

Biomaterial aspects: A key factor in the longevity of implant overdenture attachment systems

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Abstract

Background: New attachment systems are released for mandibular two-implant overdentures often without evidence-based support. Biomaterial aspects are now the parameters considered when choosing the appropriate attachment. Studies regarding their properties remain scarce. **Purpose:** The purpose of this review was to help the clinician in selecting the most adapted stud attachments according evidence-based dentistry. **Materials and Methods:** An electronic search was conducted using specific databases (PubMed, Medline, and Elsevier libraries). Peer-reviewed articles published in English up to July 2014 were identified. Emphasis was given on the biomaterial aspects and technical complications. No hand search was added. **Results:** The electronic search generated 115 full-text papers, of which 84 papers were included in the review. The majority were clinical and *in vitro* studies. Some review articles were also considered. Papers reported survival and failures of overdenture connection systems. Emphasis was laid on attachment deformation. **Conclusion:** Implant overdentures long-term follow-up studies may provide useful guidelines for the clinician in selecting the type of attachment system and overdenture design. Locator attachments are more and more used, with lesser complications reported.

Key words: Biomaterial, overdenture, stud attachments

INTRODUCTION

In terms of stability and retention, attachment system provides superior effectiveness for complete dentures.^[1] The connection reduces the denture movement without adding stress on the implants.^[2]

Long-term outcome may guide the clinicians' choice of attachment.^[3,4] Biological and technical (mechanical) are the two types of complications encountered in implant therapy. This review will consider the biomaterial aspects. Emphasis will be given on the performance of attachments over time. The wear patterns induced

are of major importance. Prosthetic maintenance (the capability to adapt or repair) is of daily clinical interest.^[5,6] Technical aspects are the parameters to be considered now.^[7] Durable retention remains the subject to debate.^[8,9]

“Technical complications” include mechanical damage to the implant and prosthetic components. Irrespective of the anchorage system, adjustments are the most commonly reported mechanical problem.^[10] Retention loss or adjustments are the most encountered problems (30% of the reported maintenance).^[11] The present review will focus on technical complications of attachments.

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MATERIALS AND METHODS

Databases from PubMed, Medline, and Elsevier were scrutinized. The following keywords directed the search: “Complications,” “retention,” “wear,” “attachment biomaterial,” “overdenture attachments,” “attachment systems,” “implant-retained overdentures,” “implant-supported overdentures,” and “locator.” Peer-reviewed articles reporting on investigations of retention, wear, or complications of overdenture attachment systems used specifically for mandibular two-implant overdentures were identified. The search included articles published in English up to July 2014 which contained all or part of the key words in their headings. The electronic search generated 115 full-text papers. Eighty-four papers were included in the review. The majority were clinical and *in vitro* studies. Some review articles were also considered. Papers reported survival and failures of overdenture connection systems. Emphasis was made on attachment deformation. No hand search was added.

Divers attachment systems are released often without evidence-based support for long-term maintenance or repair.^[12] Failure or frequent complications sometimes urged modification or withdrawal of these attachments.^[13,14]

Industry proposes to replace the well-documented ball and bars attachments by new connector type^[7] Introduced in 2001, the Locator attachment (Zest Anchors, Escondido, CA, USA) combined the best features of a ball attachment, an ERA attachment (Sterngold), and a cap attachment,^[15] with its appreciated dual retention and different retention values.^[16,17] It is classified as a resilient universal hinge, and is indicated for limited inter-arch distance. Angle corrections of up to 40° are allowed.^[18]

Limited *in vitro* reports on the Locator retentive force are published. The dual retention (inner and outer) enhances its cross-section strength^[19] by mechanical and also frictional mode.^[12,20] The slightly oversized nylon male insert and the smaller diameter inner ring of the female abutment produce a dimensional misfit.^[12] While the central stud of the nylon male insert of the Locator attachment press fits within the inner metal ring of the female abutment, the outer margin engages the shallow undercut area present at the outer margin of the abutment simultaneously and completely.^[20] The color of the patrix (replaceable nylon insert) indicates the retention value.^[16] To correct implant angulation, these attachments can be made without the inner retention feature.^[16] Long-term evaluation is still lacking.^[4,21,22]

