Effect of Implant Angulation on Attachment Retention in Mandibular Two-Implant Overdentures: A Clinical Study

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ABSTRACT

Purpose: Attachment wear can affect the performance of mandibular two-implant overdentures (IODs). This prospective clinical study aimed to investigate the effect of interimplant angulation on the retention achieved by two attachment systems at different time points within 1 year of wearing IODs.

Materials and Methods: Twenty-four patients (mean age = 73.2 years; standard deviation (SD) = 3.1) wearing IODs opposed by conventional maxillary complete dentures were randomly assigned to two groups in two-by-two crossover design. Retentive Anchor (RA) and Locator (LA) were installed in the IODs of both groups for 1 year, sequentially. Coronal and sagittal interimplant angulation were measured on posterior–anterior and lateral cephalometric radiographs. Retention was measured at baseline, 1 week, 3, 6, and 12 months postattachment installation. Data were analyzed using mixed models with $\alpha = 0.05$.

Results: Mean coronal and sagittal interimplant angulations were 4.6 (SD = 2.9) and 3.5 (SD = 2.6) degrees, respectively. Only with LAs a statistically significant decrease was found in retention (average 1.1 Newton; standard error = 0.38; $p = .007$) per 1 degree increased sagittal interimplant angulation.

Conclusions: Increased interimplant angulation appears to have higher impact on the retention of LA than of RA attachments. The effect of larger interimplant angulation on the loss of attachment retention and its clinical implications should be further assessed.

KEY WORDS: implant attachment, interimplant angulation, mandibular two-implant overdenture, retention

INTRODUCTION

Mandibular two-implant overdentures (IODs) have been suggested as the treatment of choice for edentulous elders.[1,2] They have proven to significantly improve patients' satisfaction, function, and quality of life.[3,4]

Different attachment systems have been designed to connect dental implants to IODs.[5] Presently, spherical or ball and cylindrical attachments are commonly used for retention of IODs. The ball attachment is composed of a spherical abutment (patrix) and a matrix made of gold or titanium alloys embedded in the denture base. The retention force of the ball attachment is adjustable and ranges from 200 g to 1400 g (1.96–13.7 Newton).[6] The Locator attachment is an example of cylindrical system.[7]

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It is composed of a titanium nitride-coated abutment, metallic housing embedded in the denture base, and color-coded nylon inserts for retention. Retention force in this system ranges between 680 g and 2268 g (6.67 and 22.2 Newton) depending on the nylon inserts.[8] According to the manufacturer of this type of attachment, dual inserts provide core-related internal and peripheral external retention and are designed for interimplant angulation below 20 degrees. Extended range inserts can accommodate interimplant angulation up to 40 degrees. Both attachment systems are subject to loss of retention due to wear and distortion associated with normal oral function.[9]

Although IODs are considered a reliable and relatively easy-to-perform prosthetic alternative for treating edentulous patients,[10] placing the implants in an ideal parallel position as often recommended is not as such a simple procedure. It requires extensive surgical experience or the use of guided surgery techniques.[11] In vitro studies have shown that implant inclination affects the levels of attachments retention.[12–15] In one of these studies, cylindrical attachments connected to angulated implants lost retention after fewer chewing cycles when compared with parallel implants.[14] In laboratory tests, cylindrical attachments on implants with more than 30 degrees of inclination had lower retentive forces than those inclined 30 degrees or below.[12] Implants angulated at 20 and 30 degrees with ball attachments and gold matrices showed lower retention values compared with implants angulated at 0 or 10 degrees in other in vitro tests.[15] However, little information has been reported regarding the wear and loss of retention of attachment systems associated with clinical use.[16] Although a recent clinical trial found a weak correlation between wear of ball attachment matrices and increased divergence between implant axes, the study was not randomized and included only ball attachments.[17] Furthermore, no clinical information has been provided on the effect of implant angulation on the wear of cylindrical attachments. Therefore, the aim of this crossover clinical trial was to investigate the influence of interimplant angulation on the levels of retention of spherical and cylindrical attachments used with IODs.

