Attachment Systems for Implant Retained Overdentures: A Literature Review

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Although implants have offered a great service to partially edentulous patients, the most dramatic changes in treatment have been achieved in completely edentulous patients with atrophic mandibles and/or maxillae. In cases in which the retention of the dentures is extremely difficult or impossible, the placement of ≥2 implants that retain and support an overdenture allows for optimal results with regard to patient satisfaction and function. The successful prosthetic outcome of implant-retained overdentures had such a high impact on the academic and clinical community that in a recent 2-day meeting at McGill University in Montreal, implant authorities suggested that the prosthetic rehabilitation with a conventional denture of a patient with a completely edentulous mandible should no longer be the treatment of choice. Instead, the placement of 2 implants and the fabrication of an implant-retained overdenture should be the option to consider first.[1,2]

In completely edentulous patients, implants can be used in conjunction with attachments to enhance the retention and stability of overdentures. There are many different attachments provided by a large number of manufacturers around the world. Most of these are compatible with the majority of the implant systems currently available and are divided into 2 major categories: bar and stud attachments. The large number of attachments is rather confusing for the inexperienced clinician. This problem becomes even greater because the choice as to which attachment to use is based basically on opinions and clinical experience rather than on real evidence and scientific findings.

The purpose of this article is to discuss the potential effect of the different attachments used routinely in implant-retained overdentures on: (1) implant survival rate, (2) marginal bone loss, (3) soft tissue complications, (4) retention, (5) stress distribution, (6) space requirements, (7) maintenance complications, and (8) patient satisfaction. At the end, selection criteria previously published in the literature are briefly discussed.

This article presents a comparison between different attachment systems used to retain and support maxillary and mandibular overdentures in completely edentulous patients. A literature review based on a MEDLINE search limited to English-language articles published from 1988 to the present was performed, and a large number of attachments available in the dental market were reviewed with regard to several factors, including: (1) implant survival rate, (2) marginal bone loss, (3) soft tissue complications, (4) retention, (5) stress distribution, (6) space requirements, (7) maintenance complications, and (8) patient satisfaction. These factors are considered essential for the successful outcome and good long-term prognosis of the prostheses. Selection criteria previously published in the literature are discussed as well. Product names and manufacturers are mentioned only if related to attachment systems, as they are cited in the original articles. (Implant Dent 2006;15:24–34)

Key Words: ball attachments, implant retained overdentures, bars, clips, magnets

Implant Survival Rate

The question of whether splinting implants with bar attachments contributes to a higher survival rate or not has been studied by several investigators[3-6] in the past. A retrospective study[3] of overdentures supported by implants placed in 89 patients at 11 different Swedish centers has concluded that the mode of attachment of the prosthesis to the fixtures did not seem to have a definite role in the failure of the implants. However, the investigators stated that the limited number of implants and short length of the observation period did not allow for a final assessment of the success rate in relation to different attachment systems.

In a prospective study of 13 patients, Naert *et al*[4] found a cumulative success rate of 88.6% after 4 years for overdentures retained by bars with Ceka (Ceka NY, Antwerp, Belgium) attachments and hinging type overdentures in the maxilla. This result

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contrasts with those previously published from the same group, when in a group of 5 patients who were treated with maxillary overdentures retained by 2 stud attachments (either ball or magnetic), the absolute success rate was only 40% after a mean loading time of 6.4 years. It should be mentioned that the authors' opinion is that the most favorable results in the most recent study were probably related to the number of implants that were rigidly splinted.

A longitudinal prospective study[5] of 49 patients found no difference in implant survival rate between patients restored with ball or round-bar attachments. In this study, both mandibular and maxillary overdentures retained by a minimum number of implants (2-5) were included. The survival rates were 100% and 75.4%, respectively.

The 5-year prospective randomized study by Gotfredsen and Holm[6] of overdentures retained from 2 implants in the mandible showed a success rate of 100%, which was independent from the attachment system used (ball or bar). These findings were in agreement with previous studies. It appears that the attachment system does not influence the success rate of the implants. Other factors, such as bone quality and quantity, arch morphology and implant length, seem to play far more important roles in implant survival rates.

