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The Bilateral Distal Extension Removable Partial Denture: Mechanical Problems and Solutions

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Abstract - *The bilateral distal extension removable partial denture has inherent problems of retention and stability, affecting not only the integrity of denture bearing tissues and associated structures, but also patient acceptance and compliance. This paper examines factors that contribute to and exacerbate the functional movement of free-end saddle prostheses, discusses techniques used to overcome these problems and lists alternative strategies for the management of the Kennedy class I patient.*

KEY WORDS: Kennedy class I, Bilateral, RPD, Retention, Stability, Management

INTRODUCTION

Difficulties that relate to the clinical provision and patient acceptance of removable partial dentures (RPDs) are not new [1]. Inaccuracies of diagnosis and treatment planning, inappropriate denture design or choice of component materials, technical errors, iatrogenic problems of disease, and biological or psychological patient factors are common problems that relate to RPDs [2-7].

The prevalence of missing permanent teeth is increased in the posterior dentition, with bilateral loss forming the most frequent presentation [5 8-10]. In situations where there are no terminal abutment teeth, particularly where the saddle is long, the provision of a bilateral distal extension base (or free-end saddle) RPD is a commonly used treatment option [7]. This type of prosthesis is difficult to wear, however, having problems of movement during functional loading [5 7 11-14]. It does not have the advantage of total tooth support because its bases are extensions covering the residual ridges distal to the last abutment. The distal extension RPD is dependent, therefore, on the residual ridges for either all or part of its support, stability and retention [7 15].

The position of the distal abutment, symmetry of the bilateral distal extension, arch form and cross-sectional area of the edentulous ridge are anatomical factors that influence the movement of this type of denture intra-orally [16]. The influence of framework and denture base designs must also be considered in relation to what happens to such a denture during function [7 16-18]. Anterio-posterior, lateral and rotational movements may each be affected to differing degrees, based on whether the denture is entirely 'mucosa-borne', or in cases where denture support is derived from a combination of the teeth and saddle area, the type and location of denture components.

Intra-oral patterns of tooth loss not only influence the functional movement of bilateral distal extension RPDs; the fundamental nature of such an appliance increases the risk of dental caries, periodontal disease and ultimately the loss of abutment teeth. Classical studies conducted by Carlsson *et al.* demonstrated that treatment with removable prostheses, particularly in the Kennedy class I patients, resulted in a significantly less favourable prognoses for abutment teeth compared with non-treatment[19-22]. With appropriate management of these patients, however, including regular recall, Bergman *et al.* showed that their oral health can be more easily monitored and maintained[9 23-25]. Furthermore, it must be remembered that resorption of the alveolar ridge is progressive[26]. This leads to a distinction between the rotation of the prosthesis that occurs with occlusal loading and the inevitable rotation that occurs once resorption has taken place.

It should be noted that the primary aim of this paper is to review the mechanical problems associated with the bilateral distal extension RPD. The long-term management of Kennedy class I patients will not be comprehensively discussed herewith, although obviously it is a crucial consideration within this subject area. This paper, therefore, aims to discuss the problem of support and movement associated with bilateral free-end saddle partial dentures and assess methodologies the prosthodontist may use to overcome such difficulties. Reference will be made to differences in the prosthetic rehabilitation of the partially dentate maxilla and mandible and, also, to differences that arise between the restoration of free-end saddles, with or without tooth support.

METHODS

This is not a systematic review. Source materials for the writing of this article were derived from the PubMed database using the search terms: 'Kennedy class I', 'bilateral', 'distal extension', 'free end saddle', 'partial denture' and 'RPD'. The search was limited to English language texts.

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Problems of support and resultant functional movement

Denture design influences

Acrylic mucosa-supported removable partial dentures are routinely used in general dental practice, outnumbering those involving a cobalt chrome framework five fold [15,27-29]. Whilst the provision of acrylic distal extension RPDs may be an attractive proposition in terms of reduced cost and ease of construction, this type of denture carries a significant and inherent risk of causing physical trauma to the denture bearing tissues [16,30-33]. Under occlusal force, a lack of tooth-support allows the denture to sink into the underlying mucosa and to 'strip away' the free gingivae of the remaining teeth (Fig. 1) [4,7,15]. This action can lead to a loss of attachment that compromises the integrity of the periodontium and contributes to tooth loss [15].