MATERIALS AND METHODS

This was a crossover design study approved by the McGill University Health Centre Research Ethics Office. All patients included in the study ($n = 24$) had previously received mandibular IODs with two ball attachments opposed by conventional maxillary complete dentures. Their dentures were initially evaluated by a prosthodontist with respect to stability, support, retention, peripheral seal, and hygiene. Saliva, soft, and peri-implant tissues were also assessed. Stability was considered acceptable if minimal or no denture rocking was detected under digital pressure.

The study was composed of two phases of 12 months each. At phase 1, patients randomly received either two new ball attachments (Retentive Anchor [RA], ref 048.439, Straumann, Burlington, ON, Canada) with gold matrices (Goldmatrix, ref 048.410, Straumann), or two new cylindrical stud Locator attachments (Locator [LA], Zest Anchors, Escondido, CA, USA) with clear nylon inserts (ref 8524, Zest Anchors). Both the RA and the LA attachments were installed using direct incorporation methods according to the manufacturer recommendations.[6,18] After the RA patrix components were installed, the denture was hollowed in the corresponding area for installation of the matrix components. Openings were made to allow the acrylic to flow. A small piece of rubber dam was used to prevent the acrylic from engaging around the patrix abutments or in the internal parts of the matrices. After the placement and alignment of the gold matrices following the prosthetic path of insertion, the denture was placed in the patient's mouth, and self-curing acrylic resin was inserted through the openings. For the LA attachment, white block-out spacers were used to block the undercuts during installation of the metal housings in the denture base. LA housings with black processing inserts were placed on each LA abutment, the denture was hollowed in the corresponding areas and acrylic resin was then added. After installing the LA attachments, the black insert was replaced by a clear nylon insert, which has dual, internal and external, retention and is designed for interimplant angulation between 0 and 20 degrees.[18]

Posterior–anterior and cephalometric lateral digital radiographs were taken for all patients to measure interimplant angulation in the coronal (mesial–distal) and sagittal (labial–lingual) planes, respectively. Interimplant angulation was measured as the angle between the two longitudinal axes of the implants, determined with the aid of a software-based wireframe for the implants and the ruler tool in Photoshop 10 software (Adobe, San Jose, CA, USA) (Figure 1).

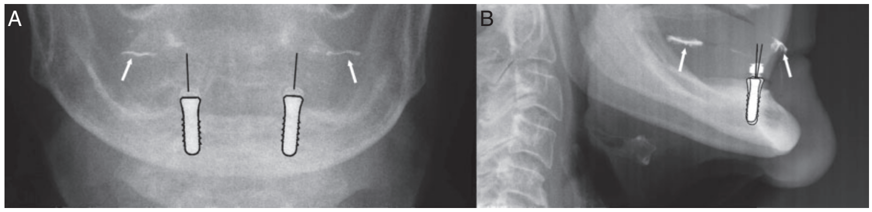

Figure 1 *A*, Coronal view of implants angulation on posterior–anterior radiograph. *B*, Sagittal view of implants angulation on lateral cephalometric radiograph. The dentures were marked with radiopaque material for assessment of the occlusal plane (arrows).

At the beginning of phase 2, all patients had their attachments changed to new ones of the other system, following the same steps described for phase 1.