Marginal Bone Loss

Longitudinal prospective studies[4-6] found no differences in implant survival rates, health of peri-implant tissue, or marginal bone loss between 2 different anchorage systems used on 2 implants retaining an overdenture. A mean marginal bone loss of 0.3 mm within the first year at implants with bars and clips or Ceka attachments was recorded. After the first year, the marginal bone level, attachment level, and Periotest (Siemens AG, Bensheim, Germany) scores hardly changed. It is believed that the direction of occlusal forces is more important than the connection of the implants. The difference in stress concentration between models with and without bars seems also to be small.[7]

Rapid bone loss around fixtures placed in the maxillae (*i.e.,* when O-rings were used as an attachment mode) has been documented too.[8] Nevertheless, it was suggested that further evaluation was needed if bone reaction differed between interconnected and noninterconnected fixtures, and between different attachment systems. However, other studies by Enquist[3] and Palmqvist[9] *et al* have not confirmed these findings. In addition, Palmqvist *et al*[9] could not find any predictive value for implant failure for a variety of superstructures that included both bars and nonconnected attachments. In this study, consideration has been given to a number of variables, such as cross-sectional form (round, ovoid, or parallel), straight *versus* curved bars, and bars with or without cantilevered sections.

It appears that there is no significant difference in mean bone loss between the subjects with ball or bar-retained overdentures. However, there is some evidence that mean bone loss values appear to be higher in subjects with ball attachments.[10] It was speculated that the reason for this loss could be related to differences in loading patterns or bone conditions.

Bone mineral content (BMC) changes in mandibles bearing implant-supported overdentures were also studied and compared to those of the physiologic age-related mandibular BMC.[11] Dual photon bone scanner (dual energy absorptiometry) measurements were performed *in vivo* at the baseline, immediately after attachment insertion, and at 2 and 5-year visits. Results of this study indicated that the increased function after the treatment seemed to cause a load-related bone formation, which minimized the physiologic age-related mandibular BMC. This effect appeared to be independent of the attachment system used.

Pantographic imaging has also been used for bone loss evaluation around mandibular implants with ball attachments, single or triple bar.[12] A 19-month examination revealed that more bone loss occurred around the 2 implants inserted in the central positions for the triple bar group, compared to other modalities. This result was speculated to be caused by unfavorable strains generated in the more rigid triple bar connection, which may have created a cantilever effect. In addition, mandibular distortion during opening can result in changes of the dental arch across the midline, leading to deformation of the structure. It appears that, according to the up-to-date published research, marginal bone loss cannot be related to the use of different attachment systems.

Soft Tissue

Many investigators have also evaluated soft tissue reactions to different attachment systems. Hyperplasia has been observed around implants, while mucositis was found in various maxillary sites.[4] These complications were attributed to the fact that implant-retained dentures usually present excellent retention, preventing a sufficient amount of saliva to enter the area underneath the denture. This effect favors an overgrowth of bacteria, leading to denture stomatitis. It is noteworthy that, although the patients who participated in this study were clearly advised to remove the dentures during nighttime, only half of them did.

Plaque accumulation has been significantly higher for magnets than for ball attachments.[13] However, no differences were recorded between the bar and ball or bar and magnets groups. The observed differences could be attributed to the magnetic field. Bleeding on probing, marginal bone level, attachment level, and Periotest values did not significantly differ among the groups, neither at year 1 nor at year 5. Nevertheless, it is noteworthy that Periotest values were significantly lower at year 5 compared to year 1 for all groups, a fact that probably indicates a higher rigidity at the bone-implant interface. No correlation was found between bleeding on probing and marginal bone loss. Subsequent studies[14] have confirmed the aforementioned results.[6,15-17]

Regarding the ball or bar design, it has been shown that either design does not affect the peri-implant condition. However, another study indicated that there is less bleeding associated with ball attachments when compared to single bar-2 implants or triple bar-4 implants scenarios.[12] The use of ovoid bars with a resilient joint between the denture and bar has also been examined.[16] The results indicated that there is a slightly increased incidence of problems associated with the denture-bearing mucosa. Improvement of oral hygiene measures and adjustment of the dentures in conjunction with the surgical removal of hyperplastic tissue resolved these problems. A significant mean increase in recession of the mucosal cuff was also found on the distal surfaces of the distal abutments in this group of patients. Soreness of the mucosal cuff and hyperplasia around the abutment were reported, occasionally necessitating surgical treatment. More problems were reported in patients whose prostheses were retained with an ovoid bar than in those with parallel-sided bars. Hyperplasia of the mucosa covering the residual ridge under the bar was noted but without any difference in the incidence of these complications between the resilient and rigid attachment designs.

