Implant retention systems for implant-retained overdentures

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In brief

Provides an overview on a variety of implant retention systems.

Informs the reader on the factors that may guide the decision-making process of selecting an implant retention system.

Highlights the literature assessing patient satisfaction and prosthodontic maintenance with a variety of implant retention systems.

Implant retained overdentures are being increasingly utilised in both general and specialist practice to rehabilitate patients with missing teeth, particularly those that are edentate. This article aims to inform the reader of a variety of retention systems that are available to retain an implant overdenture and to understand how these systems work, their advantages and disadvantages and to outline some of the clinical and treatment planning considerations involved in selecting the most appropriate retention system for patients.

Introduction

There are a number of tooth replacement options available to replace missing teeth. One of the potential options available to patients is the use of an implant-retained prosthesis. An implant-retained overdenture is a removable prosthesis that is retained by implants and can be utilised to restore both edentate and partially dentate patients. Implant-based rehabilitation can either be fixed or removable, although the advantages of fixed implant restorations are undisputed, there are many patients wherein a fixed implant rehabilitation may not be desireable.[1]

Removable implant-retained restorations might be considered a better treatment option to fixed in patients with excessive ridge resorption which has led to the loss of facial support of the lips and soft tissues of the face; inadequate access/ability to maintain good oral hygiene around the implants/prosthesis; where the number, positioning or angulation of the implant fixtures are inadequate for a fixed reconstruction; when multiple surgical procedures such as bone grafting is contraindicated; and when the financial expense and time are restricted.[2,3]

Implant-retained overdentures are a well-recognised treatment modality particularly in the restoration of edentate patients with studies showing superior patient-based outcomes of implant-retained complete overdentures in comparison to conventional complete removable prosthesis.[4,5] It has been demonstrated that implant-retained overdentures have improved retention and stability when compared to conventional dentures.[6,7] Retention is one of the most important factors for determining patient satisfaction with removable prostheses.[7]

Implant-retained overdentures may reduce residual ridge resorption and improve chewing function, nutritional status, speech and patient confidence.[6,8,9] This superiority was reflected in the McGill Consensus[8] and the York Consensus[10] which stated that the treatment of choice for an edentulous mandible should be a two-implant-retained overdenture.

The provision of dental implants within the NHS is guided by a document put together by the Royal College of Surgeons of England.[11] This guidance document outlines which patient groups may be considered for access and funding to dental implant placement within NHS services, this includes patient groups such as those that have undergone ablative surgery for head and neck cancer, patients with developmental conditions resulting in deformed and/or missing teeth, patients with localised or generalised aggressive periodontitis in the absence of secondary factors (for example, smoking) when the disease is stable, and in patients with severe denture intolerance.[11]

The use of implants to retain a removable prosthesis are indicated in patients who have altered denture bearing anatomy (for example, as a result of trauma or after surgery particularly for head and neck cancer),[12,13] patients with severe hypodontia/anodontia[11] patients with an inability to tolerate/control conventional removable prostheses such as patients with neuromuscular disorders,[11,14] or as a result of severe residual ridge resorption which commonly occurs as a result of historic tooth loss and/or periodontal disease.[13,15] They are also indicated when a fixed implant reconstruction is contraindicated.[13]

Categorisation

There are a variety of implant retention systems which can be utilised to retain an implant overdenture. These systems are comprised of two parts; one part connected to the implant directly or via a bar and the other within the prosthesis.

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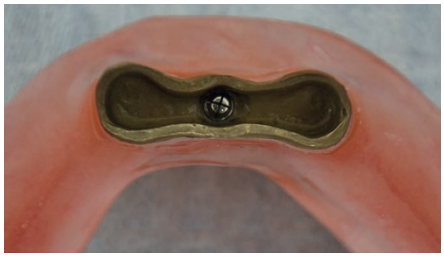

Fig. 1 A rigid attachment with a cast gold housing and Ceka Revax (M3) Attachment

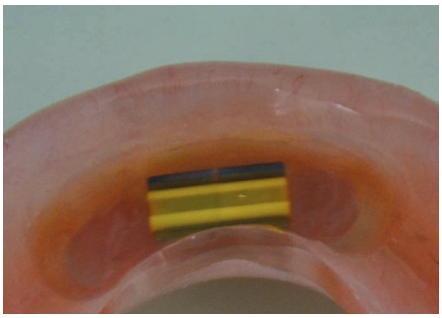

Fig. 2 A Resilient attachment with a Ceka Preci-Horix (yellow) attachment

Fig. 3 Splinted implant attachment system with a Cast Gold Dolder bar splinting two implants together

Fig. 4 Free standing implant attachment system with use of Locator Abutments

These systems can be categorised in a variety of different ways:

1. Rigidity of the retentive components
2. Whether the implants utilised are splinted together or not
3. The level of retention and support attained from the implants and soft tissues. Implant-retained overdenture vs implant-supported overdenture.

The components can be described on the rigidity of the retention systems and can either be categorised as rigid or resilient attachments.[16] Rigid attachments are those that allow no movement of their component parts during function[17,18] which includes the direct attachment onto a bar (Fig. 1). Whereas, resilient attachment allows a pre-calculated amount of movement when the attachment is fully seated and serves to distribute potentially harmful forces,[17,18] this includes clips, ball attachments, Locator® and magnets (Fig. 2). These resilient attachments can be used on their own or used as a secondary retention system in combination with a bar.[19]

The retentive system can also be categorised as to whether the implants are splinted together or free standing.[16] Splinted implants utilise some form of interconnected bar, of which there are many designs, (Fig. 3) to connect/splint the implants whereas free standing are not directly linked together (Fig. 4). Some authors define this slightly differently and believe there is some form of splinting of the implants utilised in an implant-retained overdenture and can be described as either primary or secondary splinting. Primary splinting is when there is direct splinting of the implants with an interconnected bar, whereas secondary splinting described free-standing implants that are involved in the retention of the overdenture with the overdenture stabilising the implants.

The original concept of splinting the implants was to distribute the stresses and protect the bone implant interface,[20] however, this is now shown to be unnecessary with current evidence suggesting that splinted or free-standing implant-retained overdentures are just as effective. A systematic review by Stoumpis *et al.*[21] (using studies with at least three years of follow up) reported that there was no significant difference in implant survival rates between splinted and unsplinted designs. It also found that peri-implant outcomes (which included peri-implantitis) and patients' general satisfaction between splinted and unsplinted designs showed no significant difference.[21]

The third classification sub-categorises the prostheses as an implant-supported overdenture or an implant-retained overdenture. An implant-supported overdenture is solely supported by the implants and the underlying mucosa is not loaded,[22] this would normally require at least four implants. Whereas an implant-retained overdenture is retained by the implant attachment system but supported by the underlying denture bearing tissues.

