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RESEARCH AND EDUCATION

# Retention force and deformation of an innovative attachment model for mini-implant–retained overdentures

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## ABSTRACT

**Statement of problem.** The gradual loss of retention and the need for periodic replacement of attachment-system components are the most frequent complications in implant-supported overdentures.

**Purpose.** The purpose of this in vitro study was to develop a new attachment system for overdentures with polymeric materials and compare its retention and deformation with a conventional O-ring attachment system.

**Material and methods.** A matrix with 2 mini-implants with ball abutments was used to simulate the mandibular border during a fatigue resistance test. A total of 60 polyacetal (n=20), polytetrafluoroethylene (n=20), and conventional O-ring (n=20) attachments were captured in pairs with acrylic resin and subjected to 3625 insertion and removal cycles, simulating 30 months of overdenture use. The internal and external deformations of the attachments were assessed using an optical stereomicroscope. One-way ANOVA and the Tukey honestly significant difference tests were used for statistical evaluation ($\alpha$=.05).

**Results.** The polyacetal attachment system showed the highest retention ($P$<.001), followed by the O-ring and polytetrafluoroethylene attachments. The O-ring attachments exhibited the lowest deformation ($P$<.001), and the polyacetal attachments had the highest internal deformation ($P$<.001).

**Conclusions.** The newly developed polyacetal attachment model increased the retention of mini-implant–retained overdentures, and despite the deformation experienced, the retention period appears to be better than that of conventional systems. (J Prosthet Dent 2019;121:129-34)

Complete edentulism still affects a large portion of the world's population.[1] A conventional complete denture is commonly provided to restore masticatory function and esthetics; however, complete denture stability is limited in patients with marked bone resorption, especially mandibular resorption.[1,2] Implant-retained overdentures are an excellent alternative for these patients because of improved masticatory efficiency, comfort, and patient satisfaction.[3-6]

The use of implants to support a prosthesis has significant advantages in restoring physiological functions. According to the McGill consensus,[7] the installation of 2 conventional implants is considered the standard treatment for edentulous mandibles.[8,9] However, lack of bone, systemic or psychological problems, or financial conditions may limit the placement of implants. For these patients, mini-implant–retained overdentures may be a viable treatment option.[10,11] Some authorities propose using 4[12,13] mini-implants, and others suggest using only 2[10,14-16] for overdenture retention because the authors consider that reducing the number of mini-implants reduces cost and is more favorable biomechanically.

Many mini-implants are manufactured with ball abutments (Intra-Lock International Inc). This is financially advantageous over standard implants requiring a specific retention system for prostheses, including O-ring, ERA, or clip systems.[1] The system of choice for mini-implant–retained overdentures is the ball/O-ring attachment.[1,11,14,17] These attachments enable movement in different directions; are easily inserted, removed, cleaned, and maintained; and are affordable.[2,18]

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## Clinical Implications

The need for periodic replacement of the O-ring attachments is one of the major problems with implant-retained overdentures. Thus, the use of systems with longer durability provides better quality of treatment and patient satisfaction.

The gradual loss of retention and need for periodic change[19,20] are among the disadvantages of O-rings, especially in nonparallel implants,[2,18,21,22] compromising the biomechanics and success of implant-retained overdentures.[23,24] Although the authors are unaware of studies specifying a minimum retention value for mini-implants,[11-13,25] an optimal attachment system should provide sufficient resistance to vertical displacement and impart low lateral force to the implant during prosthesis insertion and removal.[26]

The solution to the problem of retention loss and O-ring wear is the development of devices with variable retention and the ability to take full advantage of the mechanical properties of each material.[27,28] Therefore, this in vitro study tested a new overdenture attachment using polymeric materials and compared the retention and deformation forces of these materials with those of a commercially available O-ring model. The null hypothesis tested was that the different attachments tested for mini-implant–retained overdentures would have no effect on the retention force and component deformation.

## MATERIAL AND METHODS

A polyurethane resin matrix (20×10×30 mm) (F16 Polyol; Axson) with 2 mini-implants (2.0×10.0 mm) (MDL; Intra-Lock International Inc) was used to simulate implants placed in the mandible. The implants were 25 mm apart and parallel to each other (Fig. 1).