Two studies[17,18] have concluded that implant-supported overdentures may be maintained in a healthy and stable condition, independent of the retentive device used for anchorage. Probably the number of implants used to retain an overdenture does not influence peri-implant health either.[19] In contrast to root overdentures, there is a consensus of opinion regarding implant overdentures, that mucosal enlargements are most commonly found underneath maxillary prostheses. This result is probably because of the fact that the bar is usually placed close to the mucosa because of space limitations.[20] Up-to-date evidence from the literature indicates that peri-implant soft tissue health is not affected by either ball or bar attachments. However, there is published evidence that shows a higher plaque index associated with magnet-type attachments.

Retention

The select attachments for implant-supported overdentures should have enough retentive properties to enhance the stability of the prosthesis. At the same time, the attachments should allow for an easy placement and removal of the prosthesis by the patient. As the number of implants increases, so does the probability for discrepancies in alignments and, as a result, the potential for use of angulated abutments or complex laboratory designs. When a minimal number of implants are placed, the attachments used are subjected to increased stress and wear because of their higher dependence on soft tissue support. By increasing the number of implants, the potential for single axis fulcrum movement decreases and so do the retention-release episodes during function. It has also been proven that as the number of attachments increases, so does the retention. Today, there is a large selection of attachments with different retentive properties. An *in vitro* study[21] on 2 and 4 Hader clips (APM-Sterngold, Attleboro, MA) and ERAs (APM-Sterngold), and ZAAG (Zest Anchors Inc., Escondido, CA) attachments with and without a bar have shown that the lowest retentive values were recorded for the 2 and 4 Hader clip designs.

Retention seems to decrease over time, especially for the most retentive designs. This finding is in contrast with another study,[22] which concluded that even after 1500 pulling cycles, there was no difference in the retentive properties of ERA attachments. A clinical study on the life span of IMZ (Interpore Int., Irvine, CA) system bar attachments proved that is in the range of 12.8 months, without significant loss of retention.[23] Regarding the retentive properties of single attachments when compared to those of bars, there are data[24-26] showing that bars provide more retention. Bars and clips seem to be more retentive for the break load when subjected to both vertical and oblique forces. These attachments also provide the fastest release periods. They can be selected when a high degree of retention is required (*e.g.,* in cases with extremely resorbed ridges without tissue undercuts).

In addition, this design distributes torquing forces more favorably to the implants, because of the splinting effect, and enables the clip attachment to rotate around the implants. This action channels the forces to the 2 implants and edentulous areas when the overdenture is subjected to horizontal forces, which are the most damaging for the implants system. Retentive forces appear to have an effect on long-term success and patient satisfaction. The retentive forces of most attachment systems are in the range of about 20 N.[27] It is assumed that forces of 20 N are probably sufficient for overdentures in the edentulous mandibles.

However, it is probable that there is a quite wide range of retentive properties because forces of 3-85 N have been reported. Published research agrees on the fact that the least retentive attachments are the magnets. Some investigators[25] suggest that these should be used in cases of bruxers because with their use, probably less excessive forces are being delivered to the implants. Patients with dexterity problems may also benefit from less retentive mechanisms. Magnets also proved to be the attachments with the smallest standard deviation of their retentive properties. This fact does not seem to apply to other attaching mechanisms that have different mean retentive forces and standard deviation of retentive values. This is probably because of the fact that the manufacturers of the attachments cannot maintain the same retentive forces during their production. However, it is noteworthy that in all research mentioned, the testing methods were extremely simple when compared to the intraoral conditions. In these *in vitro* studies, forces were exclusively applied in the path of insertion.

Under clinical conditions, loads exerted on attachments are far more complex. Several clinical measurements proved that 3-dimensional loads occur regularly during function. A denture may rotate around an anterior bar, or it may rock slightly, when food is chewed on 1 free-end denture base. These movements can clinically lead to plastic deformation of the matrix portion, resulting in a reduction of retention or fractures of the clip.

To simulate denture movements around a bar during function, Breeding *et al*[28] developed a new experimental design by applying cyclic loads not in the path of insertion, but on the saddles. Their investigation failed to show significant changes in retentive forces, even after 345,600 cycles. Therefore, the results of fatigue tests contradict clinical experience. It is well recognized that attachments of overdentures on implants lose retention after some time. In many instances, it is even necessary to replace the keyway portion of an attachment because it is damaged, broken, or worn. Other factors, such as occlusal forces, for example, could be suspected for the loss of retention.