Systems and forces

Implant overdenture retention systems have varying degrees of retention.[23] Manufacturers supply technical information on the amount of retention for the system, with the majority of systems allowing varying degrees of retention that can be utilised.

The retention of the attachment systems is hugely variable. A wide range of retentive forces for different attachment systems are available.[23–25] Some studies have shown that there is variation in retention when using the same attachment system.[26,27] It is also well reported that these attachment systems decrease in retention over time.[20]

Several factors can influence the retentive force of the attachment systems and wear of these systems which includes: the implant and attachment angulation, inter-implant distance, the direction of applied dislodging forces, material, design, dimension, and mode of retention of the attachment systems.[29]

Attachment systems

The most suitable retention system should be hygienic, able to atraumatically and evenly distribute stresses both mechanically and biologically.[24] They should retain the prosthesis but should be easily removed and placed by the patient. They should also be easy to adjust/replace components as and when they fail.

Selection of the most appropriate attachment system for the patient relates to a variety of factors that must be identified early in the treatment planning process. These factors include the following:

- Implant number
- Implant position
- Loading of the mucosa – implant retained vs implant supported overdenture
- Oral hygiene
- Costs
- Prosthetic space
- Inter arch space
- Patient specific factors
- Movement of the denture and stress distribution
- Maintenance.

Implant number

It is generally accepted that in the mandible two interforaminal implants are the minimum number of implants required to provide a complete implant-retained overdenture.[8,10,30] Unless the implants are very short (8 mm or

Fig. 5 Sub-optimal implant positioning means that 2 implants cannot be utilised as part of the Atlantis ISUS Milled bar. If the additional two implants had been used the retention of the prosthesis would have been reduced as the retentive clips would have been too narrow

Fig. 6 Milled rectangular titanium bar on four implants with three Locator attachments to retain and support an implant supported rather than retained overdenture

Fig. 7 Soft tissue hyperplasia around Locator attachments as a result of poor oral hygiene

less) or they are severely divergent (more than 20 degrees), they need not be splinted.[31] It has been reported that a single mid-line mandibular implant can be successfully used to retain a mandibular implant-retained overdenture.[32,33] This is a promising option, however, the studies are only short term so further long-term evaluation is required and goes against the current consensus.[8,10] In the maxilla more implants are required to retain an implant-retained overdenture with four to six implants recommended.[7,30,34] A recent systematic review by Raghoebar *et al.*[35] aimed to address the lack of consensus regarding implant-retained overdentures in the maxilla and found that an implant-retained maxillary overdenture retained by four or more implants with splinted anchorage had higher implant and overdenture survival rate (both >95% per year), while there is an increased risk of implant loss when ≤4 implants with non-splinted anchorage is used.[35] The current consensus would therefore suggest that at least four implants in the maxilla are required which are preferably splinted together. However, there are cases reported in the literature that show successful rehabilitation of the maxilla with less than four implants, however, this goes against the current body of evidence.[36,37]

Implant position

The final location of the implant in relation to the bone and the prosthetic teeth will help decide the type of attachment system used. This should be determined at the treatment planning phase before the placement of implants.

Where a pre-existing satisfactory prosthesis is unavailable fabrication of a conventional prosthesis with ideal tooth position will help determine appropriate implant position.

In order for the individual attachments to provide adequate retention, all the implants need to be placed as parallel to each other as possible (Fig. 5).[24,38]

The inter-implant distance also needs to be considered. Splinting of the implants with a bar should not be carried out when the inter-implant distance is excessive as the forces generated on the bar may be excessive, particularly as bars have been shown to transmit more forces to the implants.[39] The dimensions of bar (length, width, height and curvature) should not exceed the manufacturer's recommendations to ensure structural integrity of the bar, implants and prosthesis.

The anterior-posterior (AP) spread should also be contemplated during the planning stages. This is the distance measured from the most anterior implant in the arch to the most posterior implant. With regards to implant-retained overdentures the AP spread has a bearing on the overall stability of the denture.[2] In general, the greater the AP spread of the implants the less AP movement that occurs with the prosthesis. This needs to be factored into the decision-making process when selecting the retention system modality.

Loading of the mucosa – implant-retained vs implant-supported overdenture

Implant overdentures can either be supported by implants or the underlying mucosa. Where an implant overdenture is soley supported by implants and does not load the underlying mucosa/denture bearing tissues they are termed 'implant-supported overdentures' and use a rigid attachment system to achieve this (Fig. 6).[40] This is in contrast to an 'implant-retained overdenture' that is fully supported by the underlying mucosa but retained by an implant retention system (Fig. 4).

Where an implant-supported overdenture is utilised it must be supported by an adequate number of implants in an ideal position. Costs for this type of restoration are higher than standard implant-retained overdenture prostheses, however, the satisfaction of patients is also been shown to be higher.[40] It has been shown that these prostheses have fewer post-operative visits for adjustments and un-scheduled appointments, and are an attractive choice for some patients and clinicians.[41,42]

Where patients have favourable denture bearing anatomy which can be covered and loaded with the base plate of the denture and provide a stable prosthesis, any retentive implant attachment system can be utilised. However, in patients with unfavourable denture bearing anatomy such as shallow vestibules, atrophic ridges, those patients who have suffered trauma or treatment for oral cancer[43] or have vulnerable soft tissues, such as xerostomic patients, patients after surgery or radiotherapy, mucous membrane disorders and patients with prominent anatomy such as the mental nerve, a specifically designed bar can be used to support the prosthesis as an implant-supported prosthesis[44,45,46] and prevent loading on unfavourable tissue or loading vulnerable soft tissues to make the prosthesis more comfortable for the patient.[47] Stability of the denture can also be improved with extension of the bar posteriorly with use of distal implants or distal cantilever of the bar structure,[44,48] however, this needs to be carefully planned and executed.

Oral hygiene

Any retention system selected will retain plaque to varying degrees. Bars/splinted attachments, due to their design, are more challenging for patients to clean and maintain and have been shown to be prone to mucosal hyperplasia (Fig. 7) around the implants.[40] For some patients a free-standing attachment system can be easier to clean and maintain and this should be contemplated in the treatment planning process.

