


# Angled ball and locator attachments for immediate loaded inclined implants used to retain maxillary overdentures: A cross over study of patient satisfaction and oral health related quality of life

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## Abstract

**Objectives:** The aim of this was to compare the influence of two different angulated abutment designs on patient satisfaction, oral health-related quality of life, and prosthetic aspects of implant-supported maxillary overdentures.

**Materials and Methods:** For this cross-over study, 18 patients with completely edentulous maxillary ridges opposing implant-retained mandibular overdentures received 4 implants between the maxillary sinuses using computer-guided surgery. The anterior implants were installed at canine/lateral incisor areas and inclined 15° labially. The posterior implants were inserted just anterior to the maxillary sinuses and inclined 15° distally. Eight patients received maxillary overdentures retained by angled ball attachment (ball overdenture [BOD]) and angled locator attachment in random order. After 6 months, patients indicated satisfaction with their prosthesis using a visual analog scale (VAS), and oral health impact profile (OHIP-14). Moreover, postinsertion prosthodontic maintenance and complications were recorded for both attachments. Comparisons of patient satisfaction and prosthetic complications between groups were performed using the Wilcoxon matched-pairs test and the McNemar test, respectively.

**Results:** Locator overdenture (LOD) recorded significantly higher scores than the BOD group regarding all the VAS questions except for ease of cleaning ( $p < 0.007$ ). LOD recorded significantly higher patient satisfaction regarding the pronunciation of sounds ( $p = 0.009$ ), painful aching ( $p = 0.018$ ), feeling tense ( $p = 0.011$ ), unsatisfactory diet ( $p = 0.013$ ), irritability with people ( $p = 0.005$ ), and life in general ( $p = 0.004$ ). The most common complications were matrix activation/renewal ( $n = 34$ ). BOD showed a significantly higher incidence of attachment loosening ( $p = 0.002$ ), and teeth fracture ( $p = 0.049$ ) than LOD. LOD showed a significantly higher incidence of attachment wear and replacement than BOD ( $p < 0.001$ ). There was no difference between groups regarding soft tissue complications.

**Conclusion:** Within the limitations of this study, and in terms of improved patient-centered outcomes, angled locator attachments are recommended to retain maxillary implant overdentures opposed by implant retained mandibular overdentures as it was

associated with increased patient satisfaction and oral health-related quality of life than angled ball attachments. However, locator attachment was associated with more postinsertion prosthodontic maintenance than ball attachment.

#### KEYWORDS

angled, complications, implant, implants, inclined, maintenance, maxillary, OHIP, OHRQoL, overdenture, patient satisfaction

#### What is known

The rehabilitation of the edentulous maxilla with tilted implants is widely documented lately and achieve popularity between the patients and the surgeons.

Clinical studies that compare the effect of angulated stud attachment systems on the success rate of inclined implants retaining maxillary overdentures are scarce.

#### What this study adds

Angled locator attachments are associated with increased patient satisfaction and oral health-related quality of life than angled ball attachments.

On the other hand, locator attachment was associated with more postinsertion prosthodontic maintenance than ball attachment.

## 1 | INTRODUCTION

In comparison to the mandible, using osseointegrated implants for restoring completely edentulous maxilla is regarded to be a challenging step due to its tridimensional resorptive pattern and insufficient bone volume for the ideal implant insertion.<sup>1</sup> Moreover, such treatment is often a defiance procedure due to inherent anatomical and biomechanical problems such as bone inclination, especially in the anterior area, and maxillary sinus pneumatization in the posterior area which decreases the available bone for implant-supported dental restoration.<sup>2,3</sup> Advanced surgical procedures used such as onlay bone grafts, maxillary sinus grafting,<sup>4</sup> guided bone regeneration,<sup>5</sup> and inserting the implants in specific anatomical areas such as the zygoma or the pterygoid region<sup>6</sup> may be used to overcome the limitation of available bone. However, those invasive procedures have many drawbacks such as increased risk of morbidity, high costs, unsuitability for patients with compromised medical conditions, and finally may end with failure.<sup>6</sup>

Another alternative method in the rehabilitation of the edentulous maxilla is the use of tilted implants, which is widely documented lately.<sup>7,8</sup> All-on-4 implant protocol was first applied to atrophic edentulous maxilla by Malo<sup>9</sup> in 2005. This protocol has several advantages such as maximal use of the available bone to avoid invasive bone grafting procedures (resulting in significantly less morbidity), reducing cantilever lengths, increasing anterior-posterior spread, improving support, widening the prosthetic base and enhancing implant to bone surface areas.<sup>10</sup>

Implant retained maxillary overdentures are a predictable treatment option for patients with unsatisfactory retention and stability of maxillary dentures. This prosthetic design has many advantages such as avoiding the augmentation steps needed for fixed restorations, it is

more suitable for patients needing facial support.<sup>11</sup> In comparison with full-arch fixed restoration, implant overdentures avoid augmentation procedures,<sup>12</sup> and easier to clean,<sup>2</sup> and can be used with short implants.<sup>13</sup> Moreover, implant overdentures can be used in patients with compromised maxillary ridges, buccal bone inclination, high lip line, thin mobile mucosa, and insufficient lip support.<sup>14</sup> It appears to be a consensus in the reviewed literature that a minimum of four implants is favorable for maxillary implant overdentures.<sup>3</sup>