Stress Distribution

The way stress is applied to implants after osseointegration was one of the first factors considered and studied in implant dentistry. Photo-elastic studies showed that stress distribution is a function of length, geometry, and diameter of implant.[29] Valid comparisons of the stress patterns created by different retentive mechanisms can be made only when the same length, width, and shape of implants is used. Because photo-elastic studies are lab bench simulations that provide 2 dimensional, qualitative information indicating relative stress concentrations and magnitudes, conclusions should be very carefully drawn after considering the limitations of these studies.

Under vertical forces, ball/O-ring attachments seem to transfer minimal stress to implants when compared to bar/clips. The latter tend to create immediate stress patterns of higher magnitude and concentration on the 2-implant mandibular overdenture model. Nevertheless, posterior oblique loads result in similar stress patterns to both systems, with slightly higher stress to the bar-clip overdenture.

Further *in vitro* studies,[30,31] finite element analyses,[32-35] as well as *in vivo* studies,[36,37] have confirmed that ball attachments probably provide higher stability with the load more evenly distributed onto the residual ridges on both sides of the dental arch. This result may be because of the fact that the solitary attachments allow flexure of the mandible. Compressive stresses are possibly reduced if the implants are not connected. Splinting of the implants seems to increase stress transfer, even if the number of the fixtures increases. Different attaching modalities have a detrimental effect on stress distribution. Connection of 4 implants with a cantilevered bar causes the highest stresses to the terminal implant if there is no simulated contact on the posterior edentulous ridge.[38] Spark erosion frameworks appear to cause less stress transfer, followed by the noncantilevered bar and the solitary attachments. However, there is evidence that when there is simulated tissue contact under the extension base, stress transfer to the distal implant is uniformly reduced to a low level. Retention, jaw morphology, and anatomy, as well as patient compliance for recall are probably the recommended parameters for choice of anchorage design.

In vivo studies[39] have confirmed the results of the photo-elastic studies by showing that during chewing, bars with distal cantilevers tend to increase the loads on the most distal implants by more than 3 times. This stress increase is the reason that a concentrated arrangement of implants in the anterior area is not suggested. Instead, a spread arrangement of 6 implants in the anterior, premolar, and tuberosity regions of the maxilla should be preferred.[40] Other studies[41] also confirm that the number, position, and retention of the attachment clips can affect maximum bending moments, while the influence of the stiffness of the clips on stress transfer appears to be insignificant.

Alloy selection for the construction of the superstructure seems also to be important.[40] If a soft gold alloy is used instead of a rigid nonprecious alloy, then the resistance of the superstructure to bending decreases by two thirds. As a result, calculated maximum stress in the cortical bone is about 50% larger compared to the values obtained by the rigid super structure. Important parameters influencing the stress distribution include material properties, such as the modulus of elasticity, geometry of the superstructure, bone quality, and the way these parameters interrelate. The geometry of a superstructure is significantly influenced by some anatomic limitations. Thus, the most important parameter for the rigidity of a superstructure becomes the material used. The use of an alloy with a low modulus of elasticity precludes larger stresses at the bone-implant interface on the loading side than the use of a rigid alloy, for a superstructure of the same geometry. A high risk of mechanical overloading for the terminal implants can be expected when there is a cantilevered segment made from an alloy with a low resistance to bending.

The bar and clips have been introduced as an attachment method because it was speculated that the denture could freely rotate around the bar, thus compensating for the resilience of the supporting mucosa and reducing the torsion forces to the implants. In theory, the 2 implant, single bar attachment should be able to work quite well.[42] However, when more than 2 implants and multiple bars are used between implants, the attachment clips located on each bar are often not parallel to each other, or perpendicular to the posterior ridges. In these situations, the clips can bind in function, thus limiting the movement of the prosthesis.

Contrary to the rationale and theory of free rotation, recent data suggest[43] that even if a bar that allows rotational movement is used, more load will be transferred to the implants because of the difficulty to obtain optimum implant position, which would allow a pure rotational movement. It is believed that an equilibrium should be reached between load at the implant and loading of the denture bearing area, which could potentially cause ridge atrophy. When it is determined the amount of acceptable loading on the critical areas (implants and denture bearing mucosa), overdenture constrictions, which optimally distribute the chewing forces, usually follow. An important part of these designs is the choice of a bar with the optimal degree of stiffness and guidance.