“Adequate” retentive force

The connection must provide a retentive force high enough to prevent overdenture displacement.^[23] Presumed retentive quality and improved levels of patient satisfaction empirically guide clinicians’ choice.^[21] There are vague reports of adequate retention of an attachment system in the literature.^[24] Implant manufacturers provide only little data about the retentive strength and wear of attachments.^[21] For a single individual unsplinted attachment, 4 N is mentioned as the minimum retentive force,^[19,25] whereas this retention may vary from as low as 1 N to as high as 85 N when mandibular overdentures are retained by two or more implants.^[19,24,26] When a rough estimate of 20 N of adequate retentive force has been proposed for a two-implant mandibular overdenture,^[23] Pigozzo *et al.* suggest a value of 5–7 N to stabilize the overdentures.^[27] Mechanical and frictional contacts, as well as magnetic forces of attraction between the patrix and matrix can be the basis of retentive force.^[14,28,29]

Connector type and retention

Retention and stability are significantly affected by the type of connector.^[30] Studies have classified the attachment systems into high (ERA gray), medium (Locator LR white, Spheroflex ball, Hader bar and metal clip, ERA white), low (Locator LR pink), and very low (Shiner magnet, Maxi magnet, Magedisc magnet) retention groups.^[19] Significantly higher retention and stability are provided by Locator connectors^[30] and Sterngold ERA,^[31,32] compared to Nobel Biocare ball connectors.^[33] These findings were confirmed by several studies.^[19,33] Alsabeeha *et al.* pointed that the Locator white, pink, and blue connectors demonstrated higher retentive forces than either a 7.9-mm prototype ball attachment design or the standard 2.25-mm ball attachment.^[12] The greatest reported value for the peak load was for the Zest Anchor Advanced Generation (ZAAG) attachment, compared to the Nobel Biocare ball, the Zest Anchor, and the Sterngold ERA.^[33] The peak load is defined as the maximum forces developed before complete separation of the attachment components from the implant abutments.^[34] The ZAAG attachment exhibited significantly the highest retentive vertical and oblique forces under dislodging tensile forces applied to the housings in two directions simulating function: Vertical and oblique. The lowest vertical force corresponds to the Zest Anchor and the lowest oblique retentive force to the Nobel Biocare Standard.^[35]

Change of retentive values over time

Furthermore, according to Lehmann, an attachment system must be able to maintain its retentive force during a 10-year shelf life.^[25] However, evidence from past and current studies demonstrates that the wear-induced structural changes undergone by an attachment system inevitably lead to a reduction or total loss of retention. A mechanical action alone or a combination of chemical and mechanical actions will induce loss of material from the surface. This is defined as wear.^[36] Components wear decrease ball attachment's retention.^[8] Deterioration and deformation, along with work hardening,^[37] can also lead to attachment fracture.^[38] The variations in the wear patterns seen with different attachment systems still need better understanding.^[24]

Wear simulation tests

Related to reproduced oral environment

Study designs that attempted to emulate the actual oral environment tried to investigate the effect of short- and long-term simulated function on the attachment systems' retentive force.^[26,34] The retentive forces were initially determined under axially directed tensile forces. Attachment systems were then submitted to cyclic loading under either axial or paraxial forces in the range of 540–10,000 cycles of repeated insertion and removal. This would represent 6 months to 9 years of clinical function, on the basis of three daily overdenture removals and insertions for hygienic purposes.^[14] A common trend toward reduction^[32] or total loss in retentive force was found across the majority of the attachment systems.^[12]

Repeated insertion–removal cycles provoke gradual and continuous loss of retention of ball–socket attachments.^[26] This loss can be abrupt after approximately 500 cycles^[39] and may reach 80% of the initial value after 2000 cycles.^[26]

Related to material components

To evaluate the effects of wear on overdenture resilient attachments, Rutkunas *et al.*^[40] determined the dimensional changes and surface characteristics using light microscopy and scanning electron microscopy (SEM) of ERA orange and white (EO and EW), Locator pink, white, and blue (LRP, LRW and LRB), and OP anchor (OP), respectively, after simulated 15,000 insertion–removal cycles. The sudden decrease of retentive force of ERA attachments was opposed to the retentive force fluctuation of Locator attachments throughout the wear simulation period.

