



REVIEW ARTICLE

Stud attachments for the mandibular implant-retained overdentures: Prosthetic complications. A literature review

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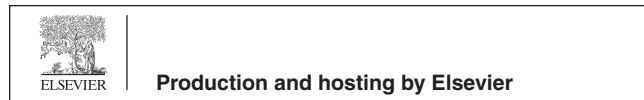
Abstract A plethora of attachment systems for mandibular two-implant overdentures is currently available often without evidence-based support. Technical aspects are now parameters considered when choosing the appropriate attachment. Despite the increasing use of the Locator attachments, studies regarding their properties remain scarce. Peer reviewed articles published in English up to 2011, were identified through a MEDLINE search (Pubmed and Elsevier) and a hand search of relevant textbooks and annual publications. Emphasis was made on the technical complications as well as the loss of retention related to the attachments in implant-retained overdentures, primarily the Locator attachment. The evaluation of the long-term outcome of implant overdentures and complications associated with different attachment systems may provide useful guidelines for the clinician in selecting the type of attachment system and overdenture design.

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1. Introduction

The attachment mechanism in the implant overdenture (IOVD) provides enhanced retention and stability compared to the conventional denture (Klemetti, 2008; Burns et al., 1995). The support is gained from both the intraoral tissues and dental implants (Simon, 2003). The connection should minimize denture movement without increasing the stress on the implants (Tokuhisa and Koyano, 2003; Chung et al., 2004). Attachment systems are easy to use and many are currently available (Alsabeeha and Swain, 2009), with new types of connectors regularly being introduced to the market. The efficiency of ball and bar attachments is well-documented (Büttel and Marinello, 2009). However, some attachments are produced without evidence-based support for their long-term maintenance or repair, and the modification or withdrawal of these attachments may only take place after their failure (Besimo, 2003; Bayer et al., 2007).

Biological and technical complications may occur during implant therapy (Andreiotelli and Strub, 2010). Technical complications include mechanical damage to the implant and prosthetic components (Andreiotelli and Strub, 2010). Regardless of the anchorage system used, adjustments to the overdenture (OVD) attachment system are the most common mechanical problem in implant prosthodontics (Watson et al., 1997). Notably, Goodacre et al. studied trends in the incidence rates of complications among raw data from multiple sources. The loss of retention or adjustment of OVDs was the most commonly reported complication type (30%) (Goodacre et al., 2003). When selecting an attachment system, the clinician should consider guidelines regarding their long-term outcomes (Visser et al., 2006; Andreiotelli and Strub, 2010; Walton and Glick, 2002). Early clinical studies focused on the implant survival, but recent studies have considered prosthetic maintenance (i.e., adaption and repair capabilities) and have compared retention devices (Attard, 2004; Meijer et al., 2004). Although some debate exists regarding the retention durability of attachments (Sadowsky, 2001; Fromentin et al., 2011a), technical aspects are now considered to be part of the process of choosing an appropriate attachment (Büttel and Marinello, 2009).

In 2001, Zest Anchors (Escondido, CA, USA) introduced the Locator attachment, which provides an improved design that combines the best features of the ball, ERA (Sterngold), and cap attachment types (Schneider, 2001). The Locator device uses a dual retention approach and different retention values (Trakas et al., 2006; Evtimovska et al., 2009). It is classified as a resilient universal hinge, is indicated for limited interarch distances, and helps to correct interimplant angles of up to 40° (Nguyen et al., 2010). Although these attachments appear to function reasonably well, they lack long-term clinical evaluation (Cune et al., 2005; Visser et al., 2006; Kleis et al., 2010).

The retention value of the Locator attachment varies according to the color of the patrix (replaceable nylon insert) (Evtimovska et al., 2009). Despite their widespread use internationally, limited in vitro reports on the retentive force of

these attachments are available. The cross-sectional strength of the Locator attachment is derived from its dual (inner and outer) retention characteristic (Chung et al., 2004; Rutkunas et al., 2007). The attachment uses mechanical and frictional retention modes (Alsabeeha and Swain, 2009; Alsabeeha et al., 2010) because the nylon male insert is slightly oversized compared to inner ring of the female abutment (Alsabeeha and Swain, 2009).