Use of a rigid joint between parallel-sided and/or angular bar and the denture usually places more load on the implants than on the denture-bearing mucosa surfaces.[44] However, it is true that stress transfer initially may be influenced by the impression technique. Selective pressure impression techniques have been used to fabricate fully extended master casts and denture bases. The objective was to distribute the load evenly between the implants and mucosa. Lack of intimate extension base contact with the edentulous ridge can cause high stress transfer to the ipsilateral terminal implant when cantilevered segments are used.

Most of the *in vitro* and *in vivo* studies agree that bars transmit more forces to the implants. However, a clinical study[45] that measured the

Table 1. Vertical Dimension for Different Attachments Used in Overdenture Fabrication

Bars		Stud	
CBS round bar	1.8 mm	Locator	1.5 mm
CM gold round bar	1.9 mm	ZAAG st	2.2 mm
Preci-bar (Dolder) mini	2.3 mm	Shiner mini	2.4 mm
Dolder gold III	2.5 mm	ORS-OD regular	2.5 mm
CBS oval bar	2.5 mm	ZAAG	3.1 mm
Preci-bar (Dolder) pall	3.0 mm	Shiner regular	3.4 mm
Hader EDS short	3.0 mm	Dalla Bonna solid	3.6 mm
Hader EDS titanium	4.0 mm	Dalla Bonna resilient	3.8 mm
Wax bar patterns up to	8.0 mm	ORS-DE	4.0 mm

force transmission onto implants supporting overdentures with piezoelectric transducers found that maximum forces measured in the vertical direction were higher with single telescopes than with bars and clips, and that rigid bars contributed to load sharing between the implants. Although further investigation is necessary, it could be stated that if the prosthesis is well designed and under ideal conditions, there is no significant difference between stud attachments and resilient bar-clip designs, in terms of stress distribution to the implants. At the same time, rigid designs and cantilever bars are more likely to increase the force transmitted to the implant fixtures.

Space Requirements

Overdenture construction necessitates the existence of sufficient room for the accommodation of the attachments (Table 1). Lack of space can result in esthetic problems, fracture of the acrylic resin,[46] or other technical problems. Besides the necessary vertical space for the housing of the attachment, sufficient horizontal space is also critical for the structural integrity of the prosthesis. The use of attaching mechanisms such as the Hader bar-clip and other similar elements requires a distance of about 10–12 mm between the implants.[47] If this space between the implants cannot be guaranteed because of a reduced alveolar bone quantity, then an individually milled bar that fits the specific dimensions should be considered. In this design, the retention is derived from the frictional fit of the overcast implant-supported superstructure. However, placement of additional retentive elements (Ceka, ERA, *etc.*) should be planned. In the vertical axis, a minimum distance of 12 mm from the implant platform to the incisal edges of the incisors should be established, when an average of 3 mm of soft tissue is present above the implant platform. Usually, problems occur when bars are used because they are more difficult to accommodate than other attachments, such as balls or magnets. According to Bidez *et al*,[48,49] the bar length should be limited to the 12–16-mm range if the placement of 2 small vertical O-ring attachments is planned for retention. The authors also believe that span length and stiffener height have probably a more profound role in structural integrity than dental alloy composition used for the bar construction. According to this, if a Hader bar is going to be used, the span length should be ≤18 mm, with a minimum 2-mm vertical stiffener height below the round portion. Extension of the cantilevered segment of a bar more than 10 mm seems to increase the chances of failure.[50] Increasing the cantilever length from 10 to 20 mm is believed to raise the maximum major stress at the superior aspect of the bar to the implant abutment junction by 111%. According to the aforementioned effect, the recommendation would be that the cantilever length should be limited to 10–12 mm, and the stiffener height should be 3 mm if there is enough clearance.

Maintenance and Complications

The consensus of many studies is that maintenance requirements are highest during the first year of service, and they are usually related to alteration of contour and repair of the matrix, or the patrix. However, controversy persists as to whether the bar or stud design requires more maintenance. Maintenance of implant-retained overdentures includes a need for reactivation or replacement of the attachment, as well as relines after placement.[51] The attachment loosening seems to be a common problem after insertion,[24,52-54] while the clip/attachment fracture is another complication with a relatively high rate.[55-57] The need for reline for prosthetic maintenance, in a period of 0.5–1.5 years, ranges from 6.5% to 18%.[8,17] Higher reline rates have also been reported.[52,54,55] It has been suggested[52] that to avoid the frequent fracture of the clip/attachment, a freedom between the bar and clip should exist. However, it is reported that excessive freedom could cause vibration of the denture against the bar, disturbing the patient when talking.