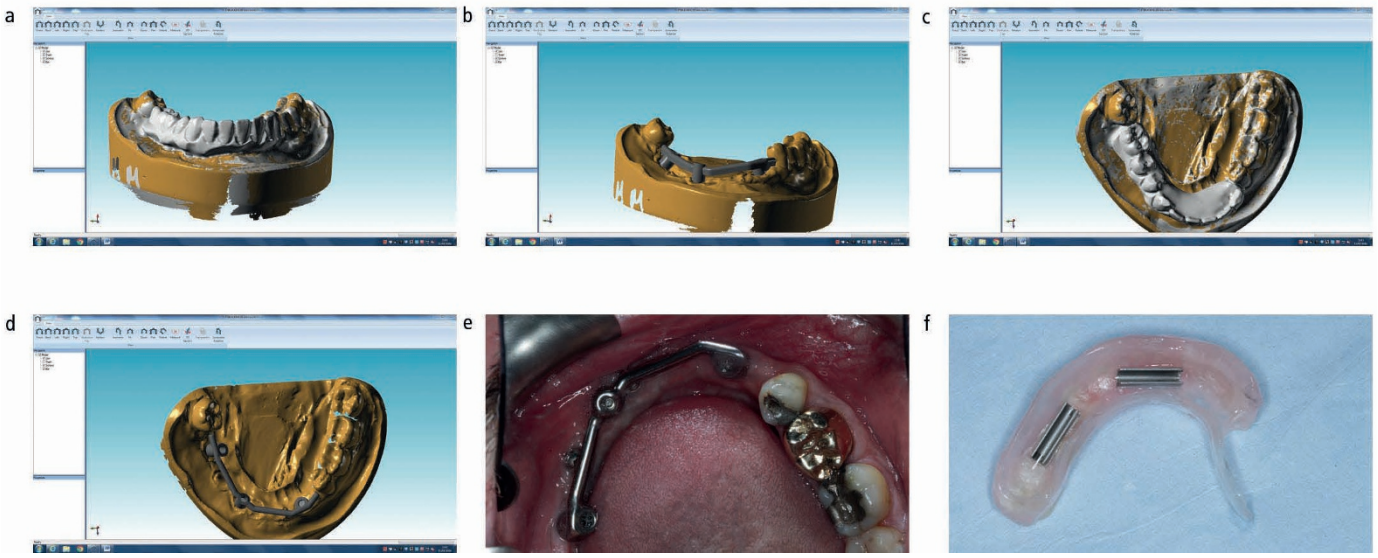

Fig. 8 An Atlantis ISUS Milled Titanium Bar designed using Atlantis Viewer software. The fabricated Atlantis ISUS Milled Titanium Bar and the prosthesis with prefabricated Titanium matrices (Straumann) to retain the bar

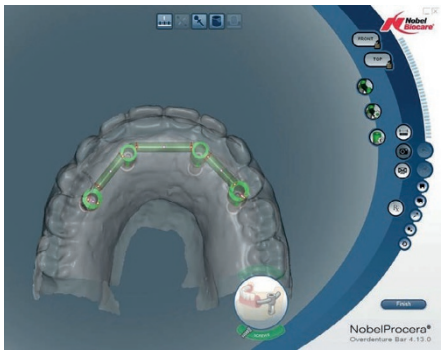

Fig. 9 Design stage for construction of a Dolder bar within prosthetic envelope using Nobel Biocare CADCAM software, note the prosthesis has been scanned into the system to ensure the bar sits within the prosthetic envelope and there is adequate space to restore the bar

Costs

The overall construction costs of an implant-retained overdenture can vary widely. The different attachments systems vary in costs but generally a bar-retained implant overdenture is more expensive to fabricate than an implant-retained overdenture retained by free-standing abutments.[7] The cost should be discussed with the patient at the outset of treatment as cost can dictate the patient's decision process.

The patient should also be aware of the cost of maintenance, which will include regular replacement of components/attachments and regular professional maintenance of the prosthesis and the implants.[30,40,49]

Prosthetic space

The prosthodontic space should be analysed 3dimensionally to analyse the available space to accommodate the implant attachment system. This space is bound in a vertical direction by the position of the occlusal plane to the denture bearing tissues and in a horizontal plane by the facial tissues and the tongue.[50] Where there is concern with the amount of space available, construction of a conventional removable prosthesis during the implant treatment planning stage can help analyse the amount of space available before implant placement and a decision on the implant retention system to be utilised. Different attachment systems require varying space requirements. It is important that there is adequate space to appropriately support the attachment system within the prosthesis and ensure the prosthesis is thick enough to resist fracture within a vertical and horizontal plane. The attachment system should also be in the correct position to allow the prosthesis to be in an ideal prosthodontic position such as within the neutral zone and also the ideal positioning of the teeth and acrylic to provide optimal denture aesthetics.

A reported minimum space requirement in the vertical plane (interocclusal space) from the platform of the implant to the opposing occlusion for implant-retained overdentures with Locator attachments is 8.5 mm,[31] an implant-retained overdenture with a bar requires 13–14 mm and an implant-retained overdenture with other free-standing attachments is 10-12 mm which can be assessed clinically.[51] Another method to assess whether there is sufficient space for the attachment system is the use of CAD-CAM software used to design some of the attachment systems, particularly customised attachments such as bars. The software can be used to overlay the proposed denture onto the bar to assess the available space and also ensure the adequate thickness and thus the integrity of the materials being used, whether that be the proposed bar or denture (Figs 8 and 9).

However, this can vary for each implant attachment system and it is appropriate to check the manufacturer recommendations and discuss with the dental technician to ensure there is adequate space available.

Movement and stress distribution

The different attachment systems allow different movements of the prosthesis; this movement can be vertical, horizontal or rotational.[19] Rigid attachments have been shown to distribute increased forces to the implants in comparison to resilient attachments.[39] It is important to appreciate how the prosthesis moves when the prosthesis is in function. If it has not been designed to move freely about an axis then premature replacement of the attachments will be required or breakage of components will ensue.[40]

Maintenance

An appropriate maintenance regime will improve the longevity of both the prosthesis and the implants. Common maintenance requirements include retentive mechanism replacement and denture base relines. Occasionally

Fig. 10 Showing a small sectional cobalt chrome strengthener within mandibular overdenture and a more extensive cobalt chrome lingual veneer used to reinforce implant retained overdenture in a patient with a history of base plate fracture and a Maxillary overdenture with horseshoe palate and metal stengthener

Fig. 11 Prefabricated Gold dolder bar on three implants

denture bases can fracture under occlusal load. This can be prevented with cobalt chromium strengtheners within the base plate although naturally this increases costs (Fig. 10).

In general, any retention system used requires some form of maintenance whether that be adjustment, modification or replacement (see Table 1).[7,21,39,52-55] When reviewing the literature on the type of retention system and maintenance issues in general, ball and socket and magnet systems appear to have greater maintenance issues in comparison to other retention systems (see Table 1).[39,53,54] When comparing splinted and unsplinted implant-retained overdentures it has been shown that unsplinted attachments tend to have more prosthetic maintenance issues,[7,21] however, in the authors' opinion these issues tend to be simpler, quicker, cheaper and easier to address than prosthetic maintenance issues associated with splinted designed implant-retained overdentures.