The dimensional changes and surface wear on the plastic rings of attachment males were less expressed than on plastic cores.^[40] SEM analysis demonstrated smoother surface after wear simulation,^[38] especially for ERA.^[23,41,42] A literature review confirmed the reduction of the retentive force of the majority of attachment systems under *in vitro* conditions.^[12]

A dramatic loss of retention for ERA attachments was observed at the conclusion of wear simulation test. Upon microscopic measurement, Gamborena noticed distinct wear patterns that arise due to distortion of the plastic patrices, with the metallic matrices remaining unchanged.^[43] Studies reported similar observations with four ball attachment systems,^[38,44] whereas some studies reported that significant and maximal amount of wear of the diameter of ball abutment was reached after 3 years of clinical use.^[8] This may indicate that severe mechanical wear on both surfaces may occur after long periods of use.^[8] While some studies sustained that attachment systems which possess a male and female component of different material composition exhibit smaller changes in the retention force,^[43] others reported the highest wear on the ball attachments for implant-retained overdentures, when antagonist to titanium matrix.^[45] Moreover, even among samples of the same attachment systems, differences in the retentive forces were evident.^[23,41,46] To increase the wear compensation and retention force, an attachment system has to be adjustable.^[43]

It is noteworthy that a minimal reduction in retentive force was achieved by the magnetic attachments^[46,47] compared to the gradual decrease of the stud attachments' retention.^[48] When tested under identical conditions, less physical deterioration was found, despite microscopic corrosion signs observed within the stainless steel magnet case.^[19,26]

In contrast, under long-term simulated function, in the case of telescopic attachments made of different alloys (titanium, gold, and cobalt-chromium), a steady increase in the retentive force has been observed. The authors explained their results by the increased mechanical adaptation of the attachment components under cyclic loading. Some variation related to the differences in the physical properties of alloys remains.^[41]

Related to insertion–removal cycles

Mechanical fatigue also induced some retention loss of the attachment systems during the experiment after 15,000 fatigue cycles,^[31,38,49] even though it was of little

value when compared to the initial retentive forces.^[23] Multiple pulls reduced the retentive values of the Locator attachments significantly.^[16,50]

Eight hundred cycles are needed to attain relatively stable retention of overdenture attachments,^[26] especially for the most retentive systems.^[51] The clinician has to place and remove the overdenture multiple times before delivery,^[16] although this reduction might not be noticeable to the patient but only to the examiner.^[22] Nevertheless, Cakarer did not find any advantage of ball and bar designs over the Locator in terms of retention.^[52] Also, the Locator root pink remained the most retentive after fatigue, compared to the ERA orange and white.^[26]

Related to mastication

The wear patterns and their related attachment deformation generated by the mastication are different from those induced by insertion–removal cycles. When occlusal loads are applied, the mucosa is displaced under the denture base resulting in denture rotation around the attachments.^[53] The amount of occlusal load transmitted to the attachments is a factor of their resiliency.^[54,55] An optimal stress distribution reduces the denture movement and, thereby, the forces on the implants.^[56] Simulated mastication reduced the Locator retention to 40% of the baseline values with a non-linear descending curve. The nylon capsules were strongly damaged.^[57] This demonstrates that for Locator system, maintenance needs are correlated with mastication.^[57] Only minor changes were found for the ball attachment tested.^[57]

Kleis declared that after 12 months of overdentures' delivery, the male parts of the Locator have to be changed, as 75.5% loss of retention has been noticed. The wear affected both male parts.^[22] However, the reduction in peak load-to-dislodgement for these attachments is more apparent in case of non-parallel implants.^[16]

Length, number, implant's angulation, opposing dentition, and parafunctional habits are among the factors that may increase susceptibility to mechanical complications.^[58] Excessive masticatory forces, as off-axis centric contacts, excursive contacts, and cantilevered loading, may be generated in severely resorbed mandible.^[59] Occlusal forces on angulated implants may cause more strain than the screw can bear.^[59,60] Correct implant placement diminishes attachment systems' maintenance.^[17] To overcome the inevitable continuous resorption of the underlying

residual ridge, frequent rebasing of implant-retained Overdentures (OVDs) may restore the proper occlusion and reduce possible rotation of the denture around the retentive components.^[61,62]

Type of attachment and incidence of mechanical complications

Etiological failure factors have been compared in case of splinting or unsplinting attachments. No major differences in prosthetic complications have been observed for bar or ball attachments, thus both are considered as reliable connectors.^[63,64] Results may be contradictory. Most of them reported more prosthetic maintenance for separated attachments,^[52,65] whereas others found more technical complications/repairs per patient around bar than ball attachments. Most of the separated attachments need more prosthetic maintenance;^[52,65] but for others, the frequency of technical complications/repairs per patient was higher around bar than ball attachments,^[52,66,67] with an increased failure rate for the cantilevered extended bars.^[68] Meanwhile, no difference was seen in the implant survival rate among splinted and unsplinted schemes.^[69,70]

Recent studies sought to compare the incidence of mechanical complications of the Locator attachments with that of the commonly used overdenture attachment systems.

