statistically similar with that of the 23-mm IID but was significantly higher for ball attachments with IIDs of 19 and 29 mm.

Conclusions. The IID is one of the factors that affect the retention of ball and LOCATOR attachments. The mean retention of both attachments was sufficient for all 3 IIDs at insertion and after 1440 cycles. (J Prosthet Dent 2019;122:550-6)

Mandibular implants are commonly used to retain fixed or removable prostheses in the treatment of edentulous patients.[1,2] The McGill consensus recommended a 2-implant overdenture as the standard of care for edentulous mandibles because at least 2 implants are deemed necessary to provide retention, support, and stability for mandibular overdentures.[3-7] Implant-supported overdentures have numerous advantages over conventional dentures, such as reduced residual ridge resorption,[8] better stability and retention, and improved function.[9] In addition, compared with fixed implant-supported prostheses, implant overdentures have advantages such as the need for fewer implants, reduced cost, more straightforward surgical procedures,[9] and easier access for oral hygiene.[10,11]

An attachment system is "a particular type of retentive mechanism using compatible matrix and patrix corresponding components. Matrix refers to the receptacle component of the attachment system, and patrix refers to the portion involving a frictional fit which engages the matrix."[12] Implant overdenture attachment systems can either splint the implants (bar attachments) or leave them unsplinted (stud-type attachments).[13] Bar attachments are helpful when implants are nonparallel[14] and have been reported to have the lowest rate of prosthetic complication, but the initial cost is high and the laboratory process is

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Clinical Implications

Based on the better initial retention observed, the use of LOCATOR attachments with interimplant distances of 23 and 29 mm can be recommended. However, ball attachments could perform better with interimplant distances of 19 and 29 mm after 1 year of clinical usage.

complicated.[4] Unsplinted systems include ball-type attachments, magnets, telescopic crowns, and LOCATOR attachments.[5] Stud attachments are better in patients with reduced interarch distances and are advantageous in terms of hygiene and initial treatment cost.[4,13,15]

The simplest type of stud attachment for clinical application is the ball attachment.[9,12] It is most commonly used for 2-implant mandibular overdentures,[16] with advantages such as lower cost,[17] more straightforward design, easier maintenance, and adequate retentive force.[18,19] However, wear of the retentive nylon insert can result in retention loss after 6 to 9 months.[4]

LOCATOR (Zest Anchors; Zest Dental Solutions) are a popular type of stud attachment with dual retention and the capability of self-alignment.[5] LOCATOR attachments are preferred when the vertical space is limited because of their low profile.[20,21] In addition, LOCATOR attachments can tolerate interimplant angulation ranging between 0 and 20 degrees.[5,22] However, these attachments are prone to wear and loss of retention over time.[5]

The selection of an appropriate attachment is based on the required retention, jaw morphology, oral function, and patient's willingness for recall.[9,23] Clinicians may select the attachment system for mandibular implant overdentures based on retentive capacity because an association has been demonstrated between adequate retention and improved patient satisfaction.[12,24,25]

Insertion and removal of an overdenture, as well as masticatory forces, lead to micromovement and macromovement between the retentive parts of the attachment, which could cause wear and loss of retention over time.[4,12,20,26,27] The interimplant distance (IID) can affect the wear rate of retentive components and the rate of retention loss of attachments.[20,28,29] Substantial wear would necessitate changing the retentive components in the maintenance period. The need for prosthesis maintenance is higher during the first year of use,[30,31] and it is important to evaluate the retentive behavior of the attachment during initial insertion and after 1 year of usage.[4]

An exponential decay model in its simplest form can be used to describe the decay in a property from an initial state as a function of time.[32] A final value can be added to the model as change occurs from an initial to a final value to allow mathematically for this change. In the case of an increase in surface hardness of light-polymerized dental composite resins after initial polymerization, an exponential decay model with parameters of initial hardness, hardness increases, and time constants to describe the rates of 2 hardness transitions was used.[33] Based on this model, the rates of the 2 transitions, one more immediate and the other occurring over days, were derived.