When comparing maxillary and mandibular implant-retained overdenture and maintenance issues there appears to be contrasting evidence. A systematic review by Andreiotelli *et al.*[52] reported that there is evidence to suggest a lower rate of implant survival and a higher frequency of prosthetic complications for maxillary implant-retained overdentures,[52] however, a systematic review by Cehreli *et al.*[53] showed comparable maintenance issues in both the maxillary and mandibular implant-retained overdentures.[53]

The majority of complications and/or maintenance issues appear to occur more frequently within the first year and one of the major factors relating to maintenance issues associated with the attachment system is related to correct positioning of the implants[34] and, therefore, implant positioning should be very carefully planned.

Bars

Bars may be rigid or resilient, depending on the attachment system used. Bar systems are generally in one of three types:

1. Direct retainers – such as the Hader or Dolder bar systems (Fig. 11)
2. Bars with secondary attachments – such as Locator ® (Zest Anchors LLC, California, USA) (Fig. 6) or Clix bar (CEKA© & PRECI-LINE©, Belgium) attachments

Table 1 Studies reporting on patient satisfaction & prosthodontic complications of implant retention systems (cont. on page 352)

Author (year)	Follow Up	Retention System	Patient satisfaction	Prosthodontic maintenance
Cakarer (2011) 54	41 months	Ball vs Bar vs Locator	Not reported.	The locator system showed superior clinical results than the ball and the bar attachments, with regard to the rate of prosthodontic complications. 14 complications in the ball attachment group and 7 complications in the bar group were observed. No complications were observed in the locator group.
Cune (2005)75	1 year	Ball vs Bar vs Magnet	Patients strongly preferred bar-clip (10/18 subjects) and ball-socket attachments (7/18 subjects) over magnet attachments (1/18 subjects).	Not reported.
Cune (2010)76	10 years	Ball vs Bar	No difference in satisfaction between ball-socket- and bar-clip-retained two-implant mandibular overdentures groups.	Not reported.
Davis (1999)83	5 years	Magnet vs Ball	Both attachment mechanisms provided patient satisfaction, although the ball attachments were better in this respect than the magnets.	No statistical difference between the 2 groups for post insertion maintenance.
Davis (2000)84	3 years	Ball vs Bar vs Magnet	Not reported.	The bar attachment mechanism required 9 episodes of maintenance, compared to 38 for the ball attachment mechanism and 23 for the magnet attachment mechanism.

Table 1 Studies reporting on patient satisfaction & prosthodontic complications of implant retention systems (cont. from page 351)

Author (year)	Follow Up	Retention System	Patient satisfaction	Prosthodontic maintenance
Ellis (2009)[77]	6 months	Ball vs Magnet	Patients' general satisfaction with ball attachment retained overdentures was greater than that for magnetic attachments.	Not reported.
Gotfredsen (2000)[85]	5 years	Ball vs Bar	Not reported.	Frequency of technical complications/repairs per patient was higher around bars than ball attachments.
Karabuda (2008)[86]	40 months	Ball vs Bar	No significant difference between the 2 attachments types used for implant-supported overdentures with respect to patient satisfaction.	Not reported.
Kleis (2009)[87]	1 year	2 types of Ball vs Locator	Patients' oral health-related life quality showed no significant difference among the three experimental groups.	Overall the Locator attachment system showed a higher rate of maintenance than the ball attachments. The Locator system brought up 34 prosthetic complications, especially the need for change of the male parts or activation because of loss of retention. The TG-O-Ring patients showed 14 complications, most of them the change of the O-Rings. The patients with the Dal-Ro abutment had seven minor complications.
Krennmair (2008)[88]	42 months	Round bar vs Milled bar	Not reported.	Rigid anchorage using milled bars and a metal-reinforced denture framework required less prosthodontic maintenance, than resilient denture stabilization using multiple round bars without a rigid denture framework.
Krennmair (2012)[78]	1 year	Ball vs Locator	There were no differences between ball or Locator attachment for any items of satisfaction evaluated and neither attachment had a significant patient preference.	Although the overall incidence rate of prosthodontic maintenance did not significantly differ between both retention modalities, the Locator attachment required more post insertion aftercare (activation of retention) than the ball anchors.
Krennmair (2011)[89]	5 years	Ball vs Telescopic crown	Patient satisfaction scores did not differ between the two retention modalities used.	Although the frequency of technical complications was initially higher with ball attachments than with resilient telescopic crowns over a 5-year period, similar frequencies of maintenance efforts may be anticipated for both retention modalities.
MacEntee (2005)[55]	3 years	Ball vs Bar	There were no notable satisfaction differences between the 2 attachment mechanisms.	Almost all repairs (90%) occurred in the ball-spring group to correct problems with the attachments. 6.7 repairs per person in the ball-spring group, compared to 0.8 in the bar-clip group ($P < .001$).
Naert (2004)[90]	10 years	Ball vs Bar vs Magnet	The ball group scored best in relation to patient satisfaction.	In the ball group, need for tightening of abutment screws was the most common mechanical complication; in the magnet and bar groups, respectively, the most common complications were wear and corrosion, and the need for clip activation.
Timmerman (2004)[67]	8 years	Ball vs Bar vs 4-implant triple bar	Participant satisfaction concerning retention and stability of the mandibular overdenture had decreased significantly in the two-implant ball attachment group, whereas the opinion of participants in the single- and triple-bar groups was still at the same level.	Not reported.
Walton (2002)[91]	1 year	Ball vs Bar	Patients were equally and highly satisfied with the improvements in function, comfort, and appearance with both types of attachment system.	Approximately 84% of patients with ball-attachment dentures needed at least 1 repair, versus 20% of those with a bar-clip mechanism. The most common repairs were replacement of the cap spring or cap for the ball-attachment and replacement of a lost or loose clip for bar-clip dentures.
Zou (2013)[92]	3 years	Telescopic crown vs bar vs Locator	Not reported.	The locator system produced superior clinical results compared with the telescopic crown (TC) and bar attachments. The number of prosthodontic maintenance visits revealed eight complications in the TC group, seven complications in the bar group, and four complications in the locator group.

3. Offset attachments – such as the Sagix (CEKA© & PRECI-LINE©, Belgium).

The shape of the bar is indicated by the amount of room available, by the shape of the alveolar ridge, and the type of attachment system to be used. The bar super structure can also be extended without direct implant support as a cantilever design, but this needs to be very carefully planned with a good understanding and appreciation of the movement of the denture and the forces and stresses being imparted.