According to the All-on-4 protocol implants were immediately loaded with a fixed acrylic prosthesis the same day of implant insertion.<sup>15</sup> This requires additional steps such as impression making and splinting of the transfer copings to obtain passive fit of the prosthesis.<sup>16</sup> Moreover, additional time is required for the laboratory to construct the screw-retained provisional acrylic restoration. This may increase the total time and costs of treatment.<sup>17</sup> Another alternative approach is the use of overdentures as a final restoration with implants placed according to the All-on-4 concept.<sup>18-21</sup> The authors in such studies<sup>18-21</sup> used conventional or milled bar overdentures as a final prosthesis. However, the construction of the bar attachments also involves many steps and increases the cost and time of the treatment. Moreover, it is associated with gingival hyperplasia and encroachment on the tongue space with tapered arches.<sup>22,23</sup> The un-splinted attachments more are commonly used than the splinted (bar) attachments owing to the smaller space requirements within the prosthesis, ease of cleaning, more economical, and lower sensitivity techniques.<sup>24,25</sup> The most common types of splinted attachments are ball and locator attachments.<sup>26</sup> Ball and socket attachment has been the most popular un-splinted attachment used to retain a mandibular overdenture because of its simplicity and cost effectiveness.<sup>27</sup> The locator attachment is resilient, self-aligning, and has double retention cylinders<sup>28</sup> with different retention forces.<sup>29</sup> Moreover, it has a low

profile, provides limited lateral movements, and contains some built-in angulation compensation.<sup>30,31</sup>

Tilted implants placement may require the use of divergence correcting attachments. Although the standard ball attachment is considered to be the most widely used of all the systems available, it only allowed angulation variations up to 20° (up to 10° convergence each).<sup>22,32</sup> Alternative prosthetic methods were suggested to compensate for malpositioned implants in the early planning stage of treatment.<sup>15,33</sup> Also, the classic locator attachment can accommodate up to 40° of divergence between implants. However, frequent wear and loss of retention have been reported as complications.<sup>26,33</sup>

Recently, premanufactured angled abutments were available in the implant market for correction of inclined implants retaining overdentures that may be less technique-sensitive, and easier to clean.<sup>34</sup> Moreover, it improves the prosthetic outcome with concern to predictable retention and avoiding premature wear of the retentive matrices.<sup>35</sup> To the best of the authors' knowledge, the literature lacks clinical studies that compare the effect of angulated stud attachment systems on the success rate of inclined implants retaining maxillary overdentures. Therefore, this study aimed to compare the influence of two different angulated abutment designs on patient satisfaction and oral health related quality of life using four implants retaining maxillary overdenture.

## 2 | MATERIALS AND METHODS

### 2.1 | Patient selection and study design

The present study cross-over study was conducted on 18 participants (10 males and 8 females) aged 58–68 years having completely edentulous maxillary ridges opposing implant-retained mandibular overdentures Table 1. Participants were admitted to the prosthodontic department, Faculty of Dentistry, Mansoura University for oral rehabilitation by implant-supported maxillary prostheses. The study was conducted according to the Helsinki Declaration of 2008 and approved by the Local Dental Research Ethical Committee. All the study participants were informed about the study procedures, and the consent form was discussed and declared before signature. This sample size was calculated to give 80% power according to the results of another crossover study<sup>36</sup> which found a significant difference in OHIP between different prosthetic options used within the same

patient (effect size = 0.49,  $\alpha$  = 0.05). Sample size calculation was performed using G-Power program (V 3.1).

The inclusion criteria are (1) completely edentulous patients with maladaptive experience of using conventional maxillary dentures, (2) patients were in good general health without any systemic diseases that would hinder implant treatment, (3) all patients had maxillary sinus pneumatization and adequate inter-arch space, and (4) patients required to have sufficient bone volume (height and width) in the area between the two maxillary sinuses to allow placement of implants (at least 3.5 mm wide and 13 mm long in the canine and premolar areas bilaterally). This was verified by preoperative cone beam computerized tomography (CBCT). Patients who had a history of alcoholism, parafunctional habits, smoking, TMJ disorders, neuromuscular problems, or metabolic disorders affecting bone such as diabetes and those who are unwilling to accept implant overdentures as a treatment modality were excluded from this study.

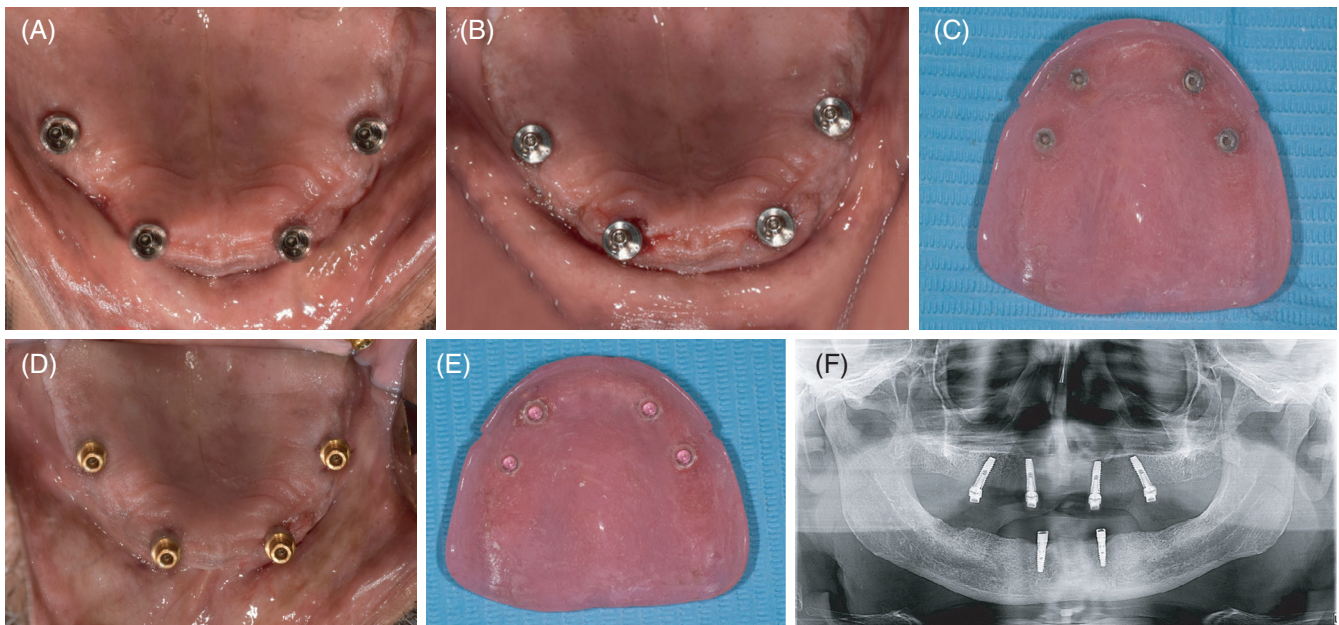
### 2.2 | Surgical and prosthetic procedures

