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Revisiting the Principles of Partial Denture Design

Abstract: Dentists may find partial denture design difficult. This is often due to lack of educational experience.^{1,2,3} Removable partial dentures (RPDs) are one-off prosthodontic solutions that require proper assessment, planning and preparation, combined with effective design. This article revisits the principles of RPD design.

Clinical Relevance: One in six people in Britain have some form of RPD.⁴ Many of these are unworn.⁵ For future well-being of patients, improvement in RPD provision is essential.

Dent Update 2010; 37: 682–690

Removable partial dentures (RPDs) are one-off prosthodontic solutions. All RPD users have their own specific needs and expectations. Each oral situation is unique. The key to successful RPDs is a systematic approach that allows the RPD to be tailored to the individual. With the aim of encouraging a change towards higher standards of RPD provision, this article will revisit the principles of RPD design with a particular emphasis on hygienic design. It will also suggest a logical order of assessment and treatment planning under the headings of:

- Indications - when is an RPD the most suitable solution?
- Complexity – how difficult is the prosthodontic situation?
- Design – which design is the most effective and hygienic?
- Preparation – why are tooth modifications required?
- Maintenance – what will be required for ongoing health?

Indications

An RPD is not an exercise in filling gaps. It is a prosthodontic solution. The decision to provide an RPD must be based on a need to restore aesthetics and function. A shortened dental arch (SDA) is acknowledged as a functionally stable concept.⁶ If an SDA exists or can be secured by a fixed solution there is no indication for an RPD. There are no evidence-based indications⁷ for RPDs but clinical experience confirms that there are a number of situations where they are ideally suited:

- Patient preference;
- Need for flange due to hard/soft tissue defects and arch discrepancy (allowing flexible tooth position and emergence);
- Limited dentition and limited bone (including free-end saddles);
- Need for future additions/modifications;
- Dentition with a range of tooth mobility;
- Two or more edentulous spaces bounded by sound teeth;
- Use of teeth as overdenture abutments (ODAs);
- Used as an interim solution.

In most cases more than one of these indications will apply and the RPD design should reflect these requirements.

Complexity

RPDs can be categorized as straightforward, advanced or complex



Figure 1. This straightforward RPD situation has bounded saddles in a healthy/stable mouth with a functional occlusion.



Figure 2. The advanced RPD situation includes one or more free-end saddles. In this example the RPD has been made in conjunction with new cast restorations on UR5 and UL7.

according to the clinical situation.⁸ For example:

- The straightforward denture (Figure 1)

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Provision of Modern Hygienic RPDs in Practice

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Assessment of complexity:

Prosthodontic Assessment	Straightforward	Advanced	Complex
Patient's needs and wishes	Realistic	Specific aesthetic and functional expectations	Preference for fixed (Precision attachments?)
Caries status	None Controlled	At risk and/or active Failure of abutment teeth due to caries	High risk & active Shortened Dental Arch SDA alternative to reduce long-term maintenance burden?
General restorative needs	None or minor	Indirect/cast restorations in same arch as RPD	RPD as part of full mouth rehabilitation
Specific restorative needs of abutment teeth	None or minor	Structural strength and restorability?	Convert to ODAs? (Over Denture Abutment) Consider implant alternative?
Periodontal status	Good Minimum bone loss	Moderate bone loss	Advanced bone loss Residual mobility Provision for modification (bounded to free-end saddles)
Occlusion	Conform	RPD making up missing criteria: Anterior guidance and/or Posterior support	In need of reorganisation incl. Change of vertical dimension And/or provisional phase
TMD	None	Myo-fascial symptoms	Internal derangement in TMJs
RPD assessment			
Teeth to be replaced (SDA not possible)	Posteriors Bounded saddles	Anteriors Unilateral free-end saddle	Most anteriors Bilateral free-end saddles
Aesthetic needs	Low lip line	Medium lip line Replacing anterior teeth	High lip line and no visible clasps; guide surfaces or precision attachments Visible anterior flange;tinting
Residual ridge reduction	Favourable (Cawood & Howell Class III-IV)	Advanced (Cawood & Howell Class V)	Severe (Cawood & Howell Class VI)
Unwanted tooth movement	None or minor	Twisted and/or tilted	Over-erupted:convert to ODA?
Strategic abutments	Present (Kennedy Class III)	One or two missing Kennedy Class I & II Convert to ODA?	Implants as ODAs? (Kennedy Class I,II & IV)
Previous RPD experience	None or good	None or difficulties	Failure and/or not used
Cost band	Standard fee	Subject to RPD design & laboratory estimate	Subject to full treatment plan, RPD design & laboratory estimate

Table 1. Classification for quick reference assessment of RPD complexity.

has bounded saddles in a healthy/stable mouth with a functional occlusion.