There are a variety of bar designs and these can be classified in a variety of ways which include the attachment system on to the bar and the manufacturing process, but also predominately the cross sectional shape of the bar.

The most common bar designs related to cross section include the Hader bar/MPClip bar which in cross section is straight with a rounded superior aspect. The Dolder bars which can either be egg shaped or Ushaped with parallel sides (Fig. 12) and the Ackermann bar or round bar which are round in the cross section.

The cross section of the bar will affect the attachment system that can be used and will also dictate the degree of movement of the prosthesis. Round bars allow increased rotation of the denture in comparison to rectangular bars and thus produce less torque on the implant, however, this movement leads to increased maintenance associated with round bars in comparison to Ushaped bars.[56] Although, this rotation can only occur if the bar is in a straight line. Bars that aren't in a straight line do not allow rotational movement regardless of the cross-sectional shape of the beam and lead to a prosthesis that is effectively implant-supported. This may have important implications on the stresses on the prostheses, the attachment system and the implants.[19]

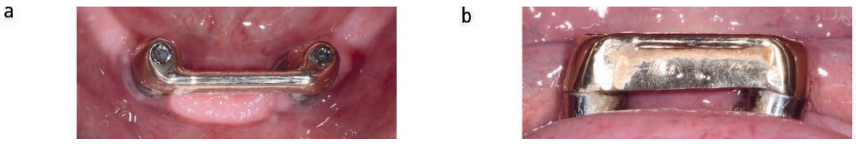

Fig. 12 Cast Gold Dolder Bar to accommodate a Clip attachment

The attachment system used on the bar will not only affect the retention but also the support. A rigid attachment to a bar will mean that the prosthesis will be entirely implant-supported regardless of the fact that it is a removable overdenture[19] it is more important to describe this prosthesis as an implant-supported overdenture.[57]

When a bar is used to connect the implants and distribute forces a passive fit of the bar is required,[58] however, attaining a passive fit can be difficult to establish, and some authors feel that bars can never be totally passive.[59]

There are a number of factors that can lead to bars being non-passive that occur either at the clinical or laboratory-based stages of treatment. From a clinical perspective this can include the position and parallelism of the implants,[60] the impression taking technique such as the material used, and the design and the positioning of the implant transfer posts.[61] The laboratory stages that can lead to bars being non-passive include the casting of the impression, the manufacturing technique used in the fabrication of the bar, the material used, the differences in tolerances among components,[60,62,63] the length/span of the bar,[64] and this list is not exhausted. It is therefore prudent to ensure each stage of treatment is carefully carried out to minimise any clinical or laboratory error that could affect the passivity of the bar.

If the bar is not passive this will lead to undue stress on the implant screws, prosthetic components and on the adjacent peri-implant bone. This can lead to patient discomfort, biological adverse reactions, mechanical failure of the components and increased chair and laboratory time as a consequence.[65]

The Sheffield test is a recognised technique[22] to asses if the implant bar fits correctly into the implant fixtures and is passive. The technique involves placing the bar onto the implant fixtures and screwing down only the most distal implant. The fit of the bar is then assessed on each of the implant fixtures to ensure it fits correctly without any horizontal or vertical gaps, if this is so the bar is deemed passive and fits correctly. Where gaps are present between the bar and the implant fixtures the

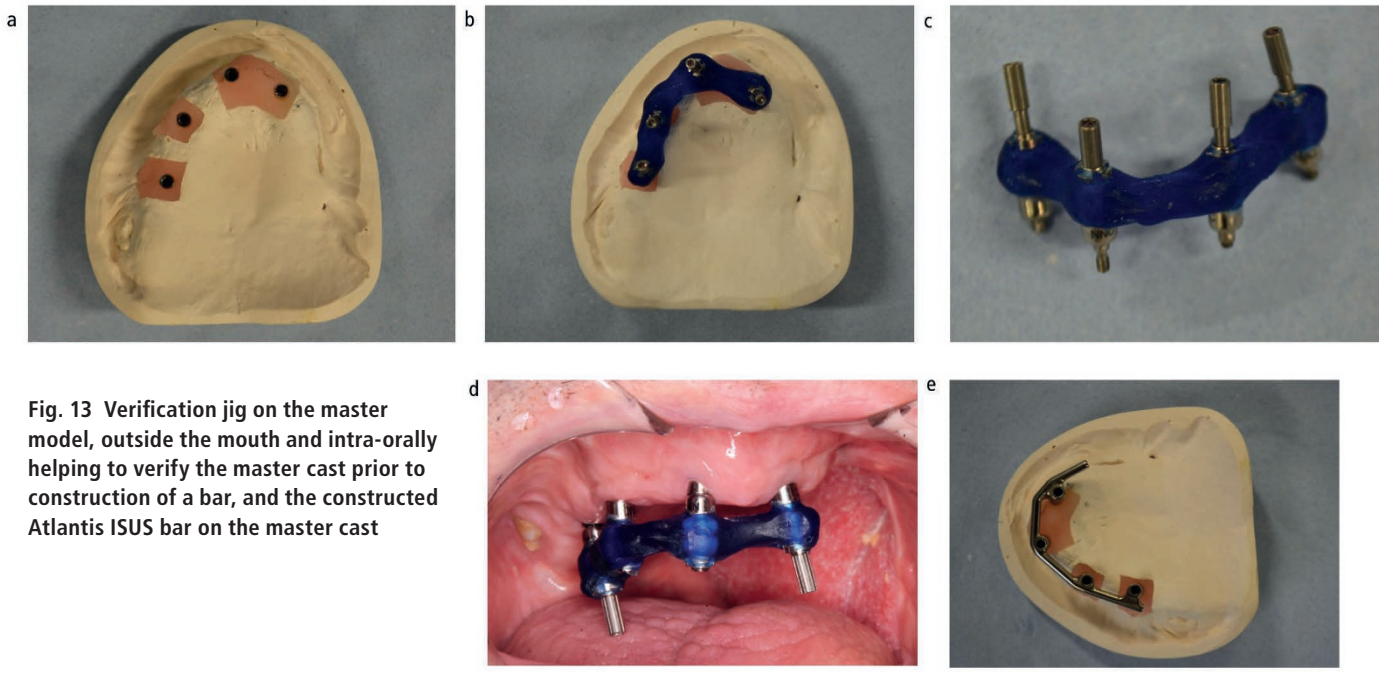

Fig. 13 Verification jig on the master model, outside the mouth and intra-orally helping to verify the master cast prior to construction of a bar, and the constructed Atlantis ISUS bar on the master cast

Fig. 14 CAD/CAM milled Dolder bar with three clips in position ready for integration onto a removable prosthesis