A total of 40 polymeric attachments measuring 4×3 mm in height (Fig. 2) were developed using polytetrafluoroethylene (PTFE) (n=20) and polyacetal (n=20). The control group consisted of 20 metallic attachments with silicone O-rings (DML; Intra-Lock International Inc).

The recommended O-ring position is determined by the ideal path of insertion, perpendicular to the occlusal plane. To capture the O-rings following the ideal path of insertion (ideal position), a dental surveyor (B2; Bio-Art Dental Equipment Ltd) was used. The polyurethane matrix was positioned in the horizontal surveyor base, and the attachments were adapted to the mini-implants and captured in pairs with acrylic resin (JET; Clássico Dental Articles) using a test device screwed to the dental surveyor rod (Fig. 3).

**Figure 1.** Polyurethane resin matrix (20×10×30 mm).

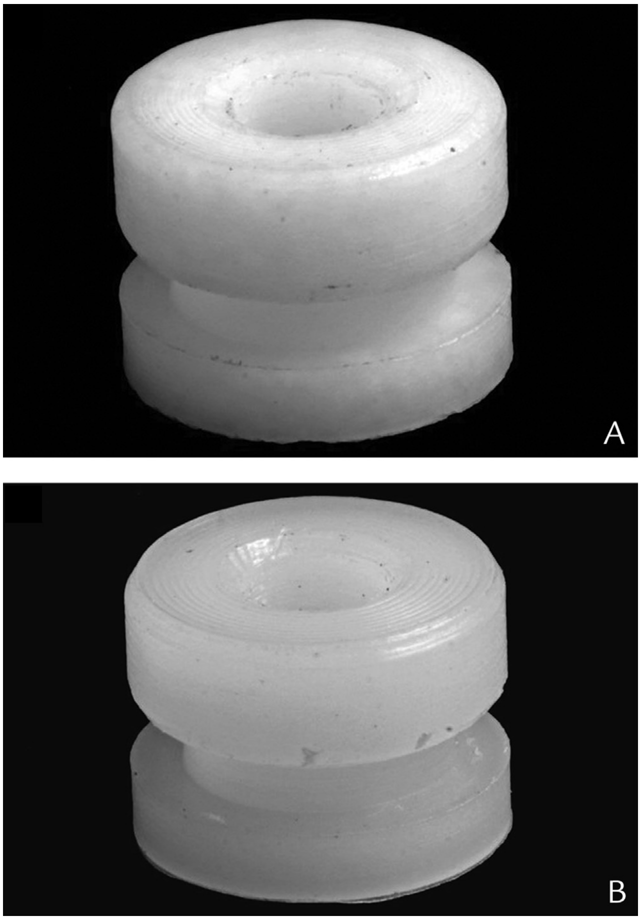

**Figure 2.** Polymeric attachments. A, Polytetrafluoroethylene (PTFE). B, Polyacetal.

A fatigue resistance testing device[29] in which the insertion/removal axis coincided with the ideal path of insertion was used to simulate the insertion and removal of the overdentures and to assess the retention force of the attachments. To perform the test, the