For all participants, new maxillary conventional dentures were constructed with a bilateral balanced occlusal concept. Maxillary dentures were duplicated into heat cure acrylic resin dentures to be used as a radiographic template. Radiopaque gutta-percha markers were attached to the polished surface of the maxillary duplicate dentures at buccal and palatal surfaces. Dual scan protocol was used for each participant using CBCT (Vatech, Seoul, Korea). One scan was performed while the patient wearing the duplicate denture and holding the dentures in centric occlusion. The other scan was performed for the maxillary denture alone. The two scans were downloaded onto a computer planning software (OnDemand3D, Cybermed Inc., Seoul, Korea) and overlapped to provide a 3-dimensional image of the edentulous maxilla. Using the software, virtual planning for the location and angulation of the implants was performed. The anterior implants were placed in the canine/lateral incisor area bilaterally to each other's and inclined 15° labially to follow the contour of the alveolar bone of the premaxilla. The posterior implants were placed just anterior to the maxillary sinus (in the area of second premolars) and inclined 15° distally. The plan was saved as STL file and used to construct a mucosal supported stereolithographic surgical guide using prototyping technology to be used for flapless implant insertion.<sup>19</sup>

One day before surgery, 0.12% Chlorhexidine mouthwash was used and continued for 2 weeks following the surgical procedures. Prophylactic antibiotic [(Augmentin® 1 gm (amoxicillin 875 mg + clavulanic acid 125 mg)] was given the day before surgery, then continued 7 days postoperatively twice daily. Surgical procedures were performed under local anesthesia using the flapless approach by the same oral and maxillofacial surgeon. The stereolithographic guide was stabilized intraorally by using silicone bite registration in maximal intercuspation then fixed to the maxillary bone with anchor pins. Tissue punch was used to cut circular incisions through the soft tissues. Implant osteotomies were performed using a computer-guided surgical kit (Dentium, South Korea). Four implants (Implant direct,

**TABLE 1** Patient information for both groups

	Ball attachments	Locator attachments
Mean age (years)	63 ± 3.9	62 ± 4.5
Gender (male/female)	5/4	5/4
Mean number of previous maxillary dentures	3.5	2.6
Mean years of edentulism	5.5 ± 2.9	4.2 ± 2.7



**FIGURE 1** (A) The transmucosal part of angled abutments screwed to the implants. (B) Ball abutments screwed to the angled transmucosal part (BOD). (C) Metal housing with the plastic cap of ball abutments attached to the overdentures (BOD). (D) Locator abutments screwed to the angled transmucosal part (LOD). (E) Metal housing with the plastic cap of locator abutments attached to the overdentures (LOD). (F) Postoperative panoramic radiograph

Oraltronics Dental Implant Technology GmbH) were inserted with at least 35 Ncm to ensure initial implant stability. Under preparation of bone osteotomies were performed in case of reduced bone density to obtain adequate primary stability.

Suitable transmucosal angled abutments (Implant direct, Oraltronics Dental Implant Technology GmbH) were selected according to the gingival height (15° for anterior and posterior implants) and screwed to the anterior fixtures at 20 Ncm torque to correct the implant inclination and ensure the parallelism of the attachments (Figure 1A).

In a simple random method, eight patients were first given the ball attachment (ball overdenture, BOD, Figure 1B) and the other eight received the locator attachment (locator overdenture, LOD, Figure 1D). After measuring patient satisfaction and oral health-related quality of life, a wash-out period of 1 month was established in which the attachments were removed, and the patients were the conventional maxillary dentures after relining. After 1 month, the first eight patients were given LOD, and the other eight patients were given BOD. This randomization aims to avoid the effect of the order of attachment on the outcome measures of the study.

The ball/locator abutments were screwed to the transmucosal angled abutment at 20 Ncm torque. The metal housings of ball/locator abutments were snapped over the abutments. Block-out spacers were placed over the head of each abutment, then a processing cap/insert was inserted into each abutment. A recess was prepared in the maxillary denture to accommodate the corresponding attachments with no contact to the denture base. Palatal vents were performed to allow escapement of excess acrylic resin during the pick-up procedure. The metal housings of the attachments were

picked up to the fitting surface of the dentures using auto polymerizing acrylic resin (Repair Material, Dentsply, York, PA; Figure 1C,E). Each patient was gently guided into centric occlusion and left for 4 min until the resin had polymerized. The denture was removed, and the excess resin was finished and polished. Occlusion was adjusted and refined. The processing caps/ inserts were replaced with color-coded retention plastic inserts. Light retention elements were used for both ball and locator attachments. For BOD and LOD, implants were loaded immediately with maxillary overdentures on the same day of implant placement. Anti-inflammatory medications (Alphinter) and analgesics (Ketolac 10 mg) were prescribed three times daily for 7 days postsurgically in addition to antibiotics and mouth wash. Postoperative instruction included the application of ice packs, avoiding hard food (maintaining a soft diet), and removal of the dentures for performing oral hygiene only. Postoperative panoramic radiographs were performed (Figure 1F).