Fig. 15 Friadent Pre-fabricated Gold Bar Clip and Straumann Pre-fabricated Titanium Bar Matrix

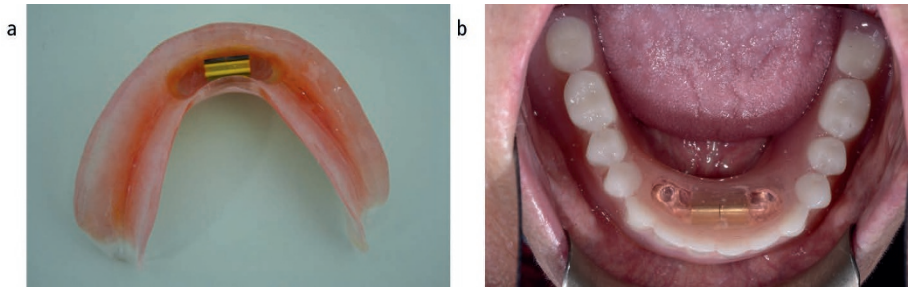

Fig. 16 Lower Complete Denture with two CEKA Preci-Horix Riders (Yellow Clip attachment) in a Preci-Horix Metal housing, out of the mouth and in situ. (Cold cured in chair side using clear acrylic)

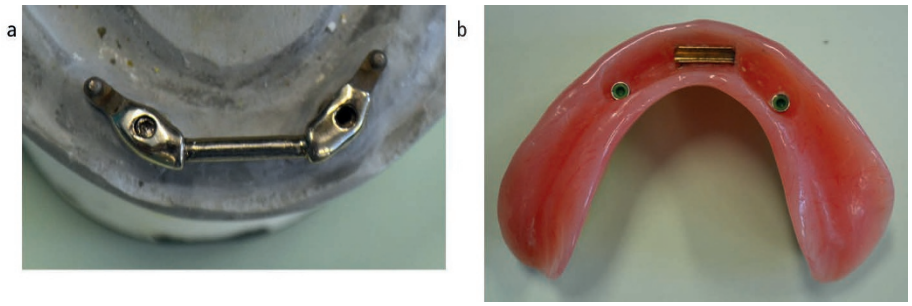

Fig. 17 A cast dolder bar with prefabricated stud attachment as distal cantilevers and the prosthesis with Cendres Metaux Gold clip and stud attachments

Fig. 18 Prei-Horix Rider (clip attachment) - Yellow, Red and White and Preci-Horix Metal housing to accommodate the Clip attachments

Fig. 19 Straumann Locator Abutments - Left: Regular Collar Locator Abutment, central: Wide Neck Locator Abutment, Right: Regular Neck Locator Abutment

bar is deemed non-passive and should not be used as this will lead to stressful forces being placed onto the implant fixtures and bar, and potentially to failure of the implant fixtures, the bar and/or the prosthesis. This should be carried out both on the master model and in the mouth. A verification jig can be used to verify the master model before construction of the bar. The verification jig is constructed on the master model using the impressions copings interconnected and linked with acrylic resin. Care is taken to ensure that this jig fits passively on the model. The verification jig is then tried intraorally, to verify the accuracy of the master model. A poorly fitting jig indicates a discrepancy between the positions of the implants intraorally and on the model. If this situation arises either another impression is taken or the jig can be sectioned around the inaccurate implant(s) and repaired intraorally using cold-cure resin (Fig. 13). The position of the implant can then be picked up onto the jig and the master model can be modified accordingly.[66]

Attaining a passive bar can be more challenging with longer spans and also when conventional casting techniques are used due to the shrinkage of metal during the casting process which needs to be adequately compensated for. Modern milling and 3D printing techniques have reduced this problem.

The bars can be constructed in a variety of ways including casting (Fig. 12), milling (Figs 5, 8, 14), laser welding prefabricated component (Figs 11 and 15) and 3D printing. The bars can be constructed in a variety of metals which include base metal alloys, gold and titanium. Where metal attachment components are used it is best to use the same material so that differential wear of the components doesn't occur.

Patient reported outcomes

It is clear within the literature that the use of implants to retain a prosthesis in comparison to a conventional prosthesis has been shown to improve patient satisfaction and oral health-related quality of life outcome measures.[4,9,67–72] In general, this improvement has shown to be maintained over time, however, in some studies and in some patients within studies this satisfaction has diminished slightly over time and it has been speculated that this is probably because patients get used to an improved situation.[73]

It has also been shown that those patients who are not dissatisfied with wearing conventional dentures show little increased

Fig. 20 Straumann Regular Neck Locator Abutments *in situ*

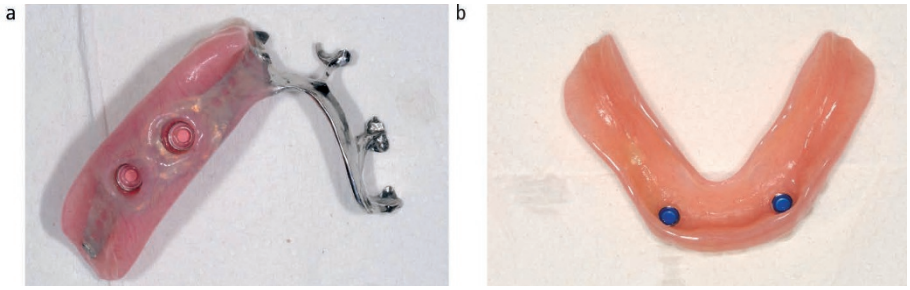

Fig 21 Implant retained over dentures using Locators - used in partial and complete dentures

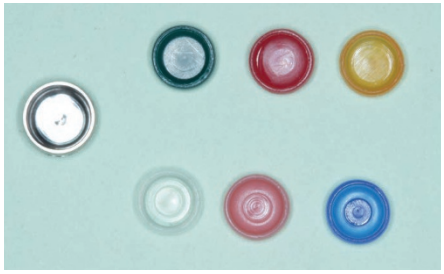

Fig. 23 Locator Male Components - Upper row: Green, Red, Orange (and grey not in the Figure) - are the extended range & Lower Row: Clear, Pink, Blue - are the standard range. The Denture cap that houses the Locator male component within the prosthesis is also in the image (left)

Fig. 24 Upper Complete Locator retained Locators - note how the Nylon Locator male components (once Pink) have deteriorated over time which is common problem with this system but a simple problem to address

Fig. 22 Straumann Locator Abutment (3 mm Height Wide Neck Locator Abutment) - showing the variable height of the Locator (3 mm height) dictated by the height of the surrounding soft tissue cuff and the standard 1.5 mm working portion that engages into the Locator Male Components

satisfaction with an implant-retained overdenture.[74] Careful evaluation of pre-treatment complaints with conventional dentures is therefore required.[73]

When specifically reviewing patient satisfaction studies on the type of retention system utilised to retain the prosthesis, there appears great variability in patient satisfaction and preference. Patient satisfaction with magnet attachments compared with other attachment mechanisms is lower (see Table 1).[67,75–77] The ability to assess which retention system will provide the greatest patient satisfaction for each individual patient is difficult[75] and cannot be subjectively predicted.