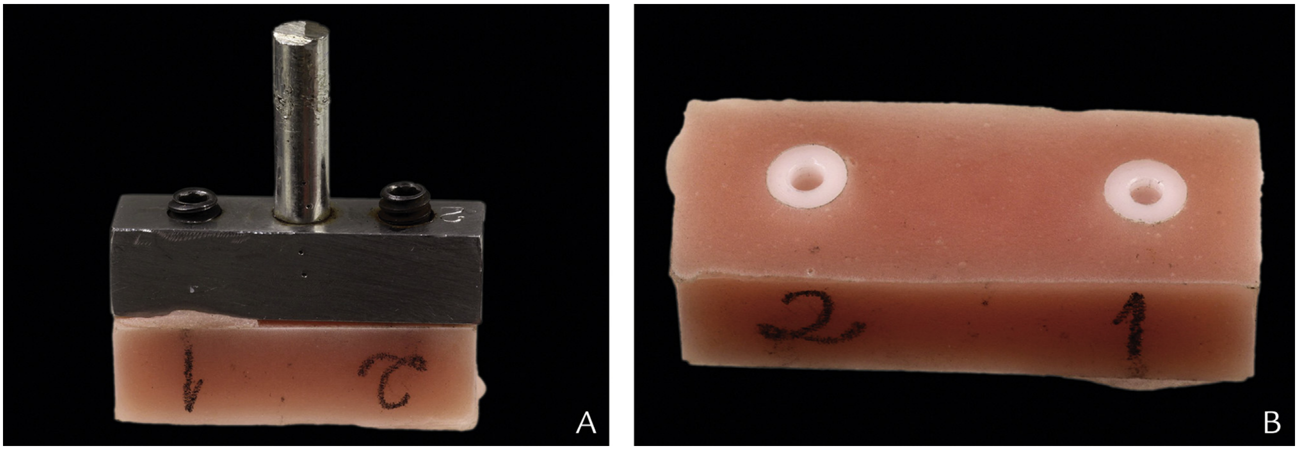


**Figure 3.** A, Test device for capture. B, Captured attachments.

matrix and resin bases were fixed in the device. A total of 60 attachments were tested during the study (commercial O-ring, polyacetal, and PTFE attachments, n=20 each).

A total of 3625 cycles were performed. Assuming 4 full cycles per day, the test simulated 30 months of overdenture insertion and removal. The test was performed at a rate of 20 cycles per minute and at a constant speed of 35.79 mm/second.[29] The data were analyzed at intervals corresponding to 0, 6, 12, 18, 24, and 30 months of use, and each interval corresponded to the arithmetic mean of 10 consecutive insertion and removal cycles. The force required for each insertion and removal cycle was recorded with the LabVIEW 8.0 software (National Instruments) linked to a load cell in the testing apparatus. The mini-implant and capsule set remained immersed in distilled water at 37°C throughout the test to simulate the temperature conditions found in the oral environment.[30]

An optical stereomicroscope (Discovery V20; Carl Zeiss AG) with ×20 magnification was used to assess the deformation of the newly developed devices in comparison with the commercial O-ring. Two methods were selected for the quantitative analysis of the deformation. In the first, internal horizontal length (IHL) and external horizontal length (EHL) and internal vertical length (IVL) and external vertical length (EVL) measurements of the attachments were obtained. In the second, internal diameter (ID) and external diameter (ED) measurements were obtained by selecting 3 points (Fig. 4). The measurements were acquired before and after the fatigue resistance test.

After verifying the homogeneity of the data through graphic analysis (residual plotted against predicted values), a repeated measures ANOVA was applied, followed by the post hoc Tukey honestly significant difference test ($\alpha$=.05).

## RESULTS

The ANOVA showed that the different attachment materials affected the retention force. A significant difference was observed between the 3 attachment systems: metal, polyacetal, and PTFE ($P$<.001). The polyacetal showed the greatest retention force, followed by the metal and PTFE attachments ($P$<.001). However, no significant change was noted over time ($P$=.071) (Table 1).

The deformation of the different attachment materials was analyzed with an optical stereomicroscope before and after the fatigue resistance test. The results from the horizontal, vertical, internal, and external measurements revealed significant differences among the attachment systems ($P$<.001). The metal attachments had the smallest deformation, followed by the polyacetal and PTFE attachments ($P$<.001) according to the internal horizontal length and internal vertical length measures, but no significant differences were observed between polyacetal and PTFE regarding the EHL ($P$=.813) and EVL ($P$=.793). The 3-point method of measurement had similar results. The metal attachments had the smallest deformation ($P$<.001) based on the ID and ED measures, and no significant differences in the ED were observed between polyacetal and PTFE attachments ($P$=.947) (Table 2).

Changes in the attachment system over time were significant only for polyacetal, with greater deformation observed after the experiment ($P$<.001) (Table 3). The deformation of the mini-implants measured before and after the resistance fatigue test did not show a significant difference for EHL ($P$=.970), EVL ($P$=.941), and ED ($P$=.867).