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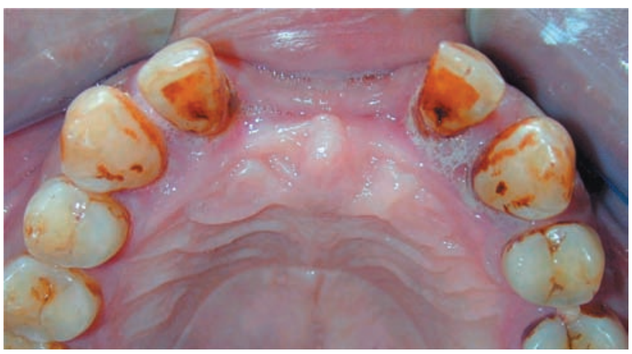

Figure 1. *(a) The upper acrylic denture covers the palatal gingival margins and has been finished below the survey line. It is an example of a 'gum stripper'. (b) The gingival margins are inflamed. Reproduced by kind permission of Prof. A. D. Walmsley.[15]*

In the maxilla, a mucosa-borne RPD is generally less damaging to the denture bearing tissues than one in the mandible[7]. The larger expanse of palatal mucosa and maxillary bone allows functional loading to be lessened per unit area relative to that observed in the lower jaw [7,34]. A lack of resorption in the centre of the hard palate contributes further, by allowing a time-dependent maintenance of 'optimal fit', thereby restricting the degree of vertical displacement of the upper denture[15]. Irrespective of whether upper or lower spaces are to be restored, the destructive nature of this RPD design indicates its use in situations where the prosthesis will fulfil a short-term function only[7,15].

Tooth support should be used where possible, especially in the case of mandibular rehabilitation [7,35,36]. Nevertheless, the transmission of functional forces to abutment teeth can have deleterious effects on the supporting structures of the abutments and on the integrity of the teeth themselves. To preserve the health of abutment teeth and their supporting periodontium, however, it is advantageous to obtain loading in the long axis of the tooth [35,36]. In the case where a prosthodontist is to provide a definitive prosthesis, this is best achieved in the form of rests derived from a rigid metallic framework. Unfortunately, functional pressure applied to the bilateral distal extensions of rigid metal RPDs causes a rotational movement around an axis that connects the most distal abutment teeth via the occlusal rests (Fig. 2) [7,16,37]. The derivation of support from tissues that exhibit relative dissimilarities in compressibility and displacement results in a greater displacement of the denture saddle into the alveolar mucosa with resultant torquing stresses being applied to clasped abutments [7,16,18,30,34,38,39].

Forces transmitted to abutment teeth are recognised as being more 'complex' in free-end saddle cases compared

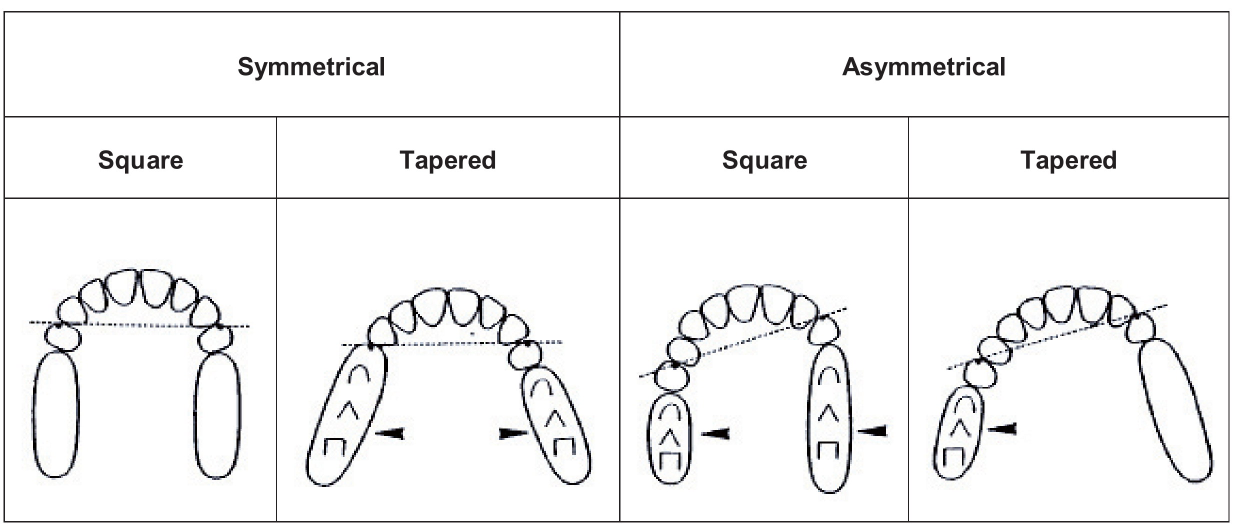

Figure 2. *The axis of rotation of bilateral distal extension RPDs causing resultant forces to act on the abutment teeth and saddle areas of different Kennedy class I arch forms. Dotted lines indicate the axis of rotation whilst arrows indicate horizontal components of the vertical load. Cross-sectional representation of the residual areas is also indicated in relevant regions. Adapted from Ben-Ur et al.[16]*