Attachments

Bar solutions

This attachment system is made of the bar and the clip, with the clip attaching onto the bar (Figs 8, 16 and 17). This is a splinted resilient attachment system. Most of the major bar systems have matching clips that attach specifically to the customised bar with the clips coming with varying retention (Fig. 18). Where customised/cast/prefabricated bars are used they either have to be designed to accommodate proprietary components or be entirely customised. Some systems have a spacer that can be incorporated at the time of processing. This spacer creates space between the clip and the bar when the prosthesis is at rest in the patient's mouth, however, when the patient bites this space is lost and allows some vertical movement of the denture and allows mucosal support of the denture during function rather than implant support only.[19]

Locator attachment

Locator® are produced by Zest Anchors LLC, California, USA and are compatible with a variety of implant systems. This is a free-standing, resilient implant system. The two components involved in this system include the Locator® abutments that are placed directly into the implant and the Locator® male component that is inserted into the denture and attaches to the Locator® abutments (Figs 19, 20 and 21).

They are a popular system as they avoid the use of complex protocols or laboratory technology. They can also be built into existing or new prostheses.

The Locator® abutments come in varying heights (1–6 mm) to accommodate the soft tissue around the implant. The soft tissue height around the implant is measured from the implant platform to the highest soft tissue point – this will then be the height of the Locator® abutment that is selected. The Locator® abutments have an additional 1.5 mm of height which is the working portion of the attachment which will remain above the soft tissue (Fig. 22).

There are currently two Locator® systems produced by Zest Anchors available on the market; the original Legacy Locator® system and the new Locator RTx® system.

For Legacy Locator® the male components are made from nylon and come as either standard or part of an extended range. The standard range has three different coloured Locator® male components with varying retention and allows restoration of implants from 0–10 degrees of divergence. The extended range come in four different coloured Locator® male components with varying retention and allow restoration of implants with up to 20 degrees of divergence (Fig. 23).

The new Locator system Locator RTx®, is similar to the Legacy Locator® system except that it allows restoration of implants up to a maximum of 30 degrees of divergence between implants. The male components for this system are also made from nylon with a single range of inserts with four different coloured Locator® male components (grey, blue, pink and clear

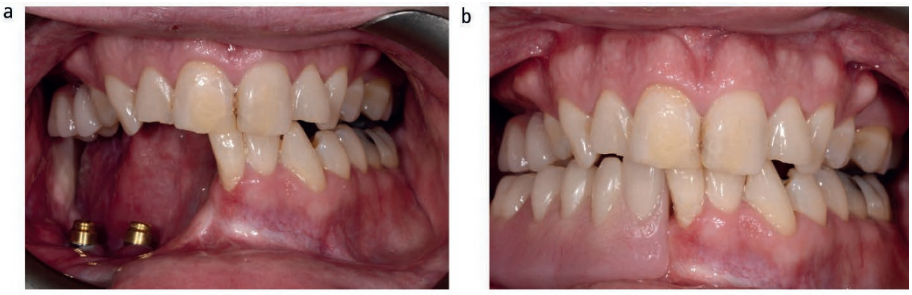

Fig. 25 Implant Retained Overdenture using Locators in a patient who had surgical intervention for head and neck oncology and reconstructed with a fibula free flap with an implant retained overdenture to replace the hard and soft tissue as a result

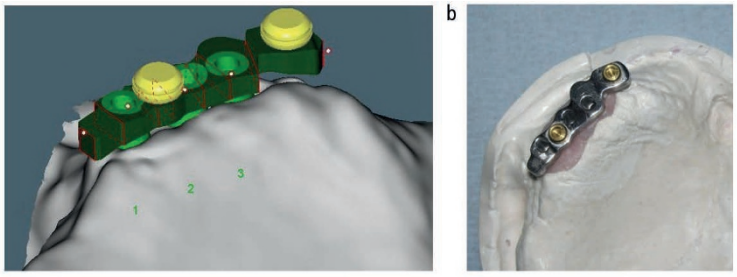

Fig. 26 Nobel Procera software used to design small rectangular titanium bar with integral Locator attachments and the fabricated milled titanium bar with Locator matrices in place

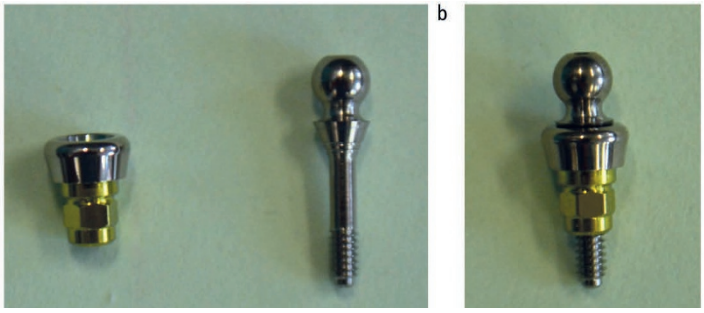

Fig. 28 Ball and Socket attachments - Friadent 3.2 mm Diameter Ball Abutment

Fig. 27 Magfit IP Magnet for use within a magnet retained implant overdenture

which have increasing retention).

The Locator® attachment system has a low profile compared to other common types of attachment (3 mm vertical space required to incorporate the male part, housing and sufficient acrylic) and is particularly useful when there is restricted prosthetic space. This system also allows optimal access for oral hygiene and with this there has shown to be improved soft tissue health around this implant attachment system.[79]

The Locator® attachment system is very simple to use and problems associated with these prostheses are usually simple and quick to resolve chairside.[24,80] The most common problem for the nylon Locator® male components is deteriation and becoming non-retentive. Replacement is a quick and straight forward clinical task (Fig. 24).

Since the object of this prosthesis is to be tissue borne, only one axis of rotation should exist for this type of prosthesis. If the prosthesis is not designed to move freely about an axis then premature replacement of the attachments will be required or breakage of components will ensue[31] (see Fig. 25 for a clinical case using the Locator® attachment system to retain a partial implant-retained overdenture).