The outer margin simultaneously and completely engages the shallow undercut area at the outer margin of the abutment, while the central stud of the nylon male insert press-fits within the inner metal ring of the female abutment (Alsabeeha et al., 2010). Locator attachments are provided without an inner retention feature when they are aimed to correct implant angulation (Evtimovska et al., 2009).

The present review concerns technical complications and loss of retention related to attachments in mandibular implant-retained OVDs, primarily the Locator attachment. The aim was to help the practitioner in IOVD attachment selection in his daily practice. An electronic search was conducted on PubMed, Medline, and Elsevier databases, by using the following keywords: “Locator,” “complications,” “retention,” “wear,” “overdenture attachments,” “attachment systems,” “implant-retained overdentures,” and “implant-supported overdentures”. Articles reporting on investigations of retention, wear, or complications of attachment systems used specifically for mandibular two-implant OVDs were identified. The search included English-language articles that were published through 2011. The electronic search was followed by hand searching through the available journals.

2. Literature review

2.1. “Acceptable” retention

The retentive force provided by an attachment system should be high enough to prevent displacement of the OVD (Setz and Engel, 1998). Clinicians often base their selection of attachment systems empirically on the presumed retentive qualities and levels of patient satisfaction offered by the system (Burns et al., 1995; Cune et al., 2005). However, a definition for what an “acceptable” level of retention is for an attachment system remains elusive (Alsabeeha and Payne, 2010), and manufacturers provide limited data about the retentive strength and wear of attachments (Pigozzo et al., 2009). For example, the minimum retentive force expected for a single individual unsplinted attachment might be 4 N (Lehmann, 1978; Chung et al., 2004). However, various retentive forces ranging from 1 to 85 N have been reported for different attachment systems in which the mandibular OVDs are retained by multiple implants (Chung et al., 2004; Petropoulos, 2002; Rutkunas et al., 2007; Alsabeeha and Payne, 2010). Although a rough estimate of 20 N of retentive force has been proposed to be adequate for mandibular two-implant OVDs (Setz and Engel, 1998), Pigozzo et al. noted that 5–7 N would stabilize an OVD (Pigozzo et al., 2009).

The retentive force is impacted by numerous features. For example, it may be gained from mechanical and frictional contacts or magnetic forces (Preiskel, 1996; Besimo, 2003; Laney et al., 2007). The interimplant distance can also affect the initial retention of some attachments (Michelinakis and Smith, 2006; Doukas et al., 2008). For an OVD supported by two implants, although the highest retentive force was reported at an interimplant distance of 29 mm, a significant change was not achieved when the implants were placed at a shorter distance of 23 or 19 mm (Michelinakis and Smith, 2006; Doukas et al., 2008).

Gulizio et al. and others noted a reduction in the retentive force for attachments when the implant angulation was increased from 0 to 30 degrees (Wiemeyer and Kazemi, 2001; Gulizio et al., 2005a,b). Increased implant angulation has been reported to reduce the longevity of the attachment retention (Al-Ghaffi et al., 2009), by causing premature wear of the components and increased maintenance (Ortegón et al., 2009). Nonetheless, many spherical attachment systems may function appropriately when the implants lack parallelism, particularly if the matrix components in the prosthesis are positioned parallel to the vertical reference plane and to the path of withdrawal of the prosthesis (Wiemeyer and Kazemi, 2001; Gulizio et al., 2005b). Yang et al. observed that the retentive force was maintained until an inclination of 30 degrees when Locator blue or ball attachments were used (Yang et al., 2011). This tolerance in attachment systems could help in clinical cases, in which implant parallelism at an optimum distance across the residual ridge cannot be ensured (Wiemeyer and Kazemi, 2001; Gulizio et al., 2005a; Michelinakis and Smith, 2006; Doukas et al., 2008; Alsabeeha and Swain, 2009). However, patients still prefer attachments with superior stability (Kenny, 1998; Setz and Engel, 1998).