with bounded saddle RPDs. This is due to the fact that the distal extension is more vulnerable to the influence of intra- and extra-oral musculature [40]. The direction of abutment tooth movement and the potential for mobility is, therefore, influenced by a number of factors. These include: the magnitude of the functional load, the consistency of the alveolar soft tissues, the periodontal status of the tooth itself and the design and placement of the rest, clasp and reciprocating elements of the denture [7 16 30-33 35-38 41-44].

When a comparison is made between the mandible and the maxilla, rotational and torquing effects are less pronounced in the latter. The upper prosthesis gains considerably greater support from the hard palate[16]. In the mandible the situation is complicated by the degree of angulation of the alveolar ridge upwards towards the ramus. Essentially, a steeper angulated ridge results in the generation of greater resultant forces with an anterior downward direction, and these tend to push the saddle towards the abutment tooth [34].

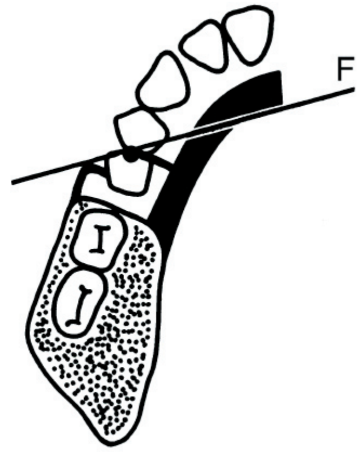

Figure 3. *RPI clasp with the retentive tip of the I bar distal to the axis of rotation. F = Shifted axis of rotation. Adapted from Ben-Ur et al.*[16]

Local anatomical influences

Whilst the prosthodontist can exploit denture design and manufacturing processes to reduce the unfavourable movement of the denture base and torquing of the abutment teeth, the contribution of local anatomy to the retention and stability of a prosthesis is somewhat beyond the control of the clinician [17 18 45-47]. Distal abutment position, arch symmetry, residual arch morphology, cross-sectional area of the edentulous ridge and thickness of the overlying mucosa, all affect movement of the bilateral free-end saddle denture [16 35 36]. Ben-Ur *et al.* proposed that these parameters be viewed as an addition to the Kennedy classification, to be considered when designing distal extension RPDs [16 37].

In a symmetrical Kennedy class I situation, the axis of rotation between the most distally placed rests is perpendicular to the sagittal plane [16]. A shifting of this axis occurs distally on the shorter extension side, however, in an asymmetrical bilateral free-end saddle case (Fig 2) [16 37]. To maintain optimal loading of the abutment teeth during function it is recommended that any retentive clasp tip be positioned distal to the shifted axis of rotation (Fig. 3) [16].

Adaptation of denture design may also be necessary to account for difficulties associated with certain arch forms. Depending on whether the arch is square or tapered, the angle of arc rotation of the denture base in relation to the edentulous saddle influences the generation of lateral forces from occlusal loading (Fig. 2) [16]. Maximal support is achieved with a symmetrical square arch shape, whereby the arc of denture base rotation is at right angles to the longitudinal axis of the residual ridge. Non-parallel arc movements with the resultant generation of lateral stresses occur with an asymmetrical square arch form and with tapered arches irrespective of symmetry (Fig. 2) [16 37].

Lateral forces may also be generated as a consequence of the inclined plane action of occluding posterior artificial teeth. The steeper the cusp inclines, the greater the force acting laterally [34]. Assuming a rigid connection between two bilateral free-end saddles, a lateral displacement of one saddle may be resisted by the structures listed in Table 1. It should be borne in mind, however, that lateral displacement due to arch form or tooth inclination not only affects the degree and direction of movement of the denture during function, but also has a deleterious effect on the integrity of the alveolar ridge, and may contribute to denture-associated pain [2 34].