Attachment retention values were measured at the moment of insertion of the new attachments (baseline), then after 1 week, 3, 6, and 12 months postattachment installation as described previously.[19] In brief, a digital force measurement gauge (Imada [IM], DS2-500N; 175 × 66 × 32.8 mm, weight: 0.42 kg, Imada Inc., Northbrook, IL, USA) assembled in a vertical wheel stand (HV 110; 597 × 309 × 214 mm; weight: 10 kg, Imada Inc.) in association with an adapted surveyor table, and a base and movable in the horizontal axis was used to assess the retentive forces of the attachments. Retentive force is defined as the minimal force necessary to separate patrices from matrices and measured as "peak load forces" in the IM gauge ("pulling test"). The IM force measurement gauge was secured to the stand to allow tensile tests perpendicularly to the base of the stand. A customized device was fabricated to hold the lower complete denture firmly on top of the surveyor table while allowing translational movements in the horizontal axis. The lower denture was oriented using the denture midline and the distal surface of the last molars. At the time of LA installation, the black insert was placed in the attachment housing, and the denture inclination was adjusted using the surveyor table so that an analogue attached passively to the black insert was parallel to the surveyor vertical pin. This method was used to simulate, as much as possible, the position of the implant in the jawbone of the patient and to allow the pulling test to be consistently performed in the IM gauge according to the long axes of the implants. The denture angulation was recorded using two digital angle measurement gauges (Wixey WR 300, Barry Wixey Development, Seattle, WA, USA) added to the surveyor table. These records were used to position the denture in the same angulation throughout the study. For the RA attachment, the pulling test was performed with the denture occlusal plane oriented horizontally because the position of the implant could not be reliably determined using the spherically shaped attachment as reference. At each follow-up appointment, the RA and LA abutments were retrieved from the patient's mouth and screwed into an implant analogue and connected to their corresponding retentive components located in the denture base. The denture was then angulated with the two digital angle measurement gauges, and the pulling test was performed five times for each attachment. The average retention value from five measurements, expressed as the peak load (Newton) capable of separating the abutments from its matrix components, was recorded.

Scanning Electron Microscopy (SEM) and Micro-Computed Tomography (μCT) Images

After 1 year of clinical use, the attachments were examined visually, and SEM micrographs of the LA and RA attachments were obtained to observe the wear patterns. SEM scanning was conducted using scanning electron microscope (JSM 6460, JEOL Ltd, Akishimashi, Tokyo, Japan, at 15–20 Kv with chamber pressure of 60 Pa). Imaging of the nylon insert of the LA attachment was performed using high-resolution μCT (Skyscan, Kontich, Belgium; 14 micrometers resolution, 35 Kv, and 211 mA).

Statistical Analyses

To investigate the effect of interimplant angulation on the retention of both attachment systems during the study period, adjusting for the baseline retention values, side of the implant (left, right), and any possible phase effect, we used a mixed model analysis.[20] Interimplant angulations measured on the coronal and sagittal planes were used as two covariates in the model. The mixed model allows for the estimation of within-subject correlations, due to the fact that each subject received treatment in both sides of the mouth and that measurements were repeated within each phase at four different time points.

TABLE 1 Mean Retention Values (in Newton) and Standard Deviations (SD) for LA and RA Attachments at Baseline and Each Follow-Up Assessment

Phase	Treatment	Side	*n*	Baseline (SD)	Week 1 (SD)	Month 3 (SD)	Month 6 (SD)	Month 12 (SD)
1	LA	L	11	43.9 (11.0)	30.5 (5.2)	22.1 (6.9)	17.7 (6.5)	14.8 (4.3)
		R	11	37.4 (11.6)	25.5 (4.8)	15.9 (7.6)	13.5 (5.1)	10.7 (5.3)
	RA	L	12	33.7 (7.6)	30.4 (6.9)	32.4 (15.1)	22.5 (6.1)	21.9 (9.8)
		R	12	32.6 (5.7)	28.4 (4.7)	28.7 (5.5)	23.5 (5.4)	20.0 (9.3)
2	LA	L	12	38.3 (14.1)	25.2 (4.9)	15.6 (10.7)	15.0 (11.1)	10.9 (8.0)*
		R	12	37.7 (5.4)	25.8 (7.0)	19.4 (9.4)	15.7 (8.9)	11.6 (7.5)*
	RA	L	11	36.4 (5.3)	30.8 (5.5)	27.8 (8.0)	24.6 (9.2)	19.0 (11.3)
		R	11	35.9 (4.6)	32.4 (3.4)	30.4 (5.7)	28.0 (8.4)	20.0 (9.0)

*$n = 11$.
LA = locator anchor; RA = retentive anchor.

All analyses were done using SAS software, version 9.2 (SAS Institute Inc., Cary, NC, USA). All statistical tests were two-sided and performed at the 0.05 significance level.