A recent survey showed that British general dental practitioners are not familiar with the Locator attachment system and are reluctant to do implant-retained OVDs maintenance. General dentist *practitioner* general practice dentists (GDPs) would like further training in this area.^[71]

Cakarer *et al.* observed less prosthodontic complications and maintenance of the oral function for the Locator system than for ball and bar attachments.^[52] Mackie *et al.*'s findings were in agreement with this when they compared Locator to Southern plastic and Straumann gold over a 3-year period.^[72]

In contrast, Kleis *et al.* argued that the creep response of the matrices and the hardness of the matrices provoked extensive deformation and deterioration of the Locator nylon parts, with a higher substantial need for maintenance, compared to ball attachments.^[22] Differences in the dimensions or material composition, and a large variation in retentive forces have been found between different batches of the same attachment system due to the poor manufacturing quality control.^[14,23,73]

Researchers concluded that implant parallelism has more impact on the complications that occur than the choice of type of attachments.^[74,75]

Any installation load greater than 0 N is recommended for the connection of ball, Locator, or magnetic attachments to a denture base. By increasing this installation load, the resultant force acting on the implant may be decreased. However, when this load surpasses 100 N, the harmful denture movement may be increased.^[76]

DISCUSSION

Implant survival rate of mandibular overdentures is reported high regardless attachment systems. The prosthetic maintenance and complications are influenced by attachment systems. However patient satisfaction is somehow, independent of the attachment system (3). In-depth studies following standardized criteria to compare different options for mandibular Implant overdentures (IOVD) treatment remain scarce.^[3,5,6] In particular, similar clinical protocols are still insufficient to allow the calculation of an overall complication incidence for Implant Overdentures IOVDs.^[77] New accurate measurement devices only permit comparisons of attachments that work on similar bases.^[61,78]

A limitation of this literature review is that it includes studies with non-declared sample size, or measurement methods. Other studies are *in vitro* experiments, whereas non-randomized controlled studies are lacking. Well-structured clinical prospective studies remain essential, in addition to well-designed *in vitro* studies. The accuracy of parameters applied to the model, including geometry, constraints, and mechanical properties, determines the value of the finite element analysis experiment.^[79] Masticatory loading submits the prosthesis to a hardly reproducible scheme of three-dimensional movements. The clinical wear can be influenced by saliva,^[14,34] denture cleansers,^[18,80] or food particles.^[21] As a result, it is hard to reproduce the oral environment *in vitro*. Factors should be investigated separately under well-controlled conditions, in order to limit the influence of confounding variables.^[12] Interpretation of results must be carefully done. Some questions remain unanswered. Evidence-based studies do not allow us to select the most effective implant-OVD connection.

Equal atraumatic distribution of forces between mechanical and biological supporting structures, and minimal complications are the ultimate goals when

placing any connector.^[19] The amount of retention desired and the specific clinical situation guide the clinician in selecting an appropriate attachment. Still, it may be based only on empirical evidence.^[33] Ability to maintain retention values under simulated function remains questionable.^[26,43] The retention measurement values provided by the manufacturer at treatment beginning and after function would help to respond to individual needs of patients.^[81] Scientific evidence related to the material's clinical performance, objective oral function, and patients' appreciation of the treatment should guide the clinician in making the ultimate choice of a specified attachment. The initial and maintenance costs have also to be considered.^[82] An annual follow-up would be necessary after Locator system placement.^[22] Adequate aftercare may be difficult or impossible when treating aging patients.^[83]

In the author's opinion and based on the presented data, the Locator attachment system is an easy-to-use connector, with less post-insertion complications. No special practical training is needed. The patient satisfaction reported is quite high. No major post-insertion reparation expenses are charged on the patient.

CONCLUSION

The choice of implant location and retentive attachments in implant-retained overdentures is based on clinician's preference, expert opinion, and empirical information. Clinical publications comparing the maintenance of attachment devices remain scarce. Long-term, well-designed studies are needed. Protocols variations preclude the proper analysis of certain complications. Careful post-insertion maintenance of the prosthesis, attachment system, and mucosa is mandatory. Out-of-pocket treatment and post-treatment expenses should be less and the treatment should not be time consuming.

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Conflicts of interest

There are no conflicts of interest.

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