It is also necessary to consider how cross-sectional changes in alveolar ridge contour contribe to the function of the bilateral free-end saddle RPD. Cawood and Howell classified edentulous ridge forms as being either well-rounded, 'knife-edged', flat or depressed [48]. The functional rotation of a free-end denture saddle around the long axis of rounded ridge forms will proceed more smoothly and cause less physical trauma than rotation around a sharp-edged ridge [16 48]. In certain situations, therefore, it may be advisable to surgically recontour the residual ridge to alleviate the effect of undesirable pressure areas or provide a resilient denture in cases where surgery is contraindicated [43].

Table 1. *Structures that communicate and resist lateral stresses in bilateral free-end saddle RPDs during function. Reproduced from Osborne and Lammie.*[34]

Stress communicated by:	*Resisting structure:*
Working side saddle	Buccal ridge on working side
Buccal part of clasp assembly on working side	Abutment tooth on working side
Balancing side saddle	Lingual ridge on balancing side
Lingual part of clasp assembly on balancing side	Abutment tooth on balancing side
Continuous clasp – if included in design	Teeth on balancing side
Lingual plate – if included in design	Lingual plate of ridge and teeth on balancing side

Treatment strategies

Contemporary design philosophies aim to reduce and optimise the loading of hard and soft tissues and account for differences in compressibility of the saddle areas and periodontium of abutment teeth, whilst alleviating torquing stresses [16 37 42 44 49]. Although novel design concepts and clinical techniques appear regularly in the dental literature, a consensus does not exist on what is considered to be the best way of overcoming problems associated with the bilateral distal extension RPD. The clinical application of ideologies and methodologies presented subsequently is subjective, therefore. They rely on the prosthodontist having a through understanding of how denture movement is influenced by component denture parts, while also taking into account local intra-oral influences as well as the needs and demands of the patient [3 7].

Reduction and dispersal of functional loading

Over the residual ridges

Decreasing the surface area of the prosthetic occlusal table can lower the vertical loading of the residual alveolar ridges with a concomitant reduction in lateral and anterio-posterior displacement of the denture base [34 50]. In the mandible, a narrowing of the occlusal table can also contribute to denture stability by creating sufficient space for the tongue to occupy following neuromuscular changes in activity [7 34]. The prescription of premolars in place of molars, or the use of a smaller mould of teeth, decreases the bucco-lingual occlusal width, whilst omission of the most distal posterior teeth results in a shortening of its anterio-posterior length. While this modification has the advantage that it can be used in all cases, it is most necessary when the occlusal load is heavy, the saddle long or the quality of the alveolar bone poor [34].

The magnitude of vertical and lateral forces may be lowered further by ensuring the maximal coverage of denture bearing soft tissues with an adequate flange extension into the functional depth of the sulci [34]. As a wider distribution of occlusal loading allows a reduction in force per unit area of underlying tissue, the denture base should ideally extend around the maxillary tuberosities of the upper palate and onto the retromolar pads of the lower jaw [7 18].

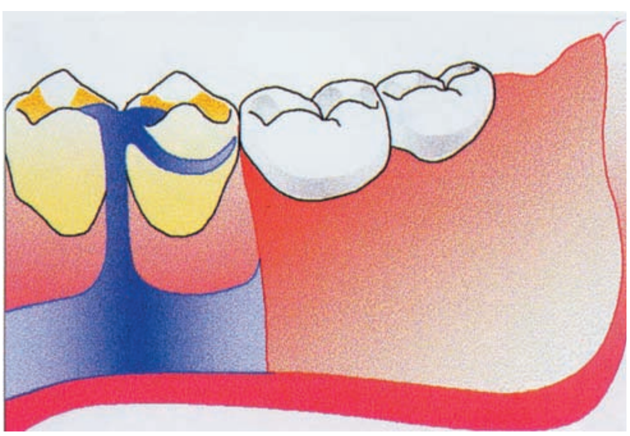

Figure 4. *It is possible to gain support from more than one tooth. In this instance, occlusal rests have been placed on both premolars so that the forces from the distal extension saddle are distributed widely. However, the occlusal rest on the first premolar will share the supportive function only if there is minimal downward movement of the saddle when a vertical load is applied. A larger movement will cause the rest to rotate away from the tooth. Reproduced by kind permission of Prof J. C. Davenport et al. from: A Clinical Guide to Removable Partial Denture Design.[51]*

Over the teeth

The rotational movement that takes place about the fulcrum of the most posterior occlusal rests does not readily encourage functional loads to be distributed widely over more than one abutment on either side of the arch. Nevertheless, a more equitable distribution of occlusal forces over the teeth may be achieved, under certain clinical circumstances, by having occlusal rests on two consecutive terminal abutment teeth (Fig. 4) [51]. This adaptation of denture design is only applicable, however, if there is a minimal downward movement of the distal extension when a vertical load is applied, since larger movements can allow the most anterior rest to move away from the tooth [51].