## DISCUSSION

Synthetic biomaterials, such as PTFE and polyacetal, have significant advantages.[27] The high chemical

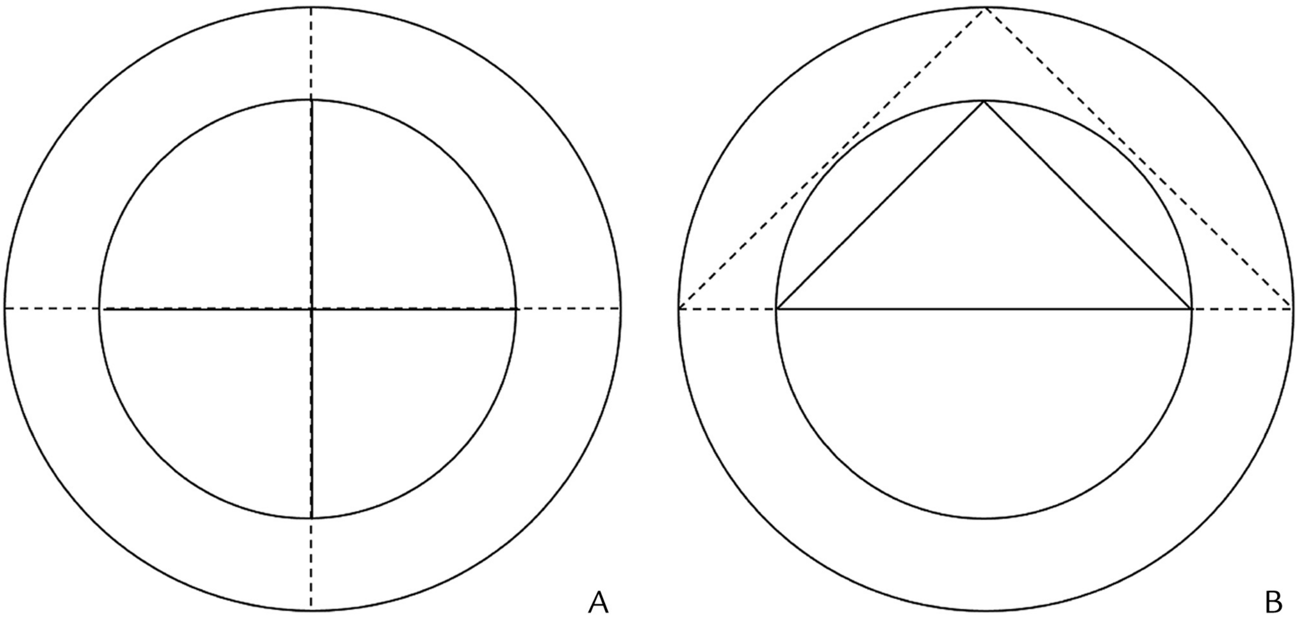


**Figure 4.** Quantitative analysis of deformation. A, Measures of horizontal and vertical length, both internal (continuous line) and external (dotted line). B, Measures of internal (continuous line) and external diameters (dotted line).

**Table 1.** Mean retentive forces (N) ±standard deviation of each material over time

| | Retention Force (N) | | |
|---|---|---|---|
| Time (mo) | Metal | Polyacetal | PTFE |
| 0 | 16.11 ±4.17[a] | 18.23 ±3.74[b] | 6.63 ±1.68[c] |
| 6 | 13.80 ±2.28[a] | 22.15 ±4.84[b] | 5.59 ±1.15[c] |
| 12 | 13.72 ±2.45[a] | 22.85 ±4.91[b] | 5.47 ±1.14[c] |
| 18 | 13.17 ±2.73[a] | 23.61 ±5.35[b] | 5.48 ±1.15[c] |
| 24 | 13.22 ±2.35[a] | 23.58 ±5.86[b] | 5.42 ±1.11[c] |
| 30 | 13.09 ±2.55[a] | 23.79 ±6.25[b] | 5.42 ±1.21[c] |

PTFE, polytetrafluoroethylene. Same superscript lowercase letters in same column indicate statistical similarity.

resistance of these materials minimizes the degradation from denture-cleaning solutions, and the low cell adhesion reduces microbial surface colonization.[28] Although the use of metal attachments with an O-ring for overdenture retention has been established,[8] the characteristics of synthetic biomaterials justify their use for producing prosthetic components.