Although previous studies have evaluated different aspects of attachments, the potential effects of different IIDs on the retention of an attachment has seldom been assessed.[20,28] IID was either ignored or arbitrarily selected in these studies.[28] Moreover, the effects of IID, attachment type, and cyclic dislodgment on retention loss remain unclear. The purpose of the present study was to determine the effects of the dislodging force, IID, and number of cycles of dislodging on the retention of an attachment. The null hypotheses were that no differences would be found between attachments at each IID and at the initial and final number of cycles studied. To determine the rate at which any decay in dislodging force occurs, this research also included fitting this force to the number of cycles by using an exponential decay model at each attachment and IID studied.

MATERIAL AND METHODS

The experimental design involved construction of 36 pairs of acrylic blocks for 3 IIDs (19, 23, and 29 mm) and 2 attachments (n=6). Raw data for LOCATOR attachments were derived from the authors' previously published research.[20] The method used was the same as that used in the present study.

Two rectangular plexiglass blocks were prepared with an internal dimension of 35×15×40 mm for each attachment pair. Based on the manufacturer's instructions, autopolymerizing polymethyl methacrylate resin (GC Reline; GC America Inc) was mixed and poured into the first block. Two pinholes were drilled (Pindex machine; Coltène) after 15 minutes with a predetermined IID at an equal distance from the block edges.

The ball (DIO IMPLANT; DIO Corp) and LOCATOR (Zest Anchors; Zest Dental Solutions) attachments were connected to their corresponding implant analogs by using an appropriate driver. Metal housings with processing caps were connected to each attachment. One of the attachment assemblies was then connected to the dental surveyor (Saeshin Precision Co) so that the metal housing was positioned downward and perpendicular to the surveyor table where the acrylic resin block was fixed with impression putty (Speedex; Coltène). The surveyor rod was moved down so that the metal housing entered the pinhole, which was 1 mm larger than the corresponding metal housing. The metal housing was fixed in the pinhole with autopolymerizing resin. The second attachment assembly was placed completely parallel to

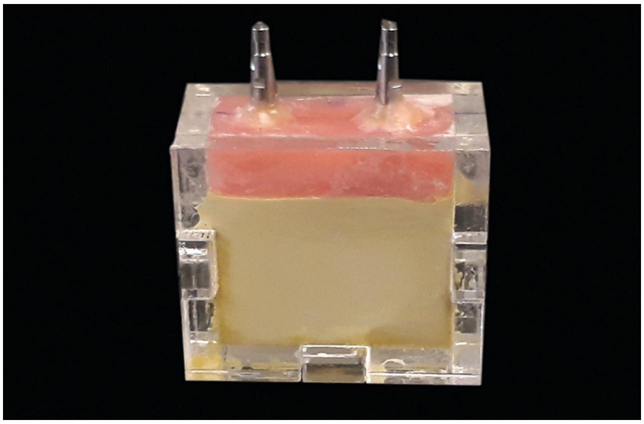

Figure 1. Fixation of attachment assemblies in corresponding holes parallel to each other.

the first one at the same height (Fig. 1). A surveyor was used to confirm the parallelism of the 2 assemblies.

The second block was filled with Type IV dental stone (Vel-Mix; Kerr Corp) and was inverted on implant analogs in the first block. The 2 blocks were attached to the universal testing machine (Zwick Roell Group) until the stone hardened. Accordingly, one block involved the balls or LOCATORS attached to implant analogs, and the other block contained the metal housings. After separating the 2 blocks, the processing cap was replaced with a corresponding nylon insert.

Subsequently, the blocks were attached to the upper and lower members of the universal testing machine (Zwick Roell Group) to apply dislodgement cycles. The maximum dislodging force was recorded through a personal computer (Asus; ASUSTeK Computer Inc) that was connected to the testing machine. Dislodging cycles were performed at a speed of 50 mm/min, a preload of 0.2 N, and a preload speed of 10 mm/min. Based on the findings from the authors' previously published study,[20] the dislodging force was applied at a rate of 20 cycles/min.

In general, patients remove or place an overdenture at least 4 times a day. Accordingly, the maximum dislodging force for the attachments was measured after 0, 120 (1 month), 360 (3 months), 720 (6 months), and 1440 (1 year) cycles of insertion and removal. The raw data for LOCATOR attachments have been published previously.[20]

The complete data set of the dislodging forces was first analyzed by using repeated-measures analysis of variance (Mixed procedure; SAS Institute Inc), with the attachment as the between-subject factor, the IID as a categorical factor, and the number of cycles as the within-subject factor. All interactions were included in this analysis. Differences in the mean dislodging force between the 2 attachments were determined at each IID studied and at the initial and final number of cycles studied by using the Bonferroni-corrected Student *t* tests (Multtest procedure; SAS Institute Inc).