Components of the metal framework that offer indirect retention can also dissipate functional stresses over the teeth. An indirect retainer is any element of the prosthesis that acts to counter the tipping forces generated from functional movement of the denture [18 34 52]. In the case of the bilateral free-end saddle RPD, components placed anterior to the axis of rotation that are also in contact with multiple teeth ensure a greater distribution of tipping forces, thus minimising the stress borne by a single abutment [7 18 52]. A good example of this is the lingual plate, a major connector that also acts as an anti-rotational component of the denture base [18].

Accounting for differences in tissue compressibility

Stress-breaking

The support differential between soft tissues overlying the residual ridges and periodontium of the abutment teeth is significant [7 9 30-33 35 36 40 41]. One solution to this predicament is to permit movement between the saddle unit and clasp system such that functional stresses are distributed differently between the two [7 43 50 51]. Stress breaker dentures use a flexible connector or movable joint so that the mucosa-borne denture base can move independently from the tooth-supported elements of the prosthesis [53 54]. The theory is that a greater, more evenly distributed proportion of the occlusal force will be transmitted to tissues underlying the free-end saddles, thereby sheltering the abutment teeth from torquing stresses [51 53 54]. Stress breaker dentures are rarely used, however, as it is difficult to predict how the position of the hinge joint or flexible connector influences tissue loading [7 51]. Furthermore, even if the incorporation of a stress-breaking element were effective in protecting the abutment teeth, it would always be to the detriment of the alveolar bone.

The resilient-layer distal extension RPD

In contrast to stress broken designs, the resilient-layer distal extension denture aims to reduce forces transmitted to the alveolar ridge by acting as a 'shock-absorber' or 'stress-regulator' [43]. This type of denture differs from conventional RPDs by the composition of materials used to construct the free-end saddles. Formed from a layer of resin filler sandwiched between hard acrylic, the resilient-layer distal extension RPD has been demonstrated to reduce stresses transmitted to mandibular alveolar ridges whilst decreasing movement of the abutment teeth [43 55].

Specialised impression techniques

There is some disagreement over whether impressions taken of free-end saddles should be mucostatic or mucodisplasive. A model cast from a mucodisplasive impression reproduces the tissues as they are under load [34]. Compared with a mucostatic impression, which records the resting shape of the residual ridges, this may have the advantage that occlusal forces are more evenly dispersed over saddle areas, such that movement of the denture base during function will be minimised [7 46 56].

The Altered Cast Technique is a method of obtaining a functional impression of tissue underlying the distal extension bases of RPDs [7 46 51 54 57]. Whilst this methodology is widely taught to the dental undergraduate, it is rarely used in dental practice [57]. Recent evidence has questioned the efficacy of this technique. Frank *et al.*, concluded that the altered cast impression procedure does not offer significant advantages over the one-piece cast, provided that the master impression is fully extended [57]. To date, no further scientific data are available to either confirm or refute these findings, hence the decision of whether to take such an impression is most often based on anecdote and clinical preference [46].

Torque-releasing flexible clasp systems

To minimise the risk of causing damage to the supporting structures of abutment teeth, combinations of stiff clasps and extensive bracing elements should not be used to rigidly retain the bilateral free-end saddle RPD [51 58]. Design factors that influence the degree of clasp flexibility include the cross-sectional shape and area, clasp-arm length, thickness and alloy composition. Many photoelastic studies have been conducted to examine the relative stress distributions that different clasp assembly systems confer upon the abutment teeth of bilateral free-end saddle RPDs [27 28 31-33 35 36 41].

The classic *in vitro* studies of Thompson *et al.*, evaluated the effects of different direct retainer designs and occlusal rest positions on the apical movement of abutment teeth after occlusal loading of mandibular distal extension denture bases [35 36]. These experiments demonstrated that mesially positioned rests provide an axis of rotation that directs forces in a more vertical direction than those located on the distal aspect of abutment teeth. The most favourable distribution of forces within abutments was observed with a mesial rest, distal guide plate and I-bar clasp configuration: the RPI system (Fig. 5) [35 36 49].