Corrosion, with a subsequent rapid loss of retention and extreme wear of some magnet systems, was identified as another complication.[8] It has also been documented[24] that more appointments after insertion were needed with magnet and ball attachments than for the bar group. These appointments were related to flange adjustments. On the other hand, long-term maintenance of the bars was only restricted by the activation of the retentive clips.

Prosthetic complications also included loosening of abutment titanium screws of ball and bar attachments, whereas wear of the attachments and gold screw loosening were of minor frequency.[4] Besides loosening of the bar screw, another problem was the frequent repair of the keyway retainers.[58] Acrylic resin or denture teeth fractures in implant retained overdentures with metal frameworks do not present a frequent complication. It was speculated that the cast metal framework enhanced the mechanical properties and stability of the dentures.

In a critical literature review of all relevant articles from 1988 to 1999, Payne and Solomons[59] concluded that there appears to be a need for a more uniform, consistent classification with solid criteria for determining prosthodontic success, in terms of maintenance and complications associated with mandibular overdentures. The prosthodontic requirements of mandibular overdentures have yet to be determined. According to Payne *et al*,[60] a treatment of implant overdenture, where marginal integrity and associated patrices/matrices are maintained regardless of modifications, as long as it continues as an implant overdenture, should be considered as a repair. These investigators consider the clinical situation in which the overdenture is no longer serviceable because of either implants failure or irreparable mechanical breakdown.

There are reports that favor ball attachments toward bars, in terms of maintenance requirements.[61] However, maintenance of ball screws, and especially of magnetic keepers, is high. It is noteworthy that time and cost of matrix maintenance are paramount for the restorative dentist. It has been recommended that O-rings should be changed either annually, or biannually, depending on the number of implants used.

During a prospective 5-year multicenter study,[62] it was found that clip adjustments occurred in 47 of 76 cases (61.8%), on 111 occasions (32% of them in the first year). Clip fracture occurred in 25 of 76 cases (32.8%) on 39 occasions (9% in the first year). A retrospective study[63] of problems of implants prostheses agreed that the most frequent repair involved retentive clips (25%), although some of the data were combined with maxillary cases. The same investigators reported that 55% of the clinician's time would be involved in replacing retentive elements.

The influence of the interabutment distance on patrix and matrix component maintenance has not been investigated thoroughly. There is some clinical evidence[45] suggesting that the distance between the abutments should be no less than 8–10 mm. This space facilitates proper placement of the clips. When the bar segment becomes shorter, there is a higher possibility for clip loosening in the acrylic resin.

Parallelism of implants also appears to be important for the prevention of future maintenance problems. It has been reported[64] that a divergence of about 10° can usually be tolerated. Higher divergences or convergences will usually result in excessive wear. Other possible complications include bending moments, interferences with denture construction by preventing a common path of insertion with individual attachments, or plaque control complications. A significant number of repairs (usually to the matrix itself) was found when implants have a lingual angulation more than 6.0°, or a facial inclination more than 6.5°, which is usually the inclination of the lower incisor teeth.

Activation of the clips seems to be a frequent maintenance problem.[53] Other complications are the fracture of the clips and relining of the prostheses. The biggest maintenance problem of the stud and magnet attachments is the need for the stud part to be retightened.[65] Loose stud attachments can cause further problems, including screw fractures. However, it is not clear if these problems apply also to 1-screw attachments.

Another maintenance complication is the screw loosening. Slotted gold screws used to secure the gold cylinders and the bars become loose quite often.[16] Recent developments of screw technology may contribute to the decrease of screw loosening rates. Other denture related problems include adjustments of the retaining sleeves around the bar and fracture. Metal reinforcement has been proposed as method to overcome fracture problems in bar overdentures.[5]

Regardless of the attaching mechanism used, it seems that prosthodontic maintenance is higher during the first year. A prospective randomized 3-year study[66] revealed that 70% of the retention clips in the 2-implant design needed activation as compared to the 44% of those with the 3 or 4-implants designs. Some other interesting facts are that retention clip fracture occurred in 30% of the patients with 3 or 4 implants and 16% of those with 2 implants. Relining of the overdentures (regardless of the design) proved to be an excessive maintenance burden in 40% of the cases. No difference was found in terms of abutment screw loosening.