### 2.3 | Evaluation of patient satisfaction

Patient satisfaction was measured using a questionnaire that depends on (1) visual analog scale (VAS),<sup>17</sup> (2) oral health impact profile (OHIP-14).<sup>37</sup> Regarding VAS, participants were asked to score their answer according to the amount of satisfaction on a 100 mm line (Score 0 = no satisfaction at all and score 100 = complete satisfaction). The questions cover several items related to maxillary overdentures such as retention, stability, comfort, ease of cleaning, ease of speaking, ease of chewing, limited activities due to embarrassment, quality of bolus, and appearance. The VAS questions address many items of patient

**TABLE 2** Comparison of visual analog scale (VAS) between groups

	Ball attachment				Locator attachment				p value
	Median	Mean ranks	Minimum	Maximum	Median	Mean ranks	Minimum	Maximum	
Max_prosth	81.50	20.5	71	76	85.00	24.5	70	95	<0.001*
Max prosthesis compared	77.50	11.75	70	95	87.50	21.25	75	100	0.004*
Retention	80.00	9.72	70	95	95.00	23.28	85	100	0.001*
Stability	82.50	9.81	70	90	95.00	23.19	80	100	0.001*
Occlusion	85.00	13.72	70	95	87.50	19.28	75	100	0.056
Comfort	75.00	11.19	65	95	90.00	21.81	80	100	0.003*
Ease of cleaning	82.50	22.09	70	90	75.00	10.91	60	80	0.002*
Ease of speaking	70.00	10.34	60	80	85.00	22.66	70	90	0.002*
Ease of chewing	75.00	10.88	60	90	87.50	22.13	75	95	0.001*
Quality of bolus	77.50	11.41	65	90	90.00	21.59	75	95	0.006*
Appearance	80.00	10.75	65	90	90.00	22.25	80	100	0.002*
Embarrassing	80.00	17.47	65	90	75.00	15.53	65	95	0.546

\*p is significant at 5% (Wilcoxon signed ranks test).

**TABLE 3** Comparison of OHIP-14 between groups

	Ball attachment				Locator attachment				p value
	Median	Mean ranks	Minimum	Maximum	Median	Mean ranks	Minimum	Maximum	
OHIP_1	2.00	20.97	1.00	9.00	2.00	12.03	1.00	2.00	0.009*
OHIP_2	2.00	22.06	2.00	3.00	2.00	21.54	2.00	3.00	0.087
OHIP_3	2.00	20.63	1.00	3.00	1.00	12.38	1.00	2.00	0.018*
OHIP_4	2.00	19.13	1.00	3.00	2.00	13.88	1.00	2.00	0.083
OHIP_5	2.00	18.50	1.00	2.00	1.50	14.50	1.00	2.00	0.064
OHIP_6	2.00	19.78	1.00	3.00	2.00	13.22	1.00	3.00	0.011*
OHIP_7	2.00	20.75	1.00	3.00	1.00	12.25	1.00	2.00	0.013*
OHIP_8	2.00	18.63	1.00	3.00	2.00	14.38	1.00	2.00	0.096
OHIP_9	2.00	19.25	1.00	3.00	2.00	13.38	1.00	2.00	0.083
OHIP_10	2.00	21.31	1.00	3.00	2.00	20.10	1.00	3.00	0.056
OHIP_11	2.00	19.94	1.00	3.00	1.00	13.06	1.00	2.00	0.005*
OHIP_12	2.00	21.00	2.00	3.00	2.00	20.00	2.00	3.00	0.098
OHIP_13	2.00	20.66	1.00	3.00	1.00	12.34	1.00	2.00	0.004*
OHIP_14	2.00	19.22	1.00	3.00	1.00	13.78	1.00	2.00	0.058

\*p is significant at 5% (Wilcoxon signed ranks test).

satisfaction that are not covered by domains of OHIP. The questions of VAS were given to the patients in Arabic<sup>20,38</sup> (Table 2). Regarding the oral health-related quality of life (OHRQoL), oral health impact profile (OHIP-14), the questions covered seven domains: functional limitation, physical pain, physical disability, psychologic discomfort, psychologic disability, social disability, and handicap (Table 3). Also, these questions were translated into Arabic by linguistic professionals who act in collaboration with the authors to prepare the final version.<sup>20,37,38</sup> The translation was made using a forward-backward approach. The answers of the questionnaire include score 1 = never, score 2 = hardly ever, score 3 = occasionally, score 4 = fairly often,

and score 5 = very often. Increased patient satisfaction is related to lower scores while higher scores indicate decreased satisfaction.

## 2.4 | Evaluation of prosthetic aspects and complications

The prosthodontic maintenance and complications for implant-supported maxillary overdentures were recorded after 6 months of function and included the frequency of mechanical complications of implant components (implants, attachments loosening/wear/activation)

and overdentures (teeth fractures, overdenture fracture, relining, and rebasing) and soft tissue complications of denture bearing areas (mucositis, soreness, ulcer decubitus, hyperplasia, and flabby ridge).<sup>39,40</sup> Attachment renewal was performed when the retention of the overdentures decreased based on objective examination by the prosthodontists.

## 2.5 | Statistical analysis

Data were analyzed using the Statistical Package of Social Science (SPSS) program for Windows (version 25). Comparisons of VAS and OHIP-14 scores between groups were made using the nonparametric Wilcoxon matched-pairs test. The McNemar test was used to compare the incidence of prosthetic complications between groups.  $p < 0.05$  was considered to be significant.

## 3 | RESULTS

The attendance of all the patients was regular with no dropouts because of the short evaluation period of this study. Two implants failed in two patients (one anterior implant belonged to the locator group and another posterior implant in the ball group). Implant failures occurred during the healing period due to implant overload resulting in 96.87% implant survival rate. No significant difference in implant failures between groups (attachments) was noted. Implant failures were associated with mobility and suppuration. For each patient,

the failed implant was removed, the overdentures were connected to the other three implants and the two patients were excluded from the study. Therefore, 16 patients completed the analysis.

Table 2 showed the results of median scores of the VAS questionnaire for both groups. LOD recorded significantly higher satisfaction than BOD regarding satisfaction with the maxillary prosthesis, maxillary prosthesis compared to teeth, stability, retention, comfort, ease of speaking, ease of chewing, quality of bolus, and appearance. BOD recorded significantly higher satisfaction than LOD regarding ease of cleaning. There was no significant difference in occlusion and embarrassment between groups.

The median scores of OHIP-14 for both groups are shown in Table 3. LOD recorded significantly higher patient satisfaction regarding the pronunciation of sounds (OHIP-1), painful aching (OHIP-3), feeling tense (OHIP-6), unsatisfactory diet (OHIP-7), irritability with people (OHIP-11), and life in general (OHIP-13). There was no significant difference in the sensation of taste (OHIP-2), comfort on eating (OHIP-4), self-consciousness (OHIP-5), interrupting meals (OHIP-8), difficulty to relax (OHIP-9), embarrassing (OHIP-10), difficulty in jobs (OHIP-12), and inability to function (OHIP-14) between groups.