RESULTS

A total of 24 patients (mean age 73.2 years, standard deviation [SD] 3.1) participated in the current study. Twenty-three patients completed phase 1 and phase 2 of the study, and only one patient missed the 12-month follow-up session at phase 2. Two patients were excluded from the study because of the need for manual adjustment to improve retention (Table 1). Stability, support, retention, peripheral seal, saliva, and hygiene were generally adequate. No noteworthy abnormalities were observed in the soft tissues around the implants.

The mean interimplant angulation in the coronal plane was 4.6 (SD 2.9) degrees (median = 4.3, range: 0.1–11.3 degrees). The mean interimplant angulation in the sagittal plane was 3.5 (SD 2.6) degrees (median = 3.1 range: 0.1–10.1 degrees).

Sagittal interimplant angulation had a significant effect on only the LA retention values. After adjusting for baseline retention values, side of the implant, phase, and time, retention values, on average, decreased by 1.1 (standard error [SE] = 0.38) Newton with any 1 degree increase in sagittal interimplant angulation ($p = .007$). Table 2 shows average retention values per degree of change in sagittal interimplant angulation at each follow-up time. These values were obtained from separate mixed models at each time point, adjusting for baseline retention, side, and phase.

Interimplant angulation measured in the coronal plane did not affect the retention values of either the LA or RA attachments.

A significant influence of the baseline time point on retention values was noted only with the RA attachments ($p = .0002$, estimated effect = 0.5 Newton, SE = 0.12).

In all models, no significant effects for side or phase were found.

SEM micrograph images of the LA and RA abutments after 1 year of insertion showed no significant wear patterns, although scratches on the external surfaces of both abutments were observed (Figure 2, b and B, narrow arrows). Minor flattening of the equatorial zone of RA abutments was observed (Figure 2B wide arrow). After 1 year of use, significant wear and deformation was found on the peripheral notch edge (Figure 2d narrow arrow) and on the edge of the

TABLE 2 Estimated Mean Loss of Retention (in Newton) and Standard Error (SE) in the LA Attachment per Increased Degree in the Labial–Lingual Angulation between the Implant Axes Measured on the Lateral Cephalometric Radiographs

Follow-Up	Mean (SE)	*p*
Week 1	−0.80 (0.42)	0.07
Month 3	−1.72 (0.74)	0.03
Month 6	−1.04 (0.72)	0.16
Month 12	−1.23 (0.50)	0.02

Estimated mean, SE and *p* values from a mixed regression model at each follow-up time, adjusted for side, phase, and baseline retention.

