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Communication

Retentive Behavior of Locator versus Ball Attachments on Parallel versus Non-Parallel Implants

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Abstract: Several factors determine the retention force in removable implant-retained overdentures using prefabricated ball- or locator-type attachment systems. In this context, it was the goal of this in vitro study to examine the effect of implant angulation and female part alignment. Two model situations with two parallel or 12° tilted implants were fabricated onto which locator or ball attachments could be mounted. Simulated prostheses (n = 5) were made as antagonist parts and the assemblies were positioned in a universal testing machine for repeatedly (three times per female attachment) quantifying retention force. Statistical analysis was based on Shapiro–Wilk tests, Levene tests, ANOVAs, Tukey's HSD tests and Welch *t*-tests, with the level of significance set at $p < 0.05$. With tilted implants, the retention force of locators was significantly diminished ($p < 0.004$) by at least 21%, while with ball attachments, a maximum reduction of 8% was noted, with only yellow inserts showing a significant difference ($p = 0.040$) compared with the parallel situation. Not aligning female retentive components on tilted implants for achieving a common path of insertion in ball anchors had only a minor effect on retentive force (6.5% increase as compared with aligned female parts), which was not statistically significant ($p = 0.100$). Not being able to establish a common path of insertion in locator attachments affects retention force. Ball anchors allow for aligning female retentive components, but due to the spherical structure of the male component this seems not even to be necessary.

Keywords: implant overdenture; retention; attachment

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1. Introduction

Implant-retained overdentures have been repeatedly shown to increase patients' satisfaction and wearing comfort [1] while at the same time showing a high survival rate regardless of the specific attachment system used [2]. In order to keep treatment costs low, prefabricated components are often employed, for which prosthesis fractures [3,4] and loss of retention due to wear of the attachment system [5,6] constitute frequently observed complications. Adjusting the retentive force of attachments may also be challenging as, besides patient-specific factors, fabrication tolerances inherent in attachment components lead to high variability [7].

Several authors pointed out that implant angulation would be a critical factor for the successful rehabilitation of edentulous jaws with implant-retained overdentures [5,8]. In order to compensate for inter-implant angular discrepancies, manufacturers exploit the geometric form of the male attachment parts and offer various retentive inserts fully or only partially engaging retentive surfaces [8].

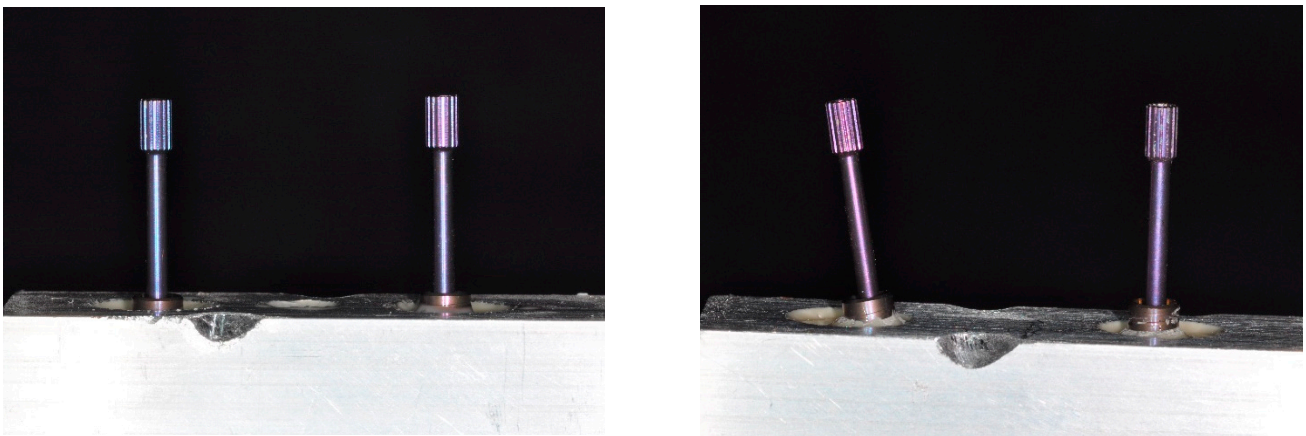
Contradictory reports on the effect of lacking a common path of insertion of attachment systems can be found in the literature. Based on in vitro studies, it has been claimed that implant angulation did not significantly affect retention behavior [7], at least for locator abutments (ZEST Dental Solutions, Carlsbad, CA, USA), with a divergence of up to 20° [9].