Table 4 demonstrated the frequency (percentage) distribution of prosthodontic maintenance and complications of maxillary overdentures in both groups. The most common complications were matrix activation/renewal for both attachments. BOD showed a significantly higher incidence of attachment loosening (18/28.1%) than LOD (8/12.5%). LOD showed a significantly higher incidence of attachment wear and replacement (24/37.5%) than BOD (10/15.6%). BOD showed a significantly higher incidence of overdenture teeth

	Ball attachments	Locator attachments	<i>p</i> value
Implant components (implant level), <i>n</i> = 64			
Attachment loosening	18 (28.1%)	8 (12.5%)	0.002*
Attachment fracture	4 (6.3%)	3 (7.4%)	1.00
Matrix wear/renewal	10 (15.6%)	24 (37.5%)	<0.001*
Overdenture prosthesis (patient level), <i>n</i> = 16			
Overdenture teeth fracture/renewed	6 (37.5%)	1 (6.3%)	0.049*
Overdenture fracture	2 (12.5%)	1 (6.3%)	1.00
Overdenture relines	1 (6.3%)	3 (18.8%)	0.500
Overdenture rebases	1 (6.3%)	2 (12.5%)	1.00

\**p* is significant at 5% (McNemar Test).

**TABLE 4** Frequency (percentage) distribution of prosthodontic maintenance and complications of maxillary overdentures in both groups

**TABLE 5** Frequency (percentage) distribution of mucosal complications of maxillary overdentures in both groups (on patient level, *n* = 16)

	Ball attachments	Locator attachments	<i>p</i> value
Mucositis	4 (25%)	5 (31.3%)	1.00
Soreness	3 (18.8%)	4 (25%)	1.00
Decubitus ulcer	1 (6.3%)	2 (12.5%)	1.00
Hyperplasia	0 (0%)	1 (6.3%)	1.00
Flappy ridge	0 (0%)	0 (0%)	–

*p* is significant at 5% (McNemar Test).

fracture and renewal (6/37.5%) than LOD (1/6.3%). No significant difference in attachment fracture (4/6.3% for ball, and 3/7.4% for locator), overdenture fracture (2/12.5% for ball, and 1/6.3% for locator), overdenture relining (1/6.3% for ball, and 3/18.8% for locator), and overdenture rebase (1/6.3% for ball, and 2/12.5% for locator) between groups was noted.

Table 5 demonstrated the frequency (percentage) distribution of mucosal complications of maxillary overdentures in both groups. The most common complication was mucositis for both attachments. There was no significant difference in mucositis (4/25% for ball, and 5/31.3% for locator), soreness (3/18.8% for ball, and 4/25% for locator), decubitus ulcer (1/6.3% for ball, and 2/12.5% for locator), hyperplasia (0/0% for ball, and 1/6.3% for locator), and flappy ridges (0/0% for both attachments) between groups was noted.

## 4 | DISCUSSION

In contrast to longitudinal study design, the cross-over study allows patients to experience all treatment modalities and to compare them personally.<sup>41</sup> Also, cross-over trials allow using small patient numbers than parallel-group trials.<sup>42</sup> The within-subject cross-over studies also allow standardization of subject and denture factors and make the comparison between prostheses more accurate with regards to patient satisfaction with each prosthesis.

In the current study, the LOD group recorded a statistically significant higher patient satisfaction regarding retention and stability of maxillary dentures (VAS) and the majority of OHIP-14 questions than the BOD group. This may be attributed to the dual (inner and outer) frictional retention mechanism of the locators as the nylon male inserts are slightly oversized compared to the inner ring of the female abutments.<sup>43</sup> The outer margin of the male nylon inserts engages simultaneously the shallow undercut area at the outer margin of the abutment, while the central stud of the insert press-fits within the inner metal ring of the female abutment.<sup>44</sup> This dual friction augments the retention of locator attachments. Moreover, locator frictional flanges behave like guiding planes, which restrict lateral movement of the prosthesis causing more stability. On the other hand, the ball attachment had an outer plastic circular cap only that fits the ball of the abutment. This may reduce the surface area of friction and could be responsible for reduced retention and stability of BOD compared to LOD. In agreement with our finding, Sultana and colleagues<sup>45</sup> found increased initial retention for locator retained mandibular overdentures than for ball retained overdentures. Although implant inclination was reported to adverse effects the retention and stability of the prosthesis retained by locator attachment,<sup>30,46,47</sup> the correction of distal inclination of posterior implants and labial inclination of anterior implants by using the angled abutments achieved a parallel path of insertion/ removal of the definitive prosthesis which enhances the retention and stability of locator attachments. In line with this explanation, another study<sup>48</sup> reported that with a parallel orientation of the implants, the locator retention may exceed bar and metal clip retention. In contrast to our findings, several studies reported no difference

in patient satisfaction (VAS) and OHRQoL (OHIP-14) between locator and ball attachments used to retain mandibular overdentures.<sup>49-51</sup>

The increased patient satisfaction with LOD regarding chewing, quality of bolus (VAS), unsatisfactory diet (OHIP7), and painful aching (OHIP-3) compared to BOD may be due to improved stability and retention of the overdentures which decrease pain, and discomfort during chewing allowing the patients to apply higher biting forces and increase the chewing efficiency. In agreement with this observation, another study<sup>52</sup> reported significant improvement of masticatory functions both subjectively and objectively after using locator attachments. The increased satisfaction with speech and esthetics (VAS), and pronunciation of sounds (OHIP-1) in the LOD group compared to the BOD group may be attributed to the reduced vertical height of the locator attachment compared to ball attachments. Consequently, locators did not cause increased bulkiness of the denture base around attachments. In contrast, the increased vertical profile of the ball attachment may cause increased bulkiness of the denture base and may interfere with appearance and speech.