Moreover, the dislodging forces were fit (NLIN procedure; SAS Institute Inc) into the following exponential decay model for each attachment and the IID studied. By modifying the model used for surface hardness[33] to allow for only one mechanism of decay in this force that occurred over all the studied cycles, the model for the dislodging force becomes

$$\text{Dislodging Force}=\text{Initial}+(\text{Final}-\text{Initial})\times\left(1-e^{-\left(\frac{\text{Cycles}}{\text{Tau}}\right)}\right),$$

where "Initial" is the initial dislodging force value before any cycling, "Final" is the dislodging force value approached as the number of cycles (Cycles) reaches infinity, and "Tau" is the Cycles constant, which describes the exponential decay rate at which the dislodging force changes from "Initial" to "Final" with continuing cyclic dislodging. Tau describes the number of cycles when the decay in dislodging force has reached 63.2% of this change. This model was subsequently used to describe the number of cycles at which half of the decay would occur.

RESULTS

The means and 95% confidence intervals of the dislodging forces for each number of cycles, the IID, and the attachments studied are presented in Figure 2. Table 1 summarizes the hypotheses tested by using repeated-measures ANOVA. The significance of the 3-way interaction ($P<.001$) required that pairwise comparisons of the 2 attachments be conducted at each IID at the initial and final number of cycles, as presented in Table 2.

Figure 3A shows data values of each specimen along with the means and model values for the ball attachment at an IID of 19 mm, and Figure 3B shows the corresponding values for the LOCATOR attachment at an IID of 19 mm. Similarly, Figure 3C, D presents the corresponding values for ball and LOCATOR attachments at an IID of 23 mm, and Figure 3E, F presents these values for ball and LOCATOR attachments at an IID of 29 mm. Table 3 summarizes estimates of the model parameters for the studied attachments and IIDs, along with the solution for the number of cycles at one-half of the decay.

DISCUSSION

The present in vitro study evaluated the effects of IID and cyclic loading on the retention of 2 overdenture attachment systems. Results of this study showed that IID and dislodging cycles can significantly affect attachment retention. Therefore, the null hypotheses that no differences would be found between attachments at each IID and at the initial and final number of cycles studied were rejected.

According to Scherer et al,[1] the canine position is preferred for the placement of fixtures for 2-implant mandibular overdentures. The 3 specific IIDs were selected based on results presented by Michelinakis