A comparison of ball and bar designs for mandibular overdentures[6] revealed a significantly higher number of complications and/or repairs for the bar group. Most of the instances occurred during the first year of function. In the following years, no significant differences were registered. The mean frequency of complications/repair per patient per year was 1.0 in the bar group and 0.6 in the ball group during a 5-year observation period. The most frequent adjustments were the activation of the matrix in the prosthesis for the ball group and clip activation of the prosthesis for the bar group. There were 4 overdenture fractures registered for the bar group *versus* 2 for the ball group. Of the patients, 6, including 2 from the ball group and 4 from the bar group, thought that the opposing denture was less retentive after implant therapy than before. A very strict hygiene program was encouraged, which influenced positively the peri-implant outcome in both groups.

Contrary to the results of previous researchers, a retrospective[16] and a randomized[67] clinical study documented more complications associated with the ball than for the bar/clip attaching mechanisms. According to these studies, matrix parts of single implant attachments were changed with a higher frequency than retainers of bar connectors, which could be activated when the retentive forces became inadequate. Regarding the maintenance of the implant-retained overdentures, the following conclusions can be drawn:

1. There is still some controversy as to whether bars or stud attachments need more maintenance.
2. Most of the complications and/or maintenance occur within the first year, which may be explained by the fact that the prosthesis needs some time to "settle down" in the mouth and work in the oral environment without problem.
3. Correct placement of the implants affects the maintenance of the attachment systems and, therefore, should be very carefully planned.

4. Magnetic keepers appear to corrode and lose their retention easier.
5. Depending on the interocclusal space, metal reinforcement of the denture is advisable.

Patient Satisfaction

Clinical studies[68,69] have concluded that there is no significant difference in patient satisfaction either by ball or bar/clip attaching mechanisms. It seems that treatment using 2 implant ball attachments is sufficient in most of the mandibular cases. ERA attachments on single implants proved to be as efficient as Hader bars, in terms of patient satisfaction.[70]

It has been documented[15] that the first year is the most critical regarding complications for both ball and bar/clip systems. Phonetic and functional problems seem to decrease after this period, while patient comfort becomes higher. However, patients who had an upper complete denture opposing a mandibular implant overdenture reported that they had poor control of the maxillary denture.[5,71]

Spark erosion technique frameworks have also been examined[72] in regard to patient satisfaction, and they proved to be a good alternative to the ball or bar/clip attachments. Preliminary data collected from a clinical trial were reviewed to assess the results from 25 spark eroded implant retained overdentures placed in 24 patients. After 13.3 months of function, most of the subjects were overall satisfied with their prostheses. Complications encountered were associated with acrylic resin and denture teeth fractures, as well as some retentive component failures. Nevertheless, these complications were easily repaired.

Although the aforementioned attachments perform rather well, magnets are associated with retention problems and other prosthetic complications, such as frequent exchange, wear, and corrosion.[14,24,73] As a result, many patients rehabilitated with magnet-retained overdentures were not satisfied. It can probably be concluded that there is no difference between the bar and ball attachment methods. Both of these mechanisms seem to satisfy patients more than the magnets.

Selection Criteria

Treatment planning and selection of the attaching mechanism for an implant-retained overdenture should consider the following: (1) cost effectiveness, (2) amount of retention needed, (3) pain caused on the soft tissue, (4) amount of available bone, (5) expected level of oral hygiene, (6) patient's social status, (7) patient's expectation, (8) maxillomandibular relationship, (9) status of the antagonistic jaw,[12] and (10) inter-implant distance.[5]

Conclusion

A review of the current literature regarding the influence of the attachment mechanisms on the outcome of the implant-retained overdenture treatment has been presented for the clinician to understand the differences and disadvantages of each method. Because each clinical situation is unique, all the previously discussed parameters have to be studied carefully to fulfill the patient's needs and expectations, as well as establish a long-term biologic and functional result.

Disclosure

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Befestigungssysteme für Implantatgehaltene Deckprothesen: ein Überblick über die Fachliteratur