LOD group recorded significantly lower patient satisfaction than the BOD group for ease of cleaning. This might be due to the cylindrical configuration with the opened upper part of the locator abutments which may collect more food debris and make its cleaning more difficult. In contrast, ball abutments have a smooth rounded surface which facilitates cleaning. In agreement with this finding, Pisani and colleagues<sup>53</sup> reported that cleaning of locator attachments was uncomfortable for the patients as they should use the toothbrush in all directions including the occlusal aspect and areas close to the gingival margin. However, ball attachments are easy to wash with horizontal brushing movements.<sup>54</sup>

LOD recorded significantly higher patient satisfaction regarding feeling Tense (OHIP-6), irritability with people (OHIP-11), and life in general (OHIP-13) than BOD. This may be due to locator attachments are designed with guiding flanges similar to guiding planes to make insertion and removal easier. This facilitates the handling of the prosthesis and improves life in general. Moreover, the reduced vertical profile of locator attachment (which reduces the bulkiness of the denture) and the increased retention and stability of locator attachments (provided by double frictional flanges) make the patient more confident, less irritable with people, reduce the feeling of tension and improve life in general. In line with these explanations, several clinical studies<sup>49,55</sup> evaluated the locator system, compared with other attachments, and concluded that the locator attachments are more profitable from a clinical viewpoint.

In this study, the most common complications were matrix activation/renewal for both attachments. However, locator attachment showed a significantly higher incidence of attachment wear and replacement than ball attachment. This may be attributed to the increased frictional contact of nylon flanges with locator abutment, which comes from a dimensional misfit between the slightly oversized nylon male insert and the smaller diameter of the inner ring of the female abutment. This frictional contact together with increased chewing ability of LOD accelerates wear of the nylon inserts, causes increased retention loss,<sup>30,47</sup> and consequently increases the number

of the nylon insert replacements. In line with these findings, Krennmair and colleagues,<sup>51</sup> in a cross-over study, found that the locator attachments require more post insertion aftercare (activation of retention) than the ball anchors. The increased attachment loosening with BOD may be attributed to the increased occluso-gingival height of ball attachment which increases vertical cantilever and transmits more load to the abutment screw causing an increased incidence of abutment screw loosening. In agreement with this explanation, Jiang and colleagues<sup>56</sup> found that ball attachment revealed more stress values in implant bodies than locator attachment with vertical and inclined implants. They attributed the reduced implant stresses to the low-profile design of locator attachment.

BOD showed a significantly higher incidence of overdenture teeth fracture and renewal than LOD. This may be due to ball attachments occupying more prosthetic space within the denture base than locator attachments<sup>57</sup> which may result in reduced surface area of contact of denture teeth with the acrylic resin of the denture base and induce more stress concentration in the thin layer of the acrylic resin surrounding the ball attachment. Consequently, denture teeth separation and fracture occur more with BOD than LOD. The absence of difference in soft tissue complications (such as mucositis, soreness, and decubitus ulcer) between groups may be attributed to the resiliency of ball and locator attachments and denture settling which may increase ridge loading and soft tissue irritation. The reduced number of soft tissue complications in both groups may be good implant distribution provided by distal tilting of posterior implants which give good prosthetic and implant support and reduce soft tissue support.<sup>11,58</sup>

The limitation of this study includes the small sample size and the short-term follow-up. Moreover, the lack of a control group that includes parallel implants is another limitation. Furthermore, the evaluation of patient satisfaction and prosthetic maintenance of opposing mandibular overdentures was not performed. Accordingly, future randomized clinical trials with large patient cohort and long-term follow-up are needed to evaluate the clinical performance of parallel implants “control group” and angled implants “test group” used to support maxillary dentures and to evaluate the effect of the type of prosthesis in the opposing mandibular arch.

## 5 | CONCLUSION

Within the limitations of this study, and in terms of improved patient-centered outcomes, angled locator attachments are recommended to retain maxillary implant overdentures opposed by implant-retained mandibular overdentures as it was associated with increased patient satisfaction and oral health-related quality of life than angled ball attachments. However, locator attachment was associated with more postinsertion prosthodontic maintenance than ball attachment.

### CONFLICT OF INTEREST

The authors declare no conflicts of interest. The study was self-funded by the authors.

### AUTHOR CONTRIBUTIONS

**Marwa Ahmed Aboelez:** perform prosthetic procedures, denture constructions, collect data, interpretation of data for the work; drafting the paper or revising it critically. Agreed to be accountable for all aspects of the work in ensuring that questions related to the accuracy or integrity of any parts of the work are appropriately investigated and resolved. **Mona Galal Abo Elezz:** data collection, or interpretation of data for the work; drafting the paper or revising it critically. Agreed to be accountable for all aspects of the work in ensuring that questions related to the accuracy or integrity of any parts of the work are appropriately investigated and resolved. **Abdelrahman Elsaid Abdrahboh:** performed data analysis/interpretation, Statistics, acquisition, analysis, agreed to be accountable for all aspects of the work in ensuring that questions related to the accuracy or integrity of any parts of the work are appropriately investigated and resolved. **Moustafa Elsyad:** formulating study concept, study design, perform prosthetic procedures, analyzed the data and drafting the paper and both authors shared in the final revisions.

### DATA AVAILABILITY STATEMENT

The data that support the findings of this study are available on request from the corresponding author. The data are not publicly available due to privacy or ethical restrictions.