A recent study by Yilmaz et al. could not find consistent effects despite using a stringent study design [10]. A greater number of publications claim that implant angulation leads to a lower retention force [11,12] of attachments as compared with parallelized situations [13]. From a long-term perspective, a significant decrease in retention seems to be inevitable, but this also occurs earlier when attachments are supported by non-parallel implants [14].

Clinical studies combining these single aspects showed that implant angulation negatively affected the longevity of attachment retention [15], with locator attachments requiring a higher rate of maintenance as compared with ball attachments [16]. Unfortunately, the large body of literature available in this field is either focusing on clinical performance or on product comparisons while basic aspects such as alignment of female retentive parts are hardly investigated. Given that locator attachments do not allow for aligning female retentive parts as compared with ball attachments, it was the goal of this study to evaluate retentive forces on parallel and tilted implant configurations in a study design, eliminating potential co-factors.

2. Materials and Methods

Two bone level implants each (BLT Bone Level Tapered 4.1 × 12 mm RC, Straumann, Basel, Switzerland) were embedded in polyurethane resin (SikaBiresin, Sika, Bad Urach, Germany) to resemble a two-implant mandibular interforaminal patient situation with either parallel orientation or 12° divergence (Figure 1). Either locators (ZEST Dental Solutions, Carlsbad, CA—group locator) or ball attachments (CLIX, Hader Solutions and Distribution, Swords, Ireland—group Clix) with 3 mm gingiva height could be attached to the implants with a torque of 35 Ncm according to the implant manufacturer's protocol.



(**a**) (**b**)

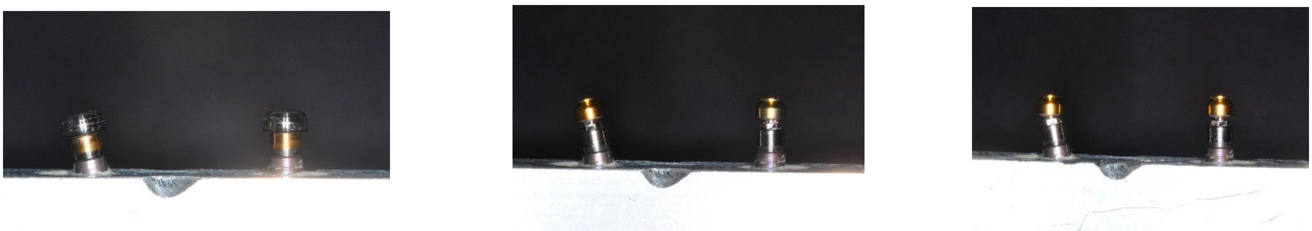
Figure 1. Model situation with either two parallel implants (**a**) or with the left implant angled at approximately 12° (**b**).

After positioning female attachment components for locator and ball attachments, respectively, a counterpart (simulated prosthesis) was fabricated using the same polyurethane resin (SikaBiresin; Figure 2a) and a bar-shaped mold made from silicone impression material (Optosil, Kulzer GmbH, Hanau, Germany) and resembling a bar-like structure. Each assembly was positioned in a custom-made high-precision jig (Bacherlschmiede, Waldmünchen, Germany), allowing for well-controlled vertical movement (Figure 2b), which could then be mounted on a universal testing machine (Z020, Zwick/Roell, Ulm, Germany). The assemblies were separated three times by controlled vertical force application at a crosshead speed of 2 mm/s [5–7,10]. After three separation cycles, the female retentive plastic parts were changed, and a total of five repetitions were carried out.

(**a**) (**b**)

Figure 2. Antagonist structure (simulated prosthesis) with two female locator attachment parts (**a**) and the assembly positioned in a universal testing machine for simulating prosthesis removal (**b**).

For the locator abutments (Figure 3a), the female parts could only be positioned in alignment with the male part, while in the Clix group, the female parts could be aligned with the male part (Figure 3b) but also be aligned in such a way that a common path of insertion was achieved (Figure 3c). For locator abutments, female inserts with 0.7 kg (blue, extra light), 1.4 kg (pink, light) and 2.3 kg (white, regular) retention force were used. For Clix abutments, female plastic inserts with 8 N (white) and 12 N (yellow) retention force were used.



(**a**) (**b**) (**c**)

Figure 3. Two female locator components positioned on the model with angulated implants (**a**). Two female components attached in line with the implants and ball abutments (**b**). Female ball attachment parts aligned for achieving a common path of insertion (**c**).