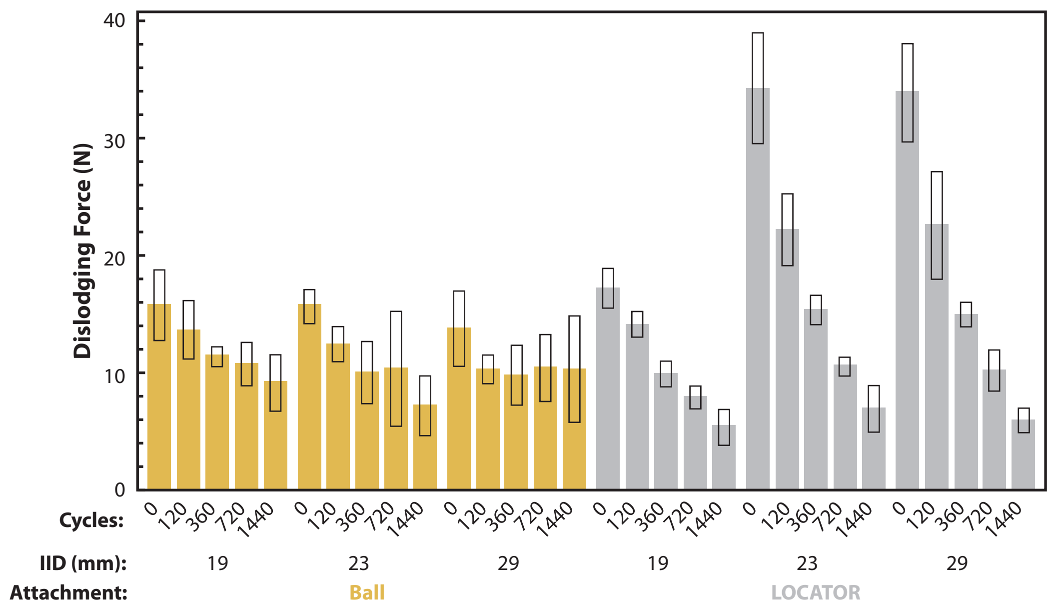

Figure 2. Means (solid colored bars) and 95% confidence intervals (open bars) for each number of cycles, IID, and attachment. IID, interimplant difference.

Table 1. Repeated-measures ANOVA for dislodging force

Effect	df of Numerator	df of Denominator	F Ratio	P
Attachment	1	29	60.632	<.001
Interimplant distance (IID)	2	29	13.842	<.001
Attachment×IID	2	29	26.525	<.001
Cycles	4	116	256.601	<.001
Attachment×cycles	4	116	88.341	<.001
IID×cycles	8	116	9.004	<.001
Attachment×IID×cycles	8	116	11.142	<.001

Table 2. Pairwise comparisons of two attachments at each IID and at initial and highest number of cycles

IID (mm)	Cycles	Difference (N)[a]	P[c]
19	0	−1.4	.595
19	1440	3.8	.022[b]
23	0	−18.5	<.001[b]
23	1440	0.3	.839
29	0	−20.1	<.001[b]
29	1440	4.4	.012[b]

IID, interimplant difference. [a]Difference=mean dislodging force of ball minus mean dislodging force of LOCATOR. [b]Statistically significant. [c]Bonferroni-corrected Student *t* test.

et al,[29] who studied 100 mandibular complete dentures and reported that the mean intercanine distance was 22.88 mm. Thus, the minimum and maximum distances were set as 19 and 29 mm according to anatomic limitations and implant space requirements.[29]

Several investigators have evaluated the short- and long-term effects of cyclic dislodgment on the retention of overdenture attachments,[7,10,11,13,16] and most have reported various degrees of retention loss after the final cycles. Reportedly, the need for maintenance of overdenture attachments is higher during the first year of use than later.[30] In the present study, retentive behavior of the attachments was evaluated after 1440 cycles of insertion and removal, which is equal to 1 year of function. Results revealed marked loss of retention for both attachments after 1440 cycles of dislodgment, which is consistent with findings from previous studies.[8,16,17,26] This retention loss could be related to the wear and deformation of the nylon inserts, as previously described.[3,8] In contrast, Elsyad et al[5] reported an increase in retention of LOCATOR attachments after wear simulation; this difference could be attributed to the varying behavior of the nylon inserts. Although nylon inserts would degrade after wear simulation, this phenomenon could increase surface roughness and thus produce increased retention through micromechanical friction.[25] Moreover, in the study by Elsyad et al,[5] the implant angulation was 20 degrees, which could also have led to the difference in the results obtained.

In attachment systems that use nylon inserts as the matrix, the cyclic dislodgement rate (cycles/min) could affect the retention. The nylon insert requires time to return to its initial shape after a dislodgment cycle. In the authors' pilot study,[20] the effects of 4 different rates of dislodgement (2, 10, 20, and 40 cycles/min) on the retention of LOCATOR attachments were evaluated; results revealed that increasing the rate to 20 cycles/min did not affect the maximum dislodging force, but at a higher rate, the force decreased significantly. The dislodgment rate was not specified in some previous studies.[4,5] Al-Ghafli et al[7] selected a dislodgment rate of 10 cycles/min, whereas most studies selected a rate of greater than 20 cycles/min,[13,19,27] which could negatively affect the retention of attachments.[20] Therefore, a dislodgment rate of 20 cycles/min was selected in the present study so that the nylon inserts could return to their basic shape before the next cycle.