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### REFERENCES

- Adell R, Eriksson B, Lekholm U, Branemark P, Jemt T. Long-term follow-up study of osseointegrated implants in the treatment of totally edentulous jaws. *Int J Oral Maxillofac Implants.* 1990;5:347-359.
- Zitzmann NU, Marinello CP. Treatment plan for restoring the edentulous maxilla with implant-supported restorations: removable overdenture versus fixed partial denture design. *J Prosthet Dent.* 1999; 82(2):188-196.
- Sadowsky JS. Treatment considerations for maxillary implant overdentures. *J Prosthet Dent.* 2007;97(6):340-348.
- Becktor JP, Isaksson S, Sennerby L. Survival analysis of endosseous implants in grafted and nongrafted edentulous maxilla. *Int J of Oral and Maxillofac Implants.* 2004;19(1):107-115.
- Chiapasco M, Abati S, Romeo E, Vogel G. Clinical outcome of autogenous bone blocks or guided bone regeneration with e-PTFE membranes for the reconstruction of narrow edentulous ridges. *Clin Oral Implants Res.* 1999;10(4):278-288.
- Branemark PI, Grondahl K, Ohnrell LO, et al. Zygoma fixture in the management of advanced atrophy of the maxilla: technique and long-term results. *Scand J Plast Reconstr Surg.* 2004;38(2):70-85.
- Soto-Penalosa D, Zaragoza-Alonso R, Penarrocha-Diago MA. The all-on-four treatment concept: systematic review. *J Clin Exp Dent.* 2017; 9:474-488.
- Durkan R, Oyar P, Deste G. Maxillary and mandibular all-on-four implant designs: a review. *Niger J Clin Pract.* 2019;22:1033-1040.
- Maló P, Rangert B, Nobre M. “All-on-four” immediate-function concept with Brånemark system® implants for completely edentulous mandibles. *Clin Implant Dent Relat Res.* 2003;5:2-9.
- Krekmanov L, Kahn M, Rangert B, Lindstrom H. Tilting of posterior mandibular and maxillary implants for improved prosthesis support. *Int J Oral Maxillofac Implants.* 2000;15(3):405-414.

11. Hof M, Tepper G, Semo B, Arnhart C, Watzek G, Pommer B. Patients' perspectives on dental implant and bone graft surgery: questionnaire-based interview survey. *Clin Oral Implants Res.* 2014;25(1):42-45.
12. Kronström M, Widbom C, Soderfeldt B. Patient evaluation with maxillary implant-supported overdentures. *Clin Oral Implants Res.* 2006; 8(1):39-43.
13. Oltra DP, Candel ME, Ali JA, Diago MP. Rehabilitation of the atrophic maxilla with tilted implants. *J Oral Implantol.* 2013;39(5):625-632.
14. Stern MR, Oetterli M, Kiener P, Mericske E. A follow-up study of maxillary implants supporting an overdenture: clinical and radiographic results. *Int J Oral Maxillofac Implants.* 2002;17(5):678-686.
15. Ayna M, Gulses A, Acil Y. A comparative study on 7-year results of "All-on-Four" immediate-function concept for completely edentulous mandibles: metal-ceramic vs. bar-retained superstructures. *Odontology.* 2018;106(1):73-82.
16. Elsyad MA, Alameldeen HE, Elsayh EA. Four-implant-supported fixed prosthesis and milled bar overdentures for rehabilitation of the edentulous mandible. *Int J Oral Maxillofac Implants.* 2019;34(6):1493-1503.
17. Elsyad MA, Elgamal M, Askar OM, Altonbary GY. Patient satisfaction and oral health-related quality of life (OHRQoL) of conventional denture, fixed prosthesis and milled bar overdenture for All-on-4 implant rehabilitation. *Clin Oral Implants Res.* 2019;30(11):1107-1117.
18. Crespi R, Vinci R, Cappare P, Romanos G, Gherlone E. A clinical study of edentulous patients rehabilitated according to the "All-on-Four" immediate-function protocol. *Int J Oral Maxillofac Implants.* 2012; 27(2):428-434.
19. Elsyad MA, Alameldeen HE, Elsayh EA. Four-implant-supported fixed prosthesis and milled bar overdentures for rehabilitation of the edentulous mandible: a 1-year randomized controlled clinical and radiographic study. *Int J Oral Maxillofac Implants.* 2019;34:1493-1503.
20. Oh SH, Kim Y, Park JY, Jung YJ, Kim SK, Park SY. Comparison of fixed implant supported prostheses, removable implant supported prostheses, and complete dentures: patient satisfaction and oral health-related quality of life. *Clin Oral Implants Res.* 2016;27(2):31-37.
21. Elsyad MA, El-Asfahani IA, Kortam SA, Mourad SI. Masseter muscle activity of conventional denture, fixed prosthesis, and milled bar overdenture used for All-on-4 implant rehabilitation: a within-subject study. *Clin Implant Dent Relat Res.* 2021;23:408-416.
22. El-Wegoud MA, Fayyad A, Kaddah A, Nabhan A. Bar versus ball attachments for implant-supported overdentures in complete edentulism. *J Clin Implant Dent Relat Res.* 2018;20(2):243-250.
23. Khadivi V. Correcting a nonparallel implant abutment for a mandibular overdenture retained by two implants. *J Prosthet Dent.* 2004;92(3): 216-219.
24. Elsyad MA, Ghoneem NE, El-Sharkay H. Marginal bone loss around unsplinted mini-implants supporting maxillary overdentures: a preliminary comparative study between partial and full palatal coverage. *Quintessence Int.* 2013;44(1):45-52.
25. Payne AG, Lownie JF, Linden WJ. Implant-supported prostheses in patients with Sjogren's syndrome: a clinical report on three patients. *Int J Oral Maxillofac Implants.* 1997;12(5):679-685.
26. Srinivasan M, Kalberer N, Maniewicz S, Muller F. Implant overdentures retained by self-aligning stud-type attachments. *J Prosthet Dent.* 2020;123(1):6-14.
27. Leite ARP, Marin DOM, Giro G, Pero AC, Pinelli LAP, Reis JMSN. Custom cast ball attachments used on outdated implants to restore a maxillary implant-supported overdenture. *J Oral Implantol.* 2017; 43(4):297-301.
28. Schneider AL, Kurtzman GM. Bar overdentures utilizing the locator attachment. *Gen Dent.* 2001;49(2):210-214.
29. Kleis WK, Kammerer PW, Hartmann S, Al-Nawas B, Wagner W. A comparison of three different attachment systems for mandibular two-implant overdentures: one-year report. *Clin Implant Dent Relat Res.* 2010;12(3):209-218.
30. 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(2): 666-674.
31. Elsyad MA, Hatem OE, Shawky AF, Emera RM. Effect of different degrees of mesial implant inclination on the retention and stability of two-implant mandibular overdentures retained with stud attachments: an in vitro study. *Int J Oral & Maxillofac Implants.* 2018;33(2):259-268.
32. Cune M, van Kampen F, van der Bilt A, Bosman F. Patient satisfaction and preference with magnet, bar-clip, and ball-socket retained mandibular implant overdentures. *Int J Prosthodont.* 2005;18:99-105.
33. Elsyad MA, Agha NN, Habib AA. Retention and stability of implant retained mandibular overdentures using different types of resilient attachments: an in vitro study. *Int J Oral & Maxillofac Implants.* 2016; 31(5):1040-1048.
34. Bidra AS, Agar JR. Management of misangulated implants for a maxillary overdenture with spherical abutments: a clinical report. *J Prosthet Dent.* 2011;106(4):209-213.
35. Uludag B, Celik G, Goktug G. Prosthetic solution for unfavorably inclined maxillary implants: a case report. *J Oral Implantol.* 2008;34(2): 111-114.
36. Elsyad MA, Mostafa AZ. Effect of telescopic distal extension removable partial dentures on oral health related quality of life and maximum bite force: a preliminary cross over study. *J Esthet Restor Dent.* 2018;30:14-21.
37. Montero J, Castillo R, Lynch CD, et al. Self perceived changes in oral health related quality of life after receiving different types of conventional prosthetic treatments: a cohort follow up study. *J Dent.* 2013; 41(6):493-503.
38. Mahanna FF, Elsyad MA, Mourad SI, Abozaed HW. Satisfaction and oral health-related quality of life of different attachments used for implant-retained overdentures in subjects with resorbed mandibles: a crossover trial. *Int J Oral Maxillofac Implants.* 2020;35:423-431.
39. Naert I, Alsaadi G, Quirynen M. Prosthetic aspects and patient satisfaction with two implant-retained mandibular overdentures: a 10-year randomized clinical study. *Int J Prosthodont.* 2004;17(4): 401-410.
40. Elsyad MA. Prosthetic aspects and patient satisfaction with resilient liner and clip attachments for bar- and implant-retained mandibular overdentures: a 3-year randomized clinical study. *Int J Prosthodont.* 2012;25(2):148-156.
41. Cune M, Burger M, van Kampen F, Putter C, van der Bilt A. Mandibular overdentures retained by two implants: 10 years results from a cross over clinical trial comparing ball-socket and bar-clip attachments. *Int J Prosthodont.* 2010;23(4):310-317.
42. Elsyad MA, Shawky AF. Masticatory function with ball and resilient telescopic anchors of mandibular implant-retained overdentures: a crossover study. *Quintessence Int.* 2017;48:615-623.
43. Chung KH, Chung CY, Cagna DR, Cronin RJJ. Retention characteristics of attachment systems for implant overdentures. *J Prosthodont.* 2004;13:221-226.
44. Elsyad MA, Dayekh MA, Khalifa AK. Locator versus bar attachment effect on the retention and stability of implant retained maxillary overdenture: an in vitro study. *J Prosthodont.* 2019;28:e627-e636.
45. 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;28:1406-1410.
46. Teimoori H, Shayegh SS, Zavaree MA, et al. Effects of excessive implant angulation on retention of two types of overdenture attachments during cyclic loading. *J Contemp Dent Pract.* 2018;19:1221-1227.
47. Elsyad MA, Emera RM, Ibrahim AM. Effect of labial implant inclination on the retention and stability of different resilient stud attachments for mandibular implant overdentures: an in vitro study. *Int J Oral Maxillofac Implants.* 2019;34:381-389.