Another parameter that has obvious clinical implications in the retention and stability of the prosthesis during function is the release period, which is “the time required for the attachment system to lose retention or disengage from the abutment during forced separation” (Petropoulos and Kousvelari, 1997). Under excessive loads, an attachment system that readily disengages may protect the implants and the bone–implant interface from potentially harmful forces. Thus, the release period acts as a safety mechanism for the attachment (Chung et al., 2004). Similarly, the maximum dislodging force or peak load is an additional retention measurement. This parameter concerns “the maximum forces [that are] developed before complete separation of attachment components from teeth or implant abutments” (Botega et al., 2004). Because the loss of retention results from the wear of the attachments (Bayer et al., 2009), the number of insertion–removal cycles influences the maximum dislodging force (Wiemeyer and Kazemi, 2001; Bayer et al., 2009; Sadig, 2009).

Numerous studies have compared the retention characteristics of various OVD attachment systems. The type of connector has been shown to affect the retention and stability of IOVDs (Sadig, 2009). Attachment systems may be classified into four categories, from high to very low retention (Chung et al., 2004). Locator (Sadig, 2009) and Sterngold ERA attachments (Bonachela et al., 2003; Tabatabaian and Seyedan, 2010) provided significantly higher retention and stability of IOVDs compared to Nobel Biocare Ball connectors (Petropoulos and Kousvelari, 1997). Other studies confirmed these findings (Chung et al., 2004; Petropoulos, 2002), but Alsabeeha et al.

reported that a prototype 7.9-mm and standard 2.25-mm ball attachment demonstrated higher retentive forces than the Locator white, pink, and blue connectors (Alsabeeha and Swain, 2009). The ZAAG attachment (Zest Anchor Advanced Generation) was more retentive for the peak load measurement than the Nobel Biocare ball, Zest Anchor, or Serngold ERA attachment (Petropoulos, 2002). When vertical and oblique functions were simulated by applying dislodging tensile forces, the ZAAG attachment was still the most retentive device. The Zest Anchor was the least retentive under vertical forces, and Nobel Biocare Standard was the least retentive under oblique retentive forces (Petropoulos, 2011).

2.2. Change of retentive values over time

It has been suggested that an attachment system must be able to maintain its retentive force during a proposed lifespan of 10 years (Lehmann, 1978). However, some in vitro studies have indicated that attachment systems inevitably undergo wear-induced structural changes, leading to a reduction or total loss of their retention. Wear is defined as a “loss of material from a surface caused by a mechanical action alone or through a combination of chemical and mechanical actions” (Anusavice, 1996). The wear of components of ball attachments was found to be responsible for a decrease in the retention of the attachments (Fromentin et al., 2011a). Deterioration, deformation (Fromentin and Tavernier, 1999), and work hardening may lead to the eventual fracture of the attachment components (Watkinson, 1987). Variations in the extent of wear patterns seen with different attachment systems remain speculative and poorly understood (Alsabeeha and Payne, 2010).

By using designs that attempted to emulate the actual oral environment, several studies (Besimo and Fluhrer, 1996; Setz and Engel, 1998; Fromentin and Tavernier, 1999; Besimo, 2003; Botega et al., 2004; Doukas et al., 2008; Rutkunas et al., 2007) investigated the effects of short- and long-term simulated function on the retentive forces of attachment systems. Retentive forces were initially determined under axially directed tensile forces, after which the systems were subjected to cyclic loading under axial or paraxial forces through 540–10,000 cycles of repeated insertion and removal. Given an assumption of three daily removals and insertions of the OVD for hygienic purposes, this range was thought to simulate 6 months to 9 years of clinical function (Besimo, 2003). Most of the attachment systems showed a common trend toward a reduction (Tabatabaian and Seyedan, 2010) or total loss in retentive force (Alsabeeha and Swain, 2009). Repeated insertion–removal cycles led to a gradual and continuous loss of retention of ball-socket attachments (Chung et al., 2004; Rutkunas et al., 2005; Evtimovska et al., 2009; Petropoulos, 2002). This loss was usually abrupt after approximately 500 cycles (Epstein et al., 1999) and reached as high as 80% of the initial value after 2000 cycles (Chung et al., 2004; Rutkunas et al., 2005; Evtimovska et al., 2009). Gamborena et al. noticed a dramatic loss of retention at the conclusion of the wear simulation test for ERA attachments. Microscopy measurements revealed distinct wear patterns characterized by the distortion of the plastic matrices, whereas the metallic matrices appeared unchanged (Gamborena et al., 1997). Similar observations were also reported with four ball-attachment systems (Fromentin and Tavernier, 1999; Barão et al., 2009).