- The advanced denture (Figure 2) includes one or more free-end saddles; need for new cast restorations; replacement of front teeth and restoration of anterior guidance.

- The complex denture (Figure 3) addresses occlusal rehabilitation (including change in vertical dimension); periodontal concerns (eg splinting of mobile teeth); critical

aesthetics of teeth and flange; precision attachments.

The Aide Memoire to RPD assessment in Table 1 is designed to assist clinicians with assessing complexity of an RPD at the outset of treatment. It is based on the ITI (International Team for Implantology) SAC Classification⁹ and template for risk assessment used in their Treatment Guide series.¹⁰ A list of



Figure 3. This complex RPD situation includes a full-mouth prosthodontic rehabilitation (including change in vertical dimension). There is also a need for critical aesthetics of the replacement teeth and flange.



Figure 4. Rest seats, undercuts and milled features can be incorporated in new cast restorations.

prosthodontic factors and specific RPD factors are listed down the left-hand side. For each factor a suggestion is given of the clinical situation that corresponds to straightforward, advanced or complex. This allows the clinician to identify specific areas that will require in depth planning and preparation.

Examples of prosthodontic factors

General restorative needs

Indirect/cast restorations for the same arch should be planned in conjunction with the RPD. Rest seats, undercuts and milled features can be incorporated in the restorations. They improve the fit and make the denture seem less bulky. They also ensure that forces are transferred correctly down the long axis of abutment teeth. The restorations should therefore not be constructed until the final RPD design is agreed with both patient and laboratory (Figure 4).

Heavily restored and broken teeth can serve as overdenture abutments



Figure 5. Three rather than four front teeth gave a better aesthetic result. The RPD teeth have recession to imitate the natural teeth.



Figure 6. A functional occlusion is secured with an arch from UR6 to UL6 (just one RPD tooth on the free-end saddle!).

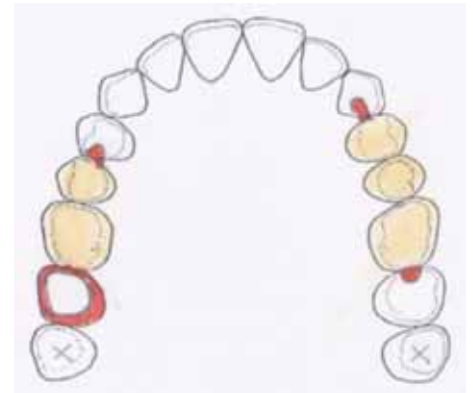


Figure 7. This RPD has two saddles. The saddles have a rest at each end. This equates to support for bridges with two abutments and two/three pontics. Overall the RPD has four rests, one in each corner of the design. This design is fully tooth supported.

and molars can be divided to allow one or two roots to be kept for strategic support and bone preservation in the arch.

In the situation in Figure 3, the RPDs are part of a full-mouth rehabilitation. There is only one set of molars that makes occlusal contact. The aesthetics and occlusion will need to be planned before the RPD design. This requires study casts mounted on a semi-adjustable articulator (in the appropriate jaw relationship) for a diagnostic set-up. The RPDs can then be designed with these aesthetic and occlusal requirements in mind.

Teeth with residual mobility

It is always advisable to preserve teeth in an already depleted dentition. Unless a tooth is irredeemably mobile, it is always worth examining the possibility of recovery. Many mobile teeth can be saved by simply correcting a traumatic occlusion. The RPD can also be designed to include protection against occlusal trauma.

Example of RPD factors

Residual ridge reduction

The degree of reduction¹¹ will have an impact on role of flanges in the RPD. With minimal loss and good tooth support a flange may not be needed. With advanced loss a flange may be an essential part of gaining support for the RPD. It could also be the means of allowing denture teeth to emerge correctly with a natural appearance (Figure 5).