48. Cavallaro JS, Tarnow DP. Unsplinted implants retaining maxillary overdenture with partial palatal coverage: report of 5 consecutive cases. *Int J Oral Maxillofac Implants*. 2007;22:808-814.
49. Krennmair G, Seemann R, Weinlander M, Piehslinger E. A comparison of ball and telescopic crown in implant retained mandibular overdentures: 5-year prospective study. *Int J Oral Maxillofac Implants*. 2011;26(3):598-606.
50. Cristache CM, Muntianu LAS, Burlibasa M, & Didilescu AC. Five-year clinical trial using three attachment systems for implant overdentures. *Clin Oral Implants Res*. 2014;25(2):e171-e117.
51. Krennmair G, Seemann R, Fazekas A, Ewers R, Piehslinger E. Patient preference and satisfaction with implant-supported mandibular overdentures retained with ball or locator attachments. *Int J Oral Maxillofac Implants*. 2012;27(6):1560-1568.
52. Bae JC, Jeong SH, Jeong CM, Huh JB. Comparison of the masticatory functions of complete dentures and implant-retained overdentures. *Int J Prosthodont*. 2015;28(4):345-347.
53. Pisani M, Bedos C, da Silva CHL, Fromentin O, de Albuquerque RF Jr. A qualitative study on patients' perceptions of two types of attachments for implant overdentures. *J Oral Implantol*. 2017;43(6):476-481.
54. Matthys C, Vervaeke S, Besseler J, Doornewaard R, Dierens M, de Bruyn H. Five years follow-up of mandibular 2-implant overdentures on locator or ball abutments: implant results, patient-related outcome, and prosthetic aftercare. *Clin Implant Dent Relat Resh*. 2019;21(5):835-844.
55. Cakarar 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(7):e953-e959.
56. Jiang MY, Wen J, Xu SS, Liu TS, Sun HQ. Three dimensional finite element analysis of four implant supported mandibular overdentures using two different attachments. *Zhonghua Kou Qiang Yi Xue Za Zhi*. 2019;54(1):41-45.
57. Elsyad MA, Errabti HM, Mustafa AZ. Mandibular denture base deformation with locator and ball attachments of implant-retained overdentures. *J Prosthodont*. 2016;25:656-664.
58. Branemark PI, Svensson B, van Steenberghe D. Ten-year survival rates of fixed prostheses on four or six implants ad modum Brånemark in full edentulism. *Clin Oral Implants Res*. 1995;6(4):227-231.

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