In the second part of the study, the retentive surfaces of the locator and ball abutments were determined by surface scanning [17] using a manual video machine (Sylvac Visio 300, Sylvac SA, Yverdon-les-Bains, Switzerland). The resulting 3D models were then imported into CAD software (SolidWorks 2022, Dassault Systèmes, Vélizy-Villacoublay, France). The CAD software allowed for directly measuring the total surface area of the male components as well as the surface parts used for retention by applying the software's weight properties calculation tool.

Statistical analysis (R version 4.3.2, The R Foundation for Statistical Computing, Vienna, Austria; www.R-project.org) was based on Shapiro-Wilk tests, Levene tests, analyses of variance (ANOVA), Tukey's Honest Significant Difference tests and Welch t-tests with the level of significance set at $p < 0.05$.

3. Results

Descriptive statistics for all measurements are given in Table 1. Measurement values could be assumed as being continuous and normally distributed as Shapiro tests showed only one significant value (Clix abutment, parallel implants, white insert $p = 0.03$). The results of Welch's t-tests for comparing parallel vs. tilted configurations are given in Table 2, and the results for comparing the different plastic inserts using ANOVAs and Tukey's Honest Significant Difference tests are given in Table 3.

In the group of locator attachments, the divergent implant model always led to lower retentive forces as compared with the parallel situation (Figure 4). This effect ranged between a reduction of 21.8% (white) and 39.1% (blue) and was statistically significant for all inserts ($p < 0.004$; Table 1(a)). The standard deviations in the group of locator abutments ranged between 8% and 23%. An increase in retentive force was observed from blue to pink and white female plastic inserts both in the parallel and the divergent implant situation, with only the difference between white and pink inserts on parallel implants not reaching statistical significance ($p = 0.088$; Table 2). The absolute values for retention force could, however, not be related to the values provided by the manufacturer for single attachments.

In general, for the Clix abutments, lower retentive values were measured as compared with the locator (Figure 4). The shift from white to yellow plastic inserts almost doubled the retention force (parallel implants: 23.16 N vs. 45.36 N; tilted implants: 24.46 N vs. 41.74 N), which reached statistical significance ($p < 0.000$; Table 3). The maximum standard deviation observed in this group was 7%. The minor (below 10% change) effects on retention force were seen when tilted implants supported the attachments as compared with parallel implants when the female attachment parts had been aligned. With yellow inserts, however, the difference between parallel and tilted configurations was statistically significant ($p = 0.040$; Table 2). Not aligning the female retentive parts placed on tilted implants led to an increase in retention force of 6.5%, which was not statistically significant ($p = 0.100$; Table 1(a)).

Table 1. Retention forces [N] calculated as descriptive statistics for all experimental groups.

Group	Minimum	Mean	Median	Standard Deviation	Maximum
Locator blue parallel [a,e,g]	49.86	66.78	68.47	11.10	86.67
Locator blue tilted [a,f,h]	24.30	40.63	43.24	9.34	54.30
Locator pink parallel [b,e]	82.17	103.30	108.30	12.83	123.97
Locator pink tilted [b,f,i]	52.16	69.62	64.29	12.94	92.85
Locator white parallel [c,g]	98.14	120.35	122.10	10.50	138.25
Locator white tilted [c,h,i]	79.36	94.09	93.87	7.20	107.27
Clix white parallel [j]	21.56	23.16	23.48	0.74	24.11
Clix white tilted [k]	21.70	24.46	24.41	1.68	27.33
Clix yellow parallel [d,j]	42.44	45.36	45.08	2.02	49.71
Clix yellow tilted [d,k]	38.21	41.74	41.93	2.48	46.44
Clix yellow tilted—not adjusted	40.36	44.44	44.95	2.29	52.31

Note: identical letters indicate statistically significant differences between groups.

Table 2. Results of Welch *t*-tests (*p*-values) comparing parallel vs. tilted configurations of attachments; significant differences are marked *.

Attachment	Plastic Insert	*p*-Value
Locator	Blue	0.004 *
	Pink	0.003 *
	White	0.002 *
Clix	White	0.200
	Yellow	0.040 *
	Yellow not adjusted	0.100

Table 3. Results of Tukey's Honest Significant Difference tests (*p*-values) on retention forces measured with different plastic inserts; significant differences are marked *.

Locator	Pink vs. Blue	White vs. Blue	White vs. Pink
Parallel	<0.000 *	<0.000 *	0.088
Tilted	0.002 *	<0.000 *	0.006 *
Clix		**Yellow vs. White**	
Parallel		<0.000 *	
Tilted		<0.000 *	

The surface area of locators was 21 mm^2 while the ball anchors had a surface area of 12 mm^2 (Figure 5). The difference in retentive surfaces between the two attachment systems (4.8 mm^2 vs. 3.7 mm^2; Figure 5) was approximately 23%.