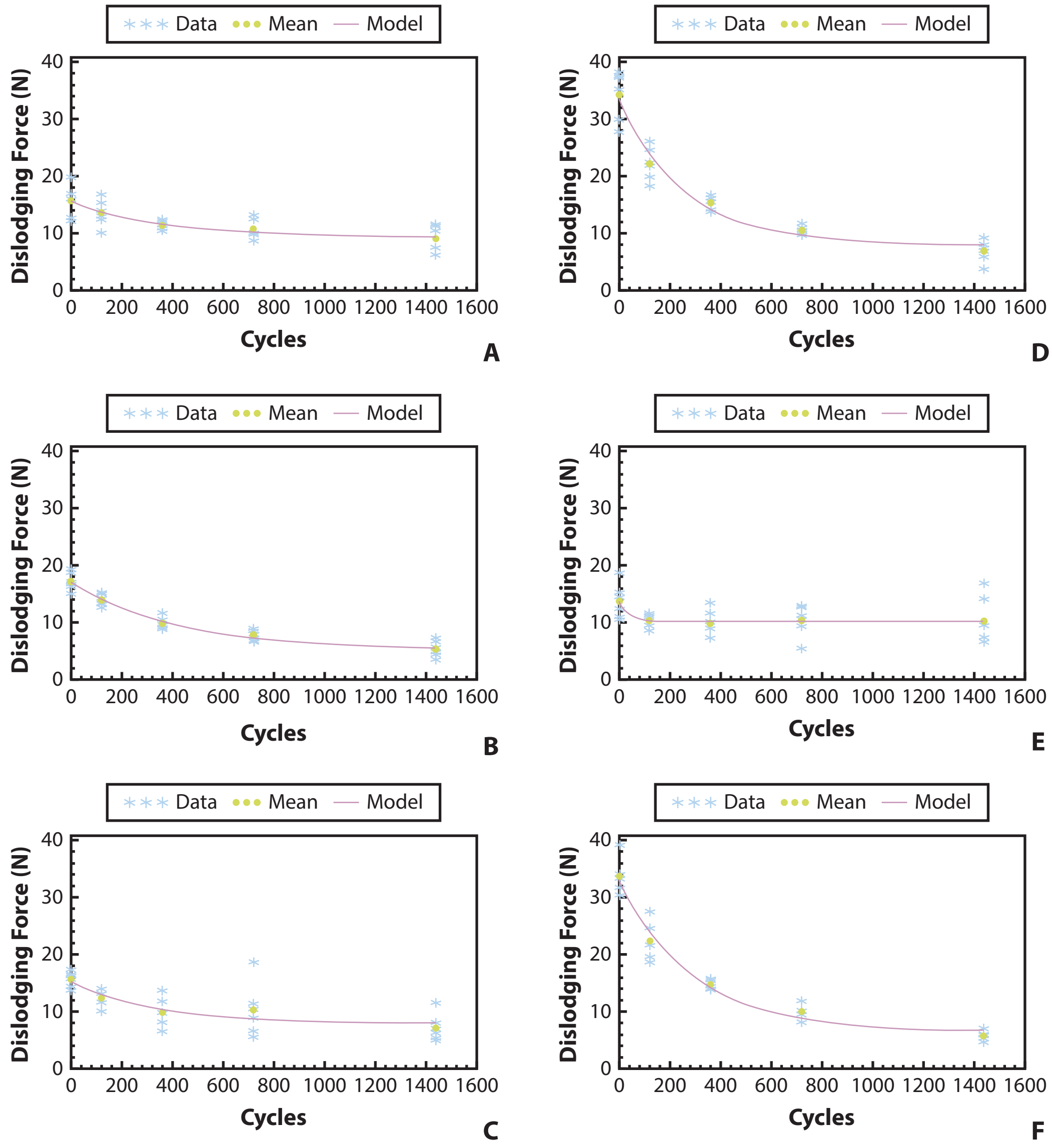

Figure 3. Data for all specimens, means, and model values of dislodging force (N). A, Ball attachment IID of 19 mm. B, LOCATOR attachment at IID of 19 mm. C, Ball attachment at an IID of 23 mm. D, LOCATOR attachment at an IID of 23 mm. E, Ball attachment at an IID of 29 mm. F, LOCATOR attachments at an IID of 29 mm. IID, interimplant difference. (Raw data for LOCATOR attachments published previously.[20])

Table 3. Estimates of model parameters for both attachments at IIDs studied, with solution of cycles for half of decay

Attachment	Interimplant Distance (mm)	Initial Dislodging Force (N)	Final Dislodging Force (N)	Cycles Constant (Tau)	Dislodging Force (N) at Average of Initial and Final	Cycles at Halfway Point
Ball	19	15.6	9.3	357.2	12.5	247.6
	23	15.3	8.0	326.1	11.7	226.1
	29	13.8	10.2	38.2	12.0	26.5
LOCATOR	19	17.1	5.2	418.7	11.2	290.2
	23	33.5	8.0	259.0	20.7	179.5
	29	33.1	6.8	288.1	20.0	199.7

IID, interimplant difference.