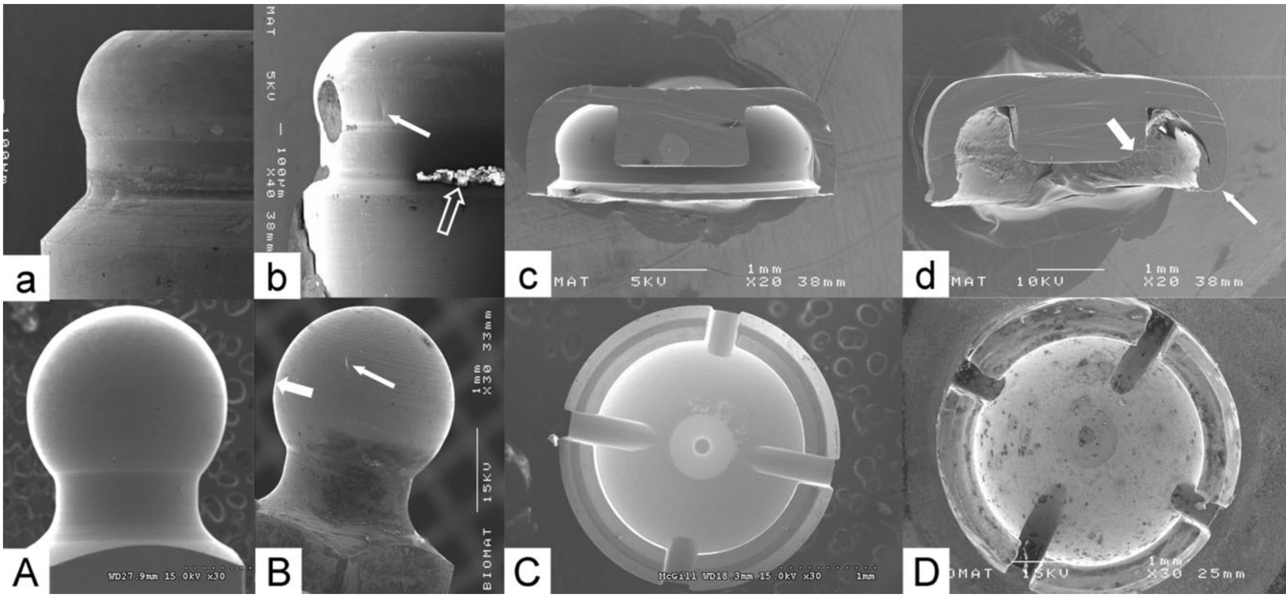

Figure 2 *a* and *A*, SEM macrographs of new LA and RA abutments. *b* and *B*, Abutments after 1 year of clinical wear. Note plaque accumulation around the LA abutment (2b outlined arrow), scratches on the external surfaces of both abutments (Figure 2b and B narrow arrows), and flattening of the external surface of the RA abutment (Figure 2B wide arrow). *c* and *C*, Cross-sectional SEM macrographs of a new LA nylon insert and RA matrix. *d* and *D*, Cross-sectional SEM macrographs of LA nylon insert and RA matrix after 1 year of use. Note the significant deformation of the peripheral notch edge (Figure 2d narrow arrow) and of the edge of the internal core (Figure 2d wide arrow) of the LA nylon insert. SEM = scanning electron microscopy; LA = locator anchor; RA = retentive anchor.

internal core (Figure 2d wide arrow) of the LA insert. Scratches and spots of metal insertion from the titanium abutments into the RA gold matrix were also observed (Figure 2D).

After 1 week of use, early deformation of the notch on the peripheral edge (Figure 3b narrow arrow) and on the edge of the internal core (Figure 3b short arrow) of the LA nylon insert was seen in the μCT sections. After 1 year of use, internal tears were observed and considered to be a result of continuous friction between the nylon insert and the metallic components (Figure 3c wide arrow). In addition, the μCT sections indicated the presence of structures compatible with deposits of mineralized plaque on the nylon inserts (Figure 3c outlined arrows).

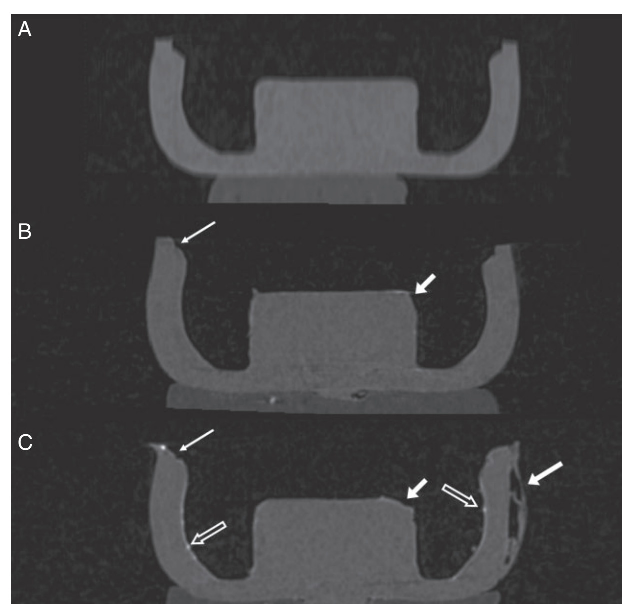

Figure 3 *A*, Micro-computed tomography (μCT) of the nylon insert of a new LA attachment. *B*, Nylon insert after 1 week of clinical service showing early deformation of the peripheral edge (narrow arrow) and the edge of the internal core (short wide arrow). *C*, Insert after 1 year of service showing deformation of the peripheral edge (narrow arrow), internal and external tear (wide arrows), and mineralized deposition of plaque on the internal surface (outlined arrows).