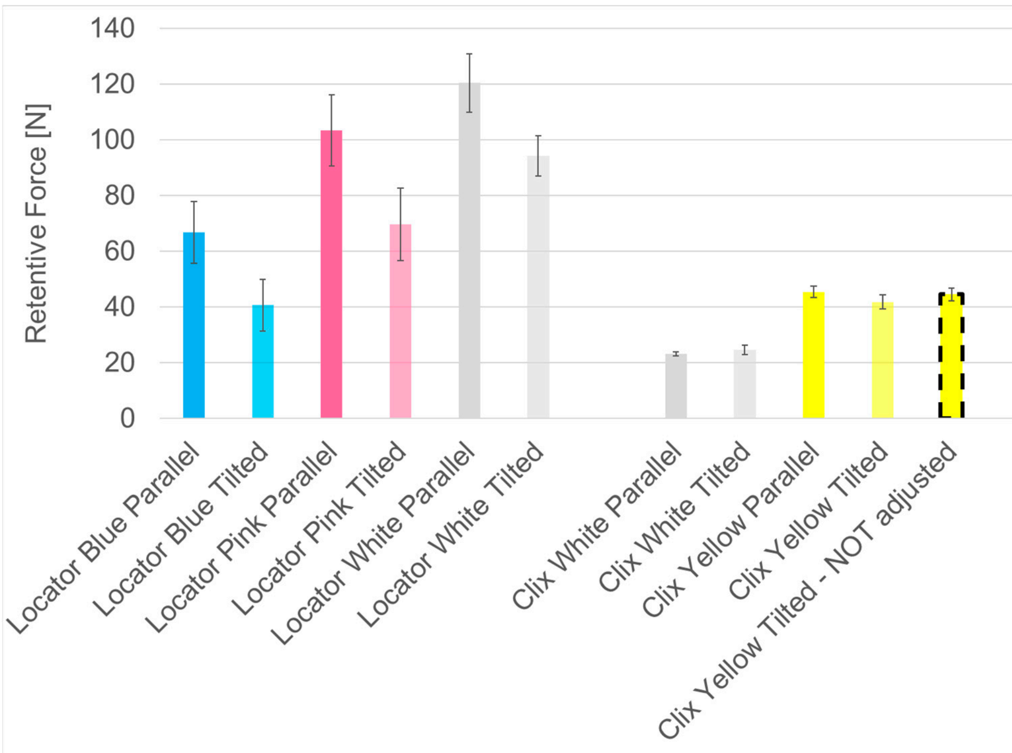


Figure 4. Mean retention force [N] of locator and Clix ball abutments tested in this study.