Results from this study showed that IID could affect the retention of both ball and LOCATOR attachments. IID and its possible effects on the retention of overdentures are often ignored. However, recent studies have reported that the interimplant and interclip distances can affect the retention of stud and bar attachments.[1,2,27-29] These findings are in accordance with results from the present study. Scherer et al[1] evaluated the effects of implant position on the retention of different attachment systems and reported that increasing the IID from canines to second premolars significantly increased the retention of ball and LOCATOR attachments. Nevertheless, they reported that ball attachments were more retentive than LOCATOR attachments in all implant positions. However, in the present study, the initial retention of LOCATOR attachments was significantly higher than that of ball attachments with IIDs of 23 and 29 mm, but no significant difference was noted with an IID of 19 mm. This difference could be explained by the different nylon inserts used in these 2 studies. In the present study, clear nylon inserts were used for LOCATOR attachments and orange inserts for ball attachments, whereas Scherer et al[1] used pink inserts for LOCATOR attachments and clear ones for ball attachments. In another study that evaluated the effects of IID on the retention of ball attachments with gold matrices,[29] the researchers failed to find any significant effect of IID on the retention of ball attachments. This could indicate that results from different studies should be compared and interpreted cautiously based on the materials used.

A major challenge for clinicians is to provide an overdenture with adequate retention for patient satisfaction.[2] A minimum retention force of 5 to 7 N for stabilizing overdentures during function has been suggested.[16] Although the retention in all study groups was reduced after 1440 dislodgement cycles, the mean retention of both attachments was adequate in all 3 IIDs at insertion and after 1 year of simulated function. In addition, results from the present study revealed that after 1 year of simulated clinical usage with IIDs of 19 and 29 mm, the final retention was significantly higher for ball attachments. With an IID of 23 mm, the final retention was statistically similar for both ball and LOCATOR attachments. Abi Nader et al[8] evaluated the retention of ball and LOCATOR attachments after 10 years of simulated clinical usage and reported similar values for both attachments. The IID used in their study was 22 mm, which is comparable with the IID of 23 mm in the present study, and their results are consistent with those of the present study.

The most common complication of implant overdentures is retention loss of the attachment.[4] Thus, clinicians could benefit from knowledge regarding the behavior of the retention loss of an attachment system as a function of time. The exponential decay model used in this study revealed that in all groups, except for ball attachment with an IID of 29 mm, attachments lose 50% of their initial retention after 2 to 3 months. This finding is in accordance with findings from previous studies, wherein retention loss was higher during the initial months of simulated clinical usage.[4,16] This phenomenon could be a result of increased deformation in nylon inserts during the initial cycles.[16]

The clinical situation includes the potential effects of complex loading on overdenture attachments. These conditions, in addition to insertion and removal of an overdenture, could change the wear pattern of polymeric nylon inserts.[8] In the present study, only the vertical loading that results from the insertion and removal of overdentures was evaluated, and this is one of the limitations of the study. In addition, the presence of saliva in the oral cavity can affect the pattern of retention loss of attachments by water absorption of polymers.[10] In the present study, artificial saliva was not used to simulate the oral environment. Moreover, the study duration was relatively short. Long-term clinical trials are warranted to support the findings of this study.

CONCLUSIONS

Within the limitations of this in vitro study, the following conclusions were drawn:

1. IID affects the retention of ball and LOCATOR attachments.
2. The initial retention of LOCATOR attachments was significantly higher than that of ball attachments with IIDs of 23 and 29 mm, but no significant difference was noted with 19 mm.
3. After 1 year of simulated clinical usage, with IIDs of 19 and 29 mm, the final retention was significantly higher for ball attachments. With an IID of 23 mm, the final retention was statistically similar for both ball and LOCATOR attachments.
4. The mean retention of both attachments was sufficient with all 3 selected IIDs at insertion and after 1 year of simulated function.