DISCUSSION

The purpose of this study was to test the effect of interimplant angulation on the loss of retention of two attachment systems with different geometric shapes.

The results showed that the retention values in the LA attachments are inversely related to labial–lingual interimplant angulation. The small range of interimplant angulation observed in the current study was probably due to the fact that the implants were originally placed by a single experienced surgeon in a hospital setting. Similar ranges of interimplant angulation were reported in a previous study with experienced surgeons.[11] In a previous in vitro experiment, Gulizio and colleagues[15] found no significant effects of implant angulation on the spherical attachment retention with gold matrices at angles less than 10 degrees. However, the authors reported that implants with angulations higher than 20 degrees had lower retention values. The findings of the current clinical study are in line with previous in vitro studies showing that implant angulation significantly affects the retention of LA attachments.[12,14,21] LA could be more sensitive than RA to differences in implant angulation due to the design of the attachment. Compared with the spherical shape of the RA attachment, which accepts higher ranges of implant angulation, LA has a cylindrical shape with lateral walls parallel to the long axis of the implant, creating a greater potential to introduce relevant undercut areas in relation to the denture insertion–removal path when the implants are not parallel. In an attempt to overcome problems of excessive interimplant angulation, the LA manufacturer offers dual or extended range inserts designed for angulation below 20 and between 20 and 40 degrees, respectively.[8]

In the current study, although the interimplant angulations projected on the coronal and sagittal planes were similar, the effect of interimplant angulation on retention was significant in the sagittal plane only. This is in agreement with previous clinical evaluations on ball attachment wear.[17,22] It was reported that wear in the labial–lingual direction was more prominent than the wear in the horizontal or mesial–distal directions.[22] In addition, although weak, a correlation was noted between wear of the ball attachments and the divergence of the implant and the matrix axes in the sagittal plane.[17] This indicates that the anterior–posterior rotation of the IODs around the axes of the two implants during mastication could be an important factor affecting the wear of the attachment systems. Although the observed changes of relatively low magnitude on retention forces of LA attachments were significantly related to labial–lingual interimplant angulation, whether these changes have relevant impact on the satisfaction of patients remains to be determined.

In the current study, the effect of baseline retention values on the retention measured at the subsequent visits was statistically significant for the RA attachment only. The range of retention for both attachments at baseline was greater than reported by the manufacturers. Although RA attachments had lower baseline values compared with LA, RA attachments lost approximately 40% of the initial retention by the end of the study. In contrast, LA attachments lost around 70% of their initial retention by the end of the study, with approximately 50% of retention loss occurring within the first 3 months of clinical function. It appears that RA attachments maintained higher retention throughout the study, whereas LA retention dropped quickly, regardless of the observed initial retention values.

Although both the LA nylon inserts and the RA gold matrices showed significant wear by the end of the study, these abutments showed minor deformations. This finding is aligned with previous investigations showing that significant wear of spherical abutments occurs after 8 years of wearing IODs.[22,23] No longitudinal information is currently available regarding the wear pattern of LA abutments. Progressive loss of retention in both systems was evident during the course of the present study. However, occasional gain in retention was also observed (Table 1). Similar observations have been reported in a previous in vitro study with other types of ball attachments.[24] Possible reasons for a gain in the RA attachment retention could be from work hardening of the gold matrix alloy or geometrical adaptation (plastic strain) of the matrix.[24,25]

One consideration in crossover studies is the potential phase effect, which results from the order the different therapies are delivered. In the present study, the phase effect was not significant. However, one of the limitations of this investigation might have been the relatively small range of interimplant angulation. In addition, two patients had to be excluded from the analysis due to the need for manual adjustment of the retentive components. Interestingly, both patients had high interimplant angulations (10.1 and 11.3 degrees).

Within the limitations of the current study, it was concluded that increased labial–lingual interimplant angulation appears to have higher impact on loss of retention of cylindrical attachments than on ball attachments. The adequate positioning of dental implants remains an important issue in planning IODs. Further investigations are needed to assess the effect of larger interimplant angulation on the amount of retention loss and its clinical relevance.

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