The Locator® attachment system can also be utilised as part of either a cast or milled implant-supported bar as a Locator bar

Fig. 29 Ball and Socket attachments - XiVE TG Ball and Socket Attachment

Fig. 30 Ceka Preci-clix Female Components – a polyacetal base socket housing which accommodates the ball attachment, coming in a variety of retentions

Fig. 31 Rhein 83 Retentive Caps for a variety of stud/ball socket attachments

attachment, however, there must be adequate prosthetic space to accommodate this and it will require about 14.5–16 mm of interocclusal space to accommodate the bar (13–14 mm) and an additional 1.5–2 mm space for the Locator® (Figs 6 and 26).

Magnet

There are a variety of manufacturers that offer magnet attachment systems for implant-retained overdentures. Manufacturers offer magnets with varying strengths to customise the retention of the overdenture (Fig. 27).

Magnet attachment systems are relatively simple and have been shown to be hygienic.[81] They are particularly useful in patients with reduced manual dexterity as they are easy to place and remove due to magnet attachment being less sensitive to the insertion pathway and are also, to a certain degree, self-locating due to the magnetism.[81]However, magnets do lose their magnetic attraction over time which will lead to the prosthesis being less retentive and they are susceptible to corrosion, even with the use of modern magnets.[82] Another issue is that the retentive force of the magnets sharply reduces as the distance between the elements increases beyond very close contact (100 microns).[19] Overall, the literatures suggest that magnets appear to be the least retentive abutments compared to other attachment systems.[24]

Stud/ball and anchor attachments

Stud/ball and anchor attachments are unsplinted resilient attachment systems. These systems are relatively straight forward and can be used in new prostheses or built into existing prostheses. These ball/stud attachments are placed in the implant fixture (Figs 28 and 29) with synthetic rubbers ring (Figs 30 and 31) or metal lamellae (Fig. 29) retained within the prosthesis. These attachments on insertion of the prosthesis distort sufficiently to engage into the circular undercut on the ball/stud abutment.[19] Like all unsplinted systems they do not compensate for poorly aligned implants, since non-parallel axes compromise the insertion path which can lead to rapid wear of matrices or patrices of ball anchors, and require frequent replacement.

The Ceka Revax system is a slightly different system whereby the male component is within the prosthesis. This is a spring pin system which attaches exactly into a conical female component. The spring component comes as either the M3 (3 mm standard) or M2 (2 mm smaller) versions. This attachment can be used for both teeth and implants to retain a removable prosthesis. The Ceka Revax system female component can be incorporated into metal and acrylic based materials and the degree of retention can be adjusted by adjusting the size of the pin (Figs 32–35).

Conclusion

Compared to conventional removable prostheses, implant-retained overdentures have improved retention and stability, and patient satisfaction levels are reported as high. They are a valuable treatment option when planned and executed properly in the right patient.

There is currently a variety of retention systems available, each with their own advantages, disadvantages, costs and space requirements. Selecting the attachment that is to be utilised should be considered early in the treatment planning process and should consider the needs of the individual patient, lifespan, ease of maintenance, cost, prosthetic space, support requirements and expected force levels.[19]

The current literature would suggest that there is no strong evidence for the superiority of one system over the others regarding patient satisfaction, survival, peri-implant bone loss

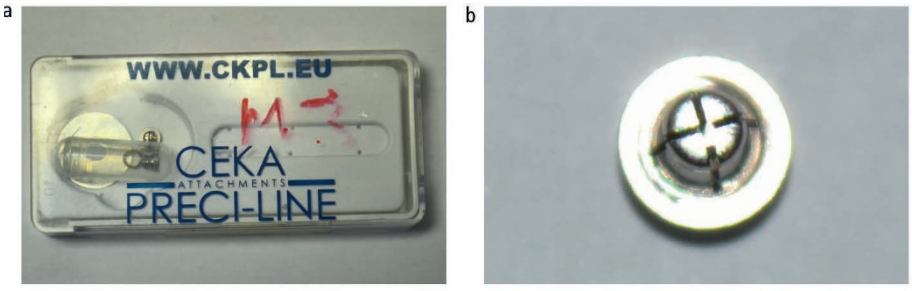

Fig. 32 Ceka Revax System: M3 Attachment in pack, M3 Male component

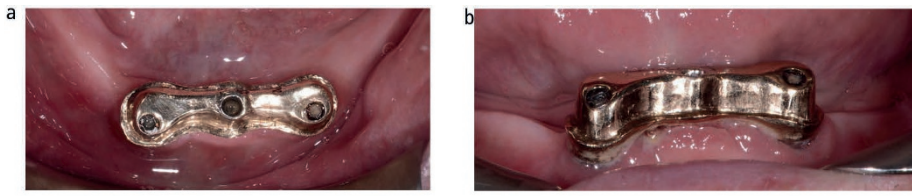

Fig. 33 Cast Gold Bar with Ceka Revax female component accommodated in middle of the bar

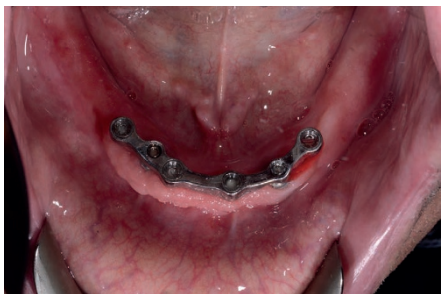

Fig. 34 Atlantis ISUS bar with distal cantilevers retained by 2 implants with Ceka Revax system housings within the bar

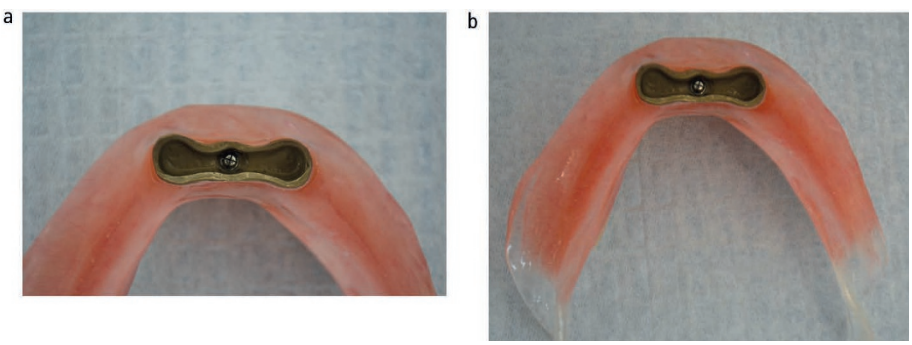

Fig. 35 Cast Gold Housing in a complete lower denture with a Ceka Revax M3 male component

and other clinical factors.[30] Common to all systems is that they require substantial prosthodontics and implant-based maintenance with implications on time and cost, which should be discussed with the patient from the outset.[30,49]

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