Some studies have found that the diameters of ball abutments were reduced significantly after 1, 3, and 8 years of clinical wear, with a maximal amount of wear after 3 years of use (Fromentin et al., 2011a). Thus, severe mechanical wear on both surfaces may be noted after long periods of use (Fromentin et al., 2011b). Although some articles have noted smaller changes in the retention force when the attachment male and female components were of different material compositions (Bayer et al., 2011), others indicated that the ball attachments exhibited the highest wear when they were combined with a titanium matrix (Branchi et al., 2010). Researchers found evidence of variations in the retentive forces among samples of the same attachment systems (Setz and Engel, 1998; Besimo, 2003; Doukas et al., 2008). An adjustable attachment system has been proposed to compensate for wear and increase the retention force (Bayer et al., 2011).

Recent studies have compared the retention characteristics of the Locator attachment to those of other commonly used systems. Wear effects on OVD resilient attachments were studied by (Rutkunas et al. (2011). [Epub ahead of print]), who simulated 15,000 insertion–removal cycles on ERA orange and white (EO and EW), Locator pink, white, and blue (LRP, LRW and LRB), and OP anchor (OP) attachments. They used light microscopy and scanning electron microscopy (SEM) to evaluate dimensional changes and surface characteristics. The retentive force of the Locator attachments fluctuated throughout the wear-simulation period, whereas the retentive forces of the EO and EW attachments rapidly decreased.

The plastic cores were more damaged than the plastic rings of the attachment male parts (Rutkunas et al., 2011). [Epub ahead of print]. An SEM analysis showed smoother surfaces of some specimens after wear simulation (Fromentin and Tavernier, 1999). Other studies have confirmed this result for the ERA (Setz and Engel, 1998; Wichmann, 1999; Besimo, 2003). A literature review provided evidence of a reduction in the retentive force under in vitro conditions for most attachment systems (Alsabeeha and Swain, 2009).

Several in vitro studies have sought to determine the influence of mechanical fatigue on different IOVD attachments (Fromentin and Tavernier, 1999; Bayer et al., 2009). All of the attachment systems tested showed some retention loss during the experiment (Bonachela et al., 2003). However, according to Setz, even after 15,000 cycles, this loss was minimal when compared with the initial retentive forces (Setz and Engel, 1998). Evtimovska and others demonstrated that multiple pulls significantly reduced the retention of Locator attachments (Al-Ghaffi et al., 2009; Evtimovska et al., 2009). In another study, simulated mastication reduced the retention of Locator attachments to 40% of the baseline value, with a nonlinear descending curve, but induced only minor changes in the retention of the ball attachment tested. The authors reported that the Locator nylon capsules were strongly affected and suggested that the maintenance needs were related to mastication (Abi Nader et al., 2011).

Twelve months after OVD delivery to patient, Kleis noticed damage in both of the male parts of the Locator group, which led to a 75.5% loss of retention and required a change of these parts (Kleis et al., 2010). Other researchers reported that nonparallel implants induce a more important reduction of the peak load-to-dislodgement (Evtimovska et al., 2009). Rutkunas reported that retention of OVD attachments became

relatively stable after 800 cycles (Rutkunas et al., 2005), especially in the case of the most-retentive designs (Williams et al., 2001). Multiple placement–removal cycles of the OVD by the clinician before delivery were recommended (Kleis et al., 2010; Evtimovska et al., 2009). Nevertheless, Cakarar argued that the Locator system did not present any problem of retention when compared to ball and bar designs (Cakarar et al., 2011). The Locator root pink was the most retentive device after fatigue when compared to the Era orange and white systems, which retained less than 37% of their initial retention (Rutkunas et al., 2005).