Reports on the minimum retention value for mini-implant–retained overdentures are lacking; values[9,11,25] ranging from 3.92 to 9.64 N have been reported. This retention is significantly lower than that of standard implants, which require at least 20 N for acceptable overdenture performance.[23] The polyacetal attachments tested in the present study result in higher retention than the commercial O-rings tested and have a retention value similar to that obtained when using standard implants. Thus, the results support the rejection of the null hypothesis that the different attachments tested would have no influence on the retention force and deformation components.

The highest retention force ($P<.001$) during the simulation of 30 months of prosthesis use was obtained with the polyacetal attachment (23.79 N), followed by the control O-rings (13.09 N) and the PTFE (5.42 N) attachments. One study using O-rings for mini-implant–retained overdenture attachments reported retention values ranging from 4.49 to 5.90 N,[21] and another study reported a mean retention value of 6.30 N[11]; these values are much lower than those observed for the proposed polyacetal capsule. PTFE, however, showed intermediate values, despite its excellent properties. Given that a mean of 3.92 N suffices for mini-implant retention and a good patient treatment satisfaction index,[11] the attachments developed in this study, especially the polyacetal attachments, showed excellent overdenture retention.

The wear and tear of components of an overdenture attachment system is caused by functional loads, the prosthesis insertion and removal trajectory, implant angulation,[24] and the presence of parafunctional habits[23] and the prosthodontic complication most commonly found (33%) among implant-supported restorations.[4,18,22] It typically occurs in the first 12 months of use, increasing the need for periodic maintenance.[18-20] In this study, O-rings had an 18.7% loss of retention after a simulated 30 months of use, whereas polyacetal had a 30.5% increase and PTFE had an 18.2% reduction. These results were better than those of other studies[18,29] that found a 16.6% loss of retention for O-rings after a

**Table 2.** Mean deformation (mm) ±standard deviation of each material in different methods

| Material | Method | | | | | |
|---|---|---|---|---|---|---|
| | IHL | EHL | IVL | EVL | ID | ED |
| Metal | 1.30 ±0.05[a] | 3.82 ±0.07[a] | 1.31 ±0.06[a] | 3.83 ±0.09[a] | 1.31 ±0.05[a] | 3.84 ±0.07[a] |
| Polyacetal | 1.61 ±0.30[b] | 4.47 ±0.17[b] | 1.62 ±0.31[b] | 4.51 ±0.13[b] | 1.63 ±0.32[b] | 4.53 ±0.14[b] |
| PTFE | 1.75 ±0.05[c] | 4.49 ±0.15[b] | 1.73 ±0.08[c] | 4.45 ±0.30[b] | 1.73 ±0.07[c] | 4.54 ±0.13[b] |

ED, external diameter; EHL, external horizontal length; EVL, external vertical length; ID, internal diameter; IHL, internal horizontal length; IVL, internal vertical length; PTFE, polytetrafluoroethylene. Same superscript lowercase letters in same column indicate statistical similarity.

**Table 3.** Mean deformation (mm) ±standard deviation of each material in different methods and times

| Material | Time | Method | | | | | |
|---|---|---|---|---|---|---|---|
| | | IHL | EHL | IVL | EVL | ID | ED |
| Metal | Before | 1.29 ±0.03[a] | 3.81 ±0.09[a] | 1.28 ±0.03[a] | 3.81 ±0.10[a] | 1.29 ±0.03[a] | 3.83 ±0.08[a] |
| | After | 1.32 ±0.05[a] | 3.83 ±0.06[a] | 1.33 ±0.07[a] | 3.85 ±0.07[a] | 1.34 ±0.04[a] | 3.85 ±0.06[a] |
| Polyacetal | Before | 1.47 ±0.35[a] | 4.46 ±0.15[a] | 1.49 ±0.36[a] | 4.51 ±0.11[a] | 1.48±0.40[a] | 4.52 ±0.10[a] |
| | After | 1.75 ±0.15[b] | 4.48 ±0.18[a] | 1.76 ±0.17[b] | 4.52 ±0.15[a] | 1.79 ±0.04[b] | 4.54 ±0.17[a] |
| PTFE | Before | 1.72 ±0.05[a] | 4.46 ±0.16[a] | 1.69 ±0.06[a] | 4.39 ±0.39[a] | 1.70 ±0.06[a] | 4.52 ±0.12[a] |
| | After | 1.78 ±0.03[a] | 4.51 ±0.15[a] | 1.77 ±0.06[a] | 4.51 ±0.15[a] | 1.76 ±0.06[a] | 4.56 ±0.13[a] |

ED, external diameter; EHL, external horizontal length; EVL, external vertical length; ID, internal diameter; IHL, internal horizontal length; IVL, internal vertical length; PTFE, polytetrafluoroethylene. Similar superscript lowercase letters in same column (before and after) for each material indicate statistical similarity

simulated 6 months of prosthesis use and a 57.1% loss after 24 months.