ZUSAMMENFASSUNG: Der vorliegende Artikel vergleicht die unterschiedlichen Befestigungssysteme, die als Halterung und Sicherung von sowohl Ober- als auch Unterkieferprothesen bei komplett zahnlosen Patienten fungieren. Eine eingehende Untersuchung der dazu bestehenden Literatur, basierend auf einer MEDLINE-Suche und begrenzt auf die zwischen 1988 und heute veröffentlichten englischsprachigen Artikel, wurde durchgeführt und eine groβe Anzahl von unterschiedlichen, auf dem zahnfachärztlichen Markt erhältliche Befestigungen im Hinblick auf verschiedene Faktoren unter die Lupe genommen. Zu den Kriterien zählten 1) die Überlebensquote der eingesetzten Implantate, 2) der marginale Knochengewebsverlust, 3) die am Weichgewebe auftretenden Komplikationen, 4) Retention, 5) Stressverteilung, 6) Platzbedarf, 7) Erhaltungsschwierigkeiten, und 8) Patientenzufriedenheit. Diese Faktoren werden für ein erfolgreiches Behandlungsergebnis sowie die langfristigen guten Erhaltungschancen einer Prothese als maβgeblich erachtet. Zuvor in der Literatur veröffentlichte Auswahlkriterien werden ebenfalls im Artikel vorgestellt. Produktnamen und Hersteller finden nur dann Erwähnung, wenn diese in Verbindung mit bestimmten Befestigungssystemen stehen, wie sie im Originalartikel aufgeführt werden.

SCHLÜSSELWÖRTER: Befestigungen, Implantatgehaltene Deckprothesen

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Sistemas de retención de sobredentaduras retenidas por implantes: Una revisión de la literatura

ABSTRACTO: Este artículo presenta una comparación entre diferentes sistemas de retención que se usan para retener y apoyar las sobredentaduras maxilares y mandibulares en pacientes completamente edentulosos. Se realizó un análisis de la literatura basado en una búsqueda en MEDLINE limitada a artículos en idioma inglés publicados desde 1988 hasta el presente y se evaluaron una gran cantidad de aparatos disponibles en el mercado dental con respecto a varios factores. Los mismos incluyen: 1) tasa de supervivencia del implante, 2) pérdida marginal del hueso, 3) complicaciones de los tejidos suaves, 4) retención, 5) distribución de la tensión, 6) requisitos de espacio, 7) complicaciones del mantenimiento y 8) satisfacción del paciente. Estos factores se consideran esenciales para el resultado exitoso y el pronóstico positivo a largo plazo de la prótesis. El criterio de selección previamente presentado en la literatura se explica también. Los nombres y fabricantes de los productos se mencionan solamente si se relacionan con los sistemas de retención como se citan en los artículos originales.

PALABRAS CLAVES: accesorios con bola, sobredentaduras retenidas con implantes, barras, presillas, imanes

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Sistemas de Attachment para Sobredentaduras Retidas por Implante: Revisão da Literatura

RESUMO: Este artigo apresenta uma comparação entre diferentes sistemas de attachment usados para reter e suportar sobredentaduras maxilares e mandibulares em pacientes completamente desdentados. Foi realizada uma revisão da literatura baseada numa busca em MEDLINE limitada a artigos em língua inglesa publicados de 1988 até o presente, e um grande número de attachments disponíveis no mercado dentário foi revisado com relação a vários fatores. Estes incluem: 1) taxa de sobrevivência do implante, 2) perda óssea marginal, 3) complicações do tecido mole, 4) retenção, 5) distribuição de tensão, 6) requisitos de espaço, 7) complicações de manutenção, e 8) satisfação do paciente. Estes fatores são considerados essenciais para o resultado bem-sucedido e o bom prognóstico de longo prazo da prótese. Critérios de seleção previamente publicados na literatura também são discutidos. Nomes e fabricantes do produto são mencionados apenas se relacionados a sistemas de ligação, já que são citados nos artigos originais.

PALAVRAS-CHAVE: attachments de esferas, sobredentaduras retidas por implante, barras, grampos, ímãs

インプラント支持オーバーデンチャーの装着システム；文献研究

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要約：本論文では、上下顎オーバーデンチャーを完全無歯の患者において固定支持するために使用される異なるアタッチメントシステムが比較される。1988年から現在までに出版された英語論文を対象としてMEDLINEサーチに基づく論文調査が遂行され、歯科業界に出回る多数のアタッチメントがいくつかのファクターに基づいて評価された。これらのファクターには、1) インプラント生存率、2) 辺縁骨喪失、3) 軟組織合併症、4) リテンション、5) 応力配分、6) 必要な空間、7) 管理上の合併症、8) 患者満足が含まれていた。これらのファクターは、補綴の成功と長期間の良好な予後にとって不可欠なものと考えられる。また、過去に出版された文献に使われていた選択条件についても論じられた。製品名と製造者名は、それがアタッチメントシステムにつながりがある場合にのみ、元の論文の形で使用された。

キーワード：アタッチメント、インプラント支持オーバーデンチャー

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