Magnetic attachments experienced a minimal reduction in their retentive force (Doukas et al., 2008; Rutkunas et al., 2007) compared to the gradual decrease in the retention of stud attachments (Fakhry et al., 2010). Despite the signs of corrosion observed microscopically within the stainless steel magnet case, magnetic attachments showed less physical deterioration when tested under identical conditions (Rutkunas et al., 2005; Chung et al., 2011). In contrast, a steady increase in the retentive force of telescopic attachments made of different alloys (titanium, gold, and cobalt-chromium) was observed under long-term simulated function. The authors related this result to the increased mechanical adaptation of the attachment components under cyclic loading, with some variation related to the differences in the physical properties of the alloys (Besimo and Fluhrer, 1996; Botega et al., 2004).

2.3. Incidence of mechanical complications

Different studies have tried to identify or compare the etiological factors underlying the failure of splinting and unsplinting attachments. Bar or ball attachments have been considered comparable in terms of the reliability and the frequency of complications (Karabuda and Bayraktar, 2008; Cehreli et al., 2010b). Most investigations have indicated that the unsplinted design requires more prosthetic maintenance (Klemetti, 2008; Stoumpis, 2011; Cakarar et al., 2011). However, others noted that the maintenance frequency is slightly higher for the bar design (Gotfredsen, 2000; Mericske-Stern et al., 2009; Cakarar et al., 2011), with higher failure rates of bars with distal cantilever extensions (Waddell and Swain, 2006). No difference in the implant survival rate between attachment systems was reported by other reports (Bergendal, 1998; Cehreli et al., 2010a).

Studies have also sought to evaluate the incidence of mechanical complications of the Locator attachments compared to other commonly used OVD attachment systems. Cakarar et al. observed that the Locator was better in terms of maintenance frequency compared to ball or bar systems (Cakarar et al., 2011). Mackie et al. agreed that a higher prosthodontic success rate was achieved with the Locator compared to other attachments (Southern plastic and Straumann gold) over a 3-year period (Mackie et al., 2011). In contrast, Kleis et al. found that the Locator nylon matrices showed extensive deformation and deterioration, with a substantially higher need for maintenance, compared to ball attachments. Although the performance of the matrices was related to the creep response, that of the matrices was related to hardness (Kleis et al., 2010). Bilhan et al. found no correlation between the attachment type and the occurrence of complications (Bilhan et al., 2011), which was correlated with implant angulation (van Kampen et al., 2003).

2.4. Mastication and force distribution

Compared to insertion–removal cycles, mastication induces different patterns of wear and deformation of the attachment system. By displacing the mucosa under the denture base, occlusal loads provoke rotation of the denture around the attachments (Porter and Brunski, 2002). The degree of the occlusal load transmitted to the attachments is related to their resiliency (Mericske-Stern, 1998; Heckmann et al., 2001). An optimal stress distribution is required to reduce the forces on the implants and the denture movement (Tokuhisa and Koyano, 2003). Both (Cakarar et al. (2011)) and (Trakas et al. (2006)) noted that correct implant placement reduced the maintenance of attachment systems. To correct for a lack of proper occlusion and possible rotation of the denture around the retentive components, due to the inevitable continuous resorption of the underlying residual ridge, constant rebasing of implant-retained OVDs may be necessary (Chaldek, 2010; Polychronakis and Zissis, 2010).