The 2 analysis methods used showed similar results regarding the measurement of deformation using an optical stereomicroscope. Polyacetal and PTFE had greater IHL, IVL, and ID deformation than the conventional O-rings, and after performing the fatigue test, the greatest deformation was observed in the polyacetal attachments. This result may be related to the increased retention (18.23 to 23.79 N) of this material during the 30-month simulation because the increase in surface roughness or hardening of some polymer components increases rather than decreases the retention force. Another likely reason for the increase in retention is the possible thermal expansion of the material during the experiment, which was performed with distilled water at 37°C to simulate conditions in the oral cavity.[18,30]

The commercial O-ring attachments tested experienced less EHL, EVL, and ED deformation than the polyacetal and PTFE attachments because metal has a higher mechanical resistance than polymers. However, this deformation had no effect on the retention of the new devices, especially in the case of polyacetal, which obtained the highest retention after 30 months. The findings of this study agree with those of others reporting an improvement in overdenture retention provided by mini-implants as an alternative solution to conventional prostheses.[1,10,13]

The limitations of this study are associated with its in vitro characteristic, which makes it difficult to simulate the exact conditions found in the buccal cavity. Thus, long-term follow-up clinical studies are recommended to confirm the results found in the present in vitro study.

## CONCLUSIONS

Based on the findings of this in vitro study, the following conclusions were drawn:

1. The polyacetal attachment showed higher retention than the commercial O-ring model tested.
2. Despite the deformation experienced by the material, polyacetal attachment should last for at least 30 months before replacement.

## REFERENCES


1. Lemos CA, Verri FR, Batista VE, Júnior JF, Mello CC, Pellizzer EP. Complete overdentures retained by mini implants: A systematic review. J Dent 2017;57:4-13.
2. de Souza RF, Ribeiro AB, Della Vecchia MP, Costa L, Cunha TR, Reis AC, et al. Mini vs. standard implants for mandibular overdentures: a randomized trial. J Dent Res 2015;94:1376-84.
3. 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.
4. Mundt T, Schwahn C, Stark T, Biffar R. Clinical response of edentulous people treated with mini dental implants in nine dental practices. Gerodontology 2015;32:179-87.
5. Shastry T, Anupama NM, Shetty S, Nalinakshamma M. An in vitro comparative study to evaluate the retention of different attachment systems used in implant-retained overdentures. J Indian Prosthodont Soc 2016;16:159-66.
6. Elsyad MA. Patient satisfaction and prosthetic aspects with mini-implants retained mandibular overdentures. A 5-year prospective study. Clin Oral Implants Res 2016;27:926-33.
7. Feine JS, Carlsson GE, Awad MA, Chehade A, Duncan WJ, Gizani S, et al. The McGill consensus statement on overdentures. Mandibular two-implant overdentures as first choice standard of care for edentulous patients. Montreal, Quebec, May 24-25, 2002. Int J Oral Maxillofac Implants 2002;17:601-2.
8. 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.