REFERENCES

1. Scherer MD, McGlumphy EA, Seghi RR, Campagni WV. Comparison of retention and stability of two implant-retained overdentures based on implant location. J Prosthet Dent 2014;112:515-21.
2. Scherer MD, McGlumphy EA, Seghi RR, Campagni WV. Comparison of retention and stability of implant-retained overdentures based upon implant number and distribution. Int J Oral Maxillofac Implants 2013;28:1619-28.
3. Chung KH, Chung CY, Cagna DR, Cronin RJ. Retention characteristics of attachment systems for implant overdentures. J Prosthodont 2004;13:221-6.
4. Choi JW, Bae JH, Jeong CM, Huh JB. Retention and wear behaviors of two implant overdenture stud-type attachments at different implant angulations. J Prosthet Dent 2017;117:628-35.
5. Elsyad MA, Emera RM, Ashmawy TM. Effect of distal implant inclination on dislodging forces of different LOCATOR attachments used for mandibular overdentures: an in vitro study. J Prosthodont 2019;28:e666-74.
6. Gulizio MP, Agar JR, Kelly JR, Taylor TD. Effect of implant angulation upon retention of overdenture attachments. J Prosthodont 2005;14:3-11.
7. Al-Ghafli SA, Michalakis KX, Hirayama H, Kang K. The in vitro effect of different implant angulations and cyclic dislodgement on the retentive properties of an overdenture attachment system. J Prosthet Dent 2009;102:140-7.
8. Abi Nader S, De Souza RF, Fortin D, De Koninck L, Fromentin O, Albuquerque Junior RF. Effect of simulated masticatory loading on the retention of stud attachments for implant overdentures. J Oral Rehabil 2011;38:157-64.
9. Cakarer S, Can T, Yaltirik M, Keskin C. Complications associated with the ball, bar and LOCATOR attachments for implant-supported overdentures. Med Oral Patol Oral Cir Bucal 2011;16:953-9.
10. Botega DM, Mesquita MF, Henriques GEP, Vaz LG. Retention force and fatigue strength of overdenture attachment systems. J Oral Rehabil 2004;31:884-9.
11. Pigozzo MN, Mesquita MF, Henriques GEP, Vaz LG. The service life of implant-retained overdenture attachment systems. J Prosthet Dent 2009;102:74-80.
12. Alsabeeha NH, Payne AG, Swain MV. Attachment systems for mandibular two-implant overdentures: a review of in vitro investigations on retention and wear features. Int J Prosthodont 2009;22:429-40.
13. Kobayashi M, Srinivasan M, Ammann P, Perriard J, Ohkubo C, Müller F, et al. Effects of in vitro cyclic dislodging on retentive force and removal torque of three overdenture attachment systems. Clin Oral Implants Res 2014;25:426-34.
14. Burns DR. Mandibular implant overdenture treatment: consensus and controversy. J Prosthodont 2000;9:37-46.