Various other factors, such as the length, number, and angulation of the implants, the opposing dentition, and para-functional habits, may increase the susceptibility to mechanical complications (Sones, 1989). In the severely resorbed mandible, implants supporting or retaining an OVD may be subjected to excessive masticatory forces, including off-axis centric contacts, excursive contacts, and cantilevered loading (Binon, 2000). In the case of angulated implants, the occlusal forces may generate more strain than the screw can bear (Rangert et al., 1995; Binon, 2000). A large variation in retentive forces was reported among samples of the same attachment system (Setz and Engel, 1998; Besimo, 2003). This finding may have been related to poor quality control during the manufacturing process of the attachment components (Setz and Engel, 1998), because differences in the dimensions or material composition have been found between different batches of the same product (Ortegón et al., 2009).

3. Discussion

Few in-depth studies and standardized criteria are available to compare different options for mandibular IOVD treatment (Attard, 2004; Meijer et al., 2004; Andreiotelli and Strub, 2010). In particular, Bryant et al. found that clinical studies with a similar study design that simultaneously evaluated all or most of the categories of complications were too rare to allow them to calculate an overall complication incidence for IOVDs (Bryant and Kim, 2007). Although accurate measurement devices have recently been developed, they only allow comparisons of attachments that work on similar bases (Fromentin et al., 2010 Chaldek, 2010).

A limitation of this literature review is that it included non-randomized controlled studies. In particular, some studies did not include significant sample size and precise and reproducible measurement methods, whereas other studies were in vitro experiments. The performance of in vitro studies cannot overcome the need for well-structured clinical prospective studies. In finite element analysis, the accuracy of the experiment relies on the parameters applied to the model, including the geometry, constraints, and mechanical properties (Saab et al., 2007). Masticatory loading submits OVDs to complex three-dimensional movements. The presence of saliva (Besimo,

2003; Botega et al., 2004), denture cleansers (Nguyen et al., 2010; You et al., 2011), and food particles (Cune et al., 2005) may influence the clinical wear. As a result, it is difficult to reproduce the oral environment in vitro. To limit the influence of confounding variables, factors must be investigated separately under well-controlled conditions (Alsabeeha and Swain, 2009), and the results should be interpreted carefully. Evidence-based studies do not permit us to determine the most effective connection between the OVD and the supporting implants, and some questions remain unanswered.

Ultimately, the goals when placing any connector should be minimal complications and an equally atraumatic distribution of forces between the mechanical and the biological supporting structures (Chung et al., 2004). The selection of an appropriate attachment by the clinician is inevitably based on empirical evidence, such as the amount of retention desired and the specific clinical situation (Petropoulos, 2002). However, the ability to maintain this retention under the simulated function remains questionable (Gamborena et al., 1997; Rutkunas et al., 2007). Measurement of the retention values at the beginning of the treatment and after function would help to provide treatment according to the individual needs of the patient (Naert et al., 1994). An annual follow-up would be necessary after the patient is given the Locator system (Kleis et al., 2010). In addition to scientific evidence related to the clinical performance of the implants and attachments, the objective oral function and the patients' appreciation of the treatment should guide the clinician in his or her ultimate choice of an attachment type. The initial and eventual costs of maintenance and repairs must also be considered (Cune et al., 2010). The clinician should consider that the provision of adequate after-care may be difficult or impossible when treating aging patients, especially if they become dependent and frail (Rentsch-Kollar and Mericske-Stern, 2010).

4. Conclusion

Clinical publications comparing the maintenance of Locator attachment devices with other systems remain scarce (Andreiotelli and Strub, 2010). Well-designed studies examining the long-term behavior of these attachments are needed (Evtimovska et al., 2009), because variations in protocols preclude the proper analysis of certain complications (Andreiotelli and Strub, 2010). Nevertheless, the Locator system provides the dental practitioner with a useful attachment option for patients requiring an implant-retained OVD (Saha, 2009). Careful postinsertion maintenance of the prosthesis, the attachment system, and the mucosa is essential (Ichikawa et al., 1996). Out-of-pocket expenses for the initial treatment and for long-term maintenance are low (Carlsson et al., 2004), and the repair and replacement processes are not time-consuming (Chung et al., 2004; Chung et al 2004; Kleis et al., 2010).

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