Devised by Krol, the RPI system has been designed to maintain tooth support and allow vertical rotation of a free-end saddle into the denture bearing mucosa while minimising the potential for damage to the periodontium of the abutment teeth [49 59]. When the saddle is loaded the denture rotates about a point close to the mesial rest, whilst the distal plate and I-bar move towards the soft tissues,

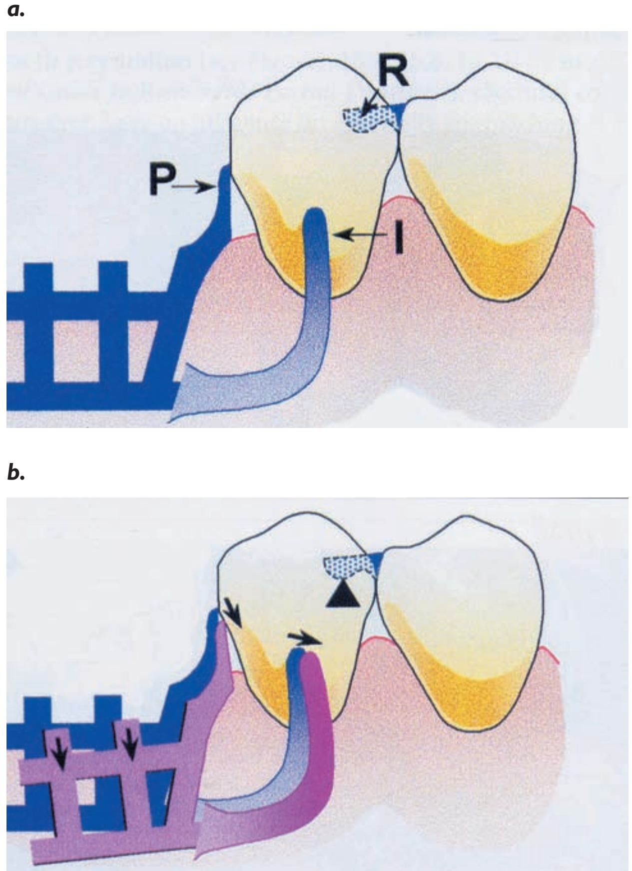

Figure 5. *RPI System. (a) The distal plate is positioned at the gingival end of a guide surface on the distal aspect on the tooth (b) The RPI system is designed to allow vertical rotation of a distal extension saddle into the denture-bearing mucosa under occlusal loading without damaging the supporting structures of the abutment tooth. As the saddle is pressed into the denture-bearing mucosa, the denture rotates about a point close to the mesial rest. Both the distal guide plate and the I bar move in the directions indicated and disengage from the tooth surface. Potential harmful torque is thus avoided. Reproduced by kind permission of Prof J. C. Davenport et al. from: A Clinical Guide to Removable Partial Denture Design.[51]*

becoming disengaged from the tooth (Fig. 5) [7 49 51 58]. This torque-releasing mechanism thereby avoids the transmission of harmful stresses to the tooth.

Additional clasp assemblies that function with a similar mode of action to the RPI system have been described in the dental literature [16 42 44 49]. These include the 'equipoise back action' clasp and the RPL system, which replaces the I-bar of the RPI assembly with an L-bar [16 42 44 49]. Whilst numerous investigations have confirmed the efficacy of these torque-releasing clasp systems, both *in vitro* and *in situ* [27 28 31-33 35 36 41], a recent study has demonstrated that rigid circumferential clasp designs are, unfortunately, used twice as often as the RPI system in Kennedy class I RPDs [8].

Alternative treatment options

Although the present communication has examined problems associated with bilateral free-end saddle RPDs, it would be remiss not to acknowledge the contribution that alternative treatment options, and accessories to conventional denture designs, can offer the Kennedy class I patient. These include:

- The 'Swinglock' RPD
- Intra- or extra-coronal precision attachments
- Straight cantilever bridges on the most distal abutments
- Osseo-integrated implants
- The concept of accepting a shortened dental arch

CONCLUSIONS

Problems associated with the bilateral free-end saddle removable partial denture have been examined, and ways in which these problems may be overcome discussed. Whilst the distal extension prosthesis is amongst the most challenging to wear, several treatment options are available that may be used to minimise the inherent difficulties of retention and stability. For any given single patient, however, not all options will be desirable or even applicable. Alternative lines of treatment include the use of adjuncts to routine care, the provision of fixed prostheses or the application of the Shortened Dental Arch concept. Selecting the best treatment modality depends upon a careful assessment and understanding of the patient, together with a comprehensive knowledge of the limitations of this type of denture.

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