15. Sultana N, Bartlett DW, Suleiman M. Retention of implant-supported overdentures at different implant angulations: comparing LOCATOR and ball attachments. Clin Oral Implants Res 2017;28:1406-10.
16. Turk P, Geckili O, Turk Y, Gunay V, Bilgin T. In vitro comparison of the retentive properties of ball and LOCATOR attachments for implant overdentures. Int J Oral Maxillofac Implants 2014;29:1106-13.
17. Rutkunas V, Mizutani H, Takahashi H. Influence of attachment wear on retention of mandibular overdenture. J Oral Rehabil 2007;34:41-51.
18. Winkler S, Piermatti J, Rothman A, Siamos G. An overview of the O-ring implant overdenture attachment: clinical reports. J Oral Implantol 2002;28:82-6.
19. Passia N, Ghazal M, Kern M. Long-term retention behaviour of resin matrix attachment systems for overdentures. J Mech Behav Biomed Mater 2016;57:88-94.
20. Shayegh SS, Hakimaneh SMR, Baghani MT, Shidfar S, Kashi FK, Zamanian A, et al. Effect of interimplant distance and cyclic loading on the retention of overdenture attachments. J Contemp Dent Pract 2017;18:1078-84.
21. Ahuja S, Cagna DR. Classification and management of restorative space in edentulous implant overdenture patients. J Prosthet Dent 2011;105:332-7.
22. Stellingsma C, Vissink A, Meijer HJA, Kuiper C, Raghoebar GM. Implantology and the severely resorbed edentulous mandible. Crit Rev Oral Biol Med 2004;15:240-8.
23. Tabatabaian F, Saboury A, Sobhani ZS, Petropoulos VC. The effect of inter-implant distance on retention and resistance to dislodging forces for mandibular implant-tissue-supported overdentures. J Dent (Tehran) 2014;11:506-15.
24. Sadig W. A comparative in vitro study on the retention and stability of implant-supported overdentures. Quintessence Int 2009;40:313-9.
25. Rutkunas V, Mizutani H, Takahashi H, Iwasaki N. Wear simulation effects on overdenture stud attachments. Dent Mater J 2011;30:845-53.
26. Branchi R, Vangi D, Virga A, Guertin G, Fazi G. Resistance to wear of four matrices with ball attachments for implant overdentures: a fatigue study. J Prosthodont 2010;19:614-9.
27. Srinivasan M, Schimmel M, Badoud I, Ammann P, Herrmann FR, Müller F. Influence of implant angulation and cyclic dislodging on the retentive force of two different overdenture attachments - an in vitro study. Clin Oral Implants Res 2016;27:604-11.
28. Doukas D, Michelinakis G, Smith PW, Barclay CW. The influence of inter-implant distance and attachment type on the retention characteristics of mandibular overdentures on 2 implants: 6-month fatigue retention values. Int J Prosthodont 2008;21:152-4.
29. Michelinakis G, Barclay CW, Smith PW. The influence of interimplant distance and attachment type on the retention characteristics of mandibular overdentures on 2 implants: initial retention values. Int J Prosthodont 2006;19:507-12.
30. Trakas T, Michalakis K, Kang K, Hirayama H. Attachment systems for implant retained overdentures: a literature review. Implant Dent 2006;15:24-34.
31. Chaffee NNR, Felton DA, Cooper LFL, Palmqvist U, Smith R. Prosthetic complications in an implant-retained mandibular overdenture population: Initial analysis of a prospective study. J Prosthet Dent 2002;87:40-4.
32. Leike A. Demonstration of the exponential decay law using beer froth. Eur J Phys 2002;23:21-6.
33. Johnston W, Leung R, Fan P. A mathematical model for post irradiation hardening of photoactivated composite resins. J Dent Mater 1985;1:191-4.

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Noteworthy Abstracts of the Current Literature

Bite force, masseter thickness, and oral health-related quality of life of elderly people with a single-implant mandibular overdenture

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Purpose. To compare maximum bite force, masseter thickness, and oral health-related quality of life (OHRQoL) in elderly patients rehabilitated with conventional complete dentures (CDs) and single-implant overdentures (SIOs).

Material and methods. A paired design was conducted, and 12 elderly patients were selected. Initially, a set of new CDs was manufactured and placed. After a 2-month adaptation period, the mandibular CD was transformed into an SIO by inserting one osseointegrated implant into the symphysis region. All variables were evaluated 2 months after both treatments (CD and SIO). Maximum bite force was evaluated using pressure sensors, while masseter thickness was obtained via ultrasound during muscle contraction and relaxation. The Oral Health Impact Profile for edentulous people (OHIP-Edent) was used to measure OHRQoL. Data were analyzed using Student t test and Wilcoxon test. Pearson coefficient of correlation between bite force and masseter thickness was calculated.

Results. Values for maximum bite force and masseter thickness during contraction increased significantly after SIO use ($P<.001$), indicating an improvement in muscle function. Considering OHRQoL, the general score and the domains functional limitation and physical pain were reduced ($P<.05$), indicating better perception of OHRQoL, with SIO use. Moreover, masseter thickness during contraction was moderately correlated with bite force (r=0.480; $P=.018$).

Conclusions. Using SIO increased the maximum bite force and masseter thickness of elderly patients, leading to an improved OHRQoL.