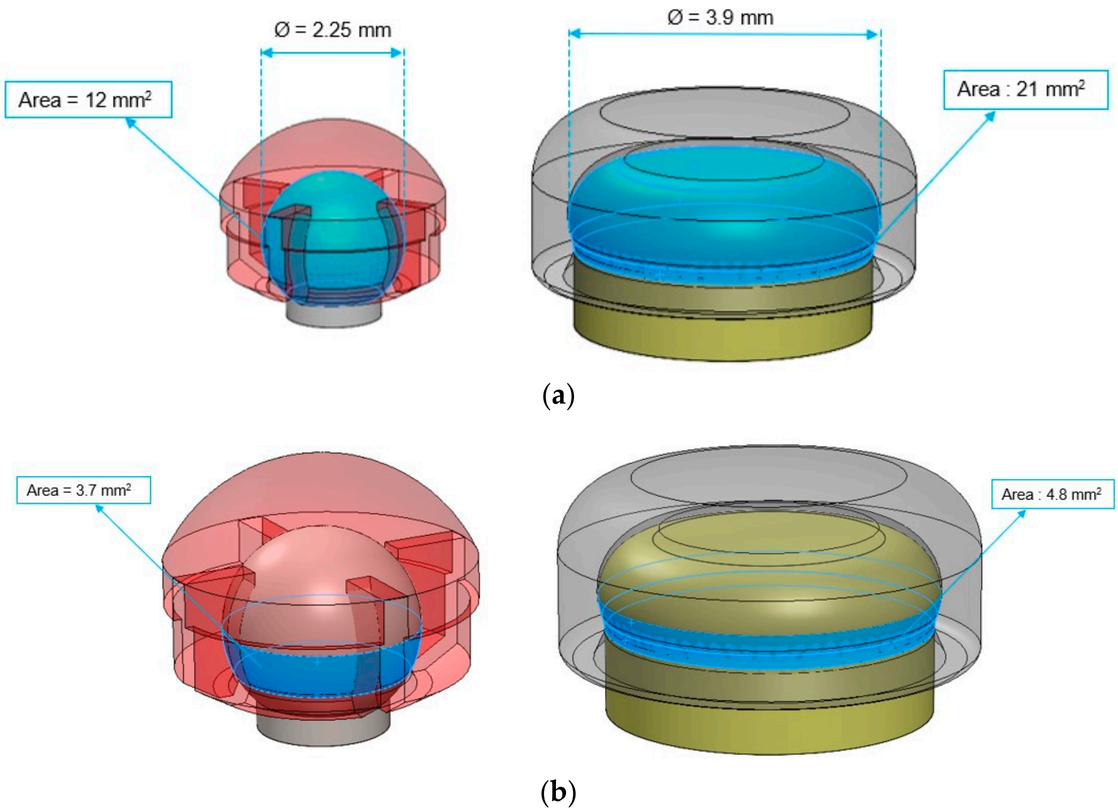


Figure 5. Virtual assemblies of locator and ball anchors used in this study show the total surface areas of the male components (**a**) and the regions used for retaining female attachment parts (**b**).

4. Discussion

This study, transferring an existing patient situation to an in vitro model, evaluated the effect of implant angulation and attachment type on initial retention force. Given the clinicians' preference [2] of rather using locators than ball anchors as prefabricated attachment systems and acknowledging the relevance of implant angulation as a critical factor for the success of implant-retained overdentures [5,8], this in vitro study compared locators and ball anchors. Locators placed on tilted implants consistently showed lower retention values as compared with the situation of parallel implants while inserts with increasing retention values could still be differentiated. Alignment of female retentive parts was not possible with locator attachments, which may be seen as a disadvantage, ultimately causing a higher rate of maintenance [16]. The reduction in retention force seen in tilted situations can only be explained by the female attachment parts not fully embracing the male components in a divergent implant configuration. This seems to be consistent with a report by Srinivasan and coworkers [8], and this may also hold true for so-called extended-range female components.

The ball anchors used here showed only a very minor effect of implant angulation on retention force. Not adjusting the female attachment part to achieve a common path of insertion also only had a minor effect on retention force, making the ball anchor a more forgiving device as compared with the locator. This may be seen as one reason for ball anchors to require a lower rate of maintenance as compared with locators [16].

The ball anchors used here represented a much smaller component as compared with the locator allowing for greater flexibility in terms of implant positioning and angulation. However, retention has to be realized and maintained by matching attachment surfaces, which are approximately 23% smaller as compared with locators. It can only be speculated how much effect the smaller component size would have on longevity, which is affected by several factors, including [18] tooth brushing [19], implant angulation [12,13], as well as the material of the female component [6]. From a technical point of view, smaller components are advantageous as the removable restorations become less bulky and less prone to fractures. Previous work in this field has shown that combinations of different materials, i.e., male attachment parts made from titanium and female parts made from plastic, were advantageous with respect to loss of retention [20].

The following limitations have to be considered when interpreting the findings presented. A simplistic but well-controllable in vitro study design was chosen in order to focus on one isolated parameter, i.e., implant angulation and its effect on retention. Other than using a parallel implant situation, only one specific tilted orientation of implants, which was based on a real patient, has been considered. Based on a retrospective measurement in a profile projector, a 12° divergence in the mesial-distal direction was determined. From a clinical point of view, deviations in the anterior-posterior direction are more common as a result of bone resorption in the anterior mandible. It can only be speculated how an alternative misalignment would have affected the study outcomes. The experiment was run under dry conditions, which certainly does not represent the clinical conditions [21,22], and hence, no conclusions should be drawn on the long-term behavior of retentive plastic inserts [22] based on this experiment. A recent study analyzing the surface topography of attachment parts showed that the chemical composition of the surrounding medium also had a considerable impact on retention [23].

Within the limitations of this experiment, ball anchors seem to constitute a more versatile attachment as compared with locators due to their reduced space requirements. Misalignment seems to have only a minor effect on retention due to the geometry of the ball attachment, and alignment of female parts seems not to be required.

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Conflicts of Interest: D. Roth is an employee of Hader Solutions & Distribution, the manufacturer of the Clix abutments used here. The remaining authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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