9. Naert I, Alsaadi G, Quirynen M. Aspects and patient satisfaction with two-implant-retained mandibular overdentures: a 10-year randomized clinical study. Int J Prosthodont 2004;17:401-10.
10. Tomasi C, Idmyr BO, Wennström JL. Patient satisfaction with mini-implant stabilised full dentures. A 1-year prospective study. J Oral Rehabil 2013;40: 526-34.
11. Catalán A, Martínez A, Marchesani F, González U. Mandibular overdentures retained by two mini-implants: a seven-year retention and satisfaction study. J Prosthodont 2016;25:364-70.
12. Maryod WH, Ali SM, Shawky AF. Immediate versus early loading of mini-implants supporting mandibular overdentures: a preliminary 3-year clinical outcome report. Int J Prosthodont 2014;27:553-60.
13. Scepanovic M, Calvo-Guirado JL, Markovic A, Delgardo-Ruiz R, Todorovic A, Milicic B, et al. A 1-year prospective cohort study on mandibular overdentures retained by mini dental implants. Eur J Oral Implantol 2012;5:367-79.
14. Ribeiro AB, Della Vecchia MP, Cunha TR, Sorgini DB, Dos Reis AC, Muglia VA, et al. Short-term post-operative pain and discomfort following insertion of mini-implants for retaining mandibular overdentures: a randomized controlled trial. J Oral Rehabil 2015;42:605-14.
15. Jofre J, Cendoya P, Munoz P. Effect of splinting mini-implants on marginal bone loss: a biomechanical model and clinical randomized study with mandibular overdentures. Int J Oral Maxillofac Implants 2010;25:1137-44.
16. Jofré J, Hamada T, Nishimura M, Klattenhoff C. The effect of maximum bite force on marginal bone loss of mini-implants supporting a mandibular overdenture: a randomized controlled trial. Clin Oral Implants Res 2010;21: 243-9.
17. Omran M, Abdelhamid A, Elkarargy A, Sallom M. Mini-implant overdenture versus conventional implant overdenture (a radiographic and clinical assessments). J Am Sci 2013;9:89-97.
18. ELsyad MA, Elhaddad AA, Khirallah AS. Retentive properties of O-ring and Locator attachments for implant-retained maxillary overdentures: an in vitro study. J Prosthodont 2016:1-9.
19. MacEntee MI, Walton JN, Glick N. A clinical trial of patient satisfaction and prosthodontic needs with ball and bar attachments for implant-retained complete overdentures: three-year results. J Prosthet Dent 2005;93:28-37.
20. Mericske-Stern R, Probst D, Fahrlander F, Schellenberg M. Within-subject comparison of two rigid bar designs connecting two interforaminal implants: patients' satisfaction and prosthetic results. Clin Implant Dent Relat Res 2009;11:228-37.
21. Chaves CA, Souza RF, Cunha TR, Vecchia MP, Ribeiro AB, Bruniera JF, et al. Preliminary in vitro study on O-ring wear in mini-implant-retained overdentures. Int J Prosthodont 2016;29:357-9.
22. Goodacre CJ, Bernal G, Rungcharassaeng K, Kan JY. Clinical complications with implants and implant prostheses. J Prosthet Dent 2003;90:121-32.
23. Kim SM, Choi JW, Jeon YC, Jeong CM, Yun MJ, Lee SH, et al. Comparison of changes in retentive force of three stud attachments for implant overdentures. J Adv Prosthodont 2015;7:303-11.
24. Valente MLDC, de Castro DT, Macedo AP, Shimano AC, Dos Reis AC. Comparative analysis of stress in a new proposal of dental implants. Mater Sci Eng C Mater Biol Appl 2017;77:401-10.
25. Preoteasa E, Meleşcanu-Imre M, Preoteasa CT, Marin M, Lerner H. Aspects of oral morphology as decision factors in mini-implant supported overdenture. Rom J Morphol Embryol 2010;51:309-14.
26. Yang TC, Maeda Y, Gonda T, Kotecha S. Attachment systems for implant overdenture: influence of implant inclination on retentive and lateral forces. Clin Oral Implants Res 2011;22:1315-9.
27. Falco EE, Patel M, Fisher JP. Recent developments in cyclic acetal biomaterials for tissue engineering applications. Pharm Res 2008;25: 2348-56.
28. Gabriel M, Niederer K, Frey H. Wet chemistry and peptide immobilization on polytetrafluoroethylene for improved cell-adhesion. J Vis Exp 2016;114.
29. Rodrigues RC, Faria AC, Macedo AP, Sartori IA, de Mattos Mda G, Ribeiro RF. An in vitro study of non-axial forces upon the retention of an o-ring attachment. Clin Oral Implants Res 2009;20:1314-9.
30. Botega DM, Mesquita MF, Henriques GE, Vaz LG. Retention force and fatigue strength of overdenture attachment systems. J Oral Rehabil 2004;31: 884-9.

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