Design

RPD design can be explained in a logical sequence of six core elements.

Hygienic principles should be applied to each of these elements:

1. Teeth to be replaced;
2. Support;
3. Rigid major connector;
4. Retention;
5. Anti-rotation;
6. Reciprocation.

A practitioner can design any RPD, with a cast or an acrylic frame, if these six elements are employed correctly. A practitioner can make the RPD safer if the hygienic principles¹² are understood and incorporated.

Teeth to be replaced

The aim is only to replace the teeth required for aesthetics and function, not to make up numbers. In the RPD in Figure 5, three rather than four front teeth gave a better aesthetic result. It is helpful to have a try-in of anterior teeth as early as possible in the RPD planning; the aesthetic arrangement of the anterior teeth often dictates the path of insertion of the RPD.

In Figure 6, a functional occlusion is secured with an arch from UR6 to UL6. Unnecessary denture teeth on free-end saddles increase the occlusal table size. This in turn increases the forces from occlusal pressure on the edentulous ridges.

Support

The aim is to make the RPD as stable as possible and reduce its potential for movement. To achieve this an RPD needs adequate support for each saddle and for the design overall.

Sound teeth are ideally suited to offer support and they should be used wherever possible. Rest seats must be



Figure 8. (a–b) Support is needed for all saddles, including anterior saddles. Rest seats (by preparation or addition see Figures 25 and 26) are required to ensure axial loading of the teeth. In this example the additional rest behind UR2 allows for future addition of the known periodontally compromised UR1 to the RPD.

prepared or added to ensure the occlusal forces placed on the RPD are transferred favourably to the supporting teeth (see section on clinical preparation later).

Soft tissues are more resilient than teeth and the alveolar bone in the edentulous ridges is prone to resorption

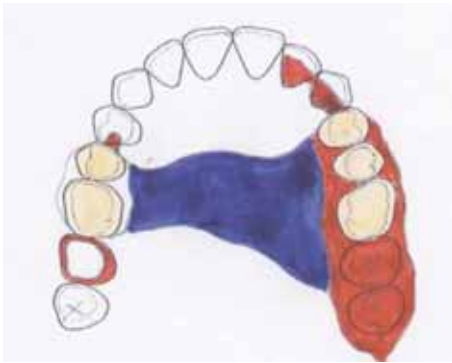


Figure 9. The saddle on the right is tooth supported. The saddle on the left is supported by two teeth (at the front) and optimum extension of the saddle (back and around the tuberosity). It also gains assistance from the major connector across the palate.

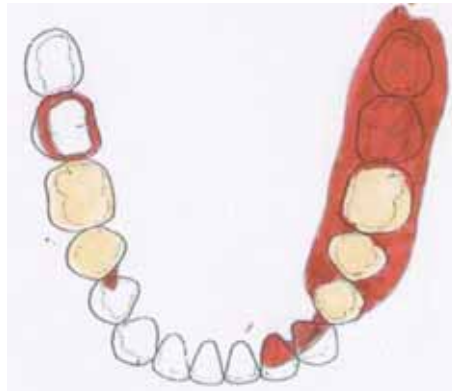


Figure 10. The saddle on the right is tooth supported with a rest at each end. The saddle on the left is part tooth supported, part tissue supported. To reduce the impact on the vulnerable alveolar bone the saddle is extended to make optimum use of support from the retromolar pad.

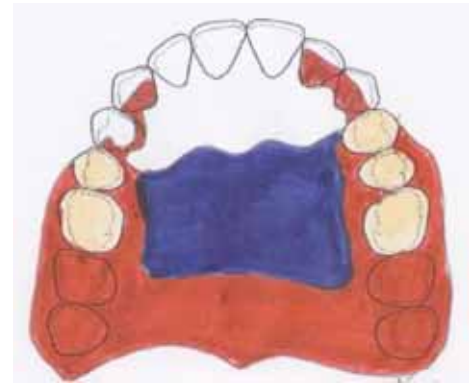


Figure 11. The bilateral free-end saddle is at best partly supported by the front teeth. Most of its support, however, comes from optimum coverage of the edentulous ridges and full use of the hard palate.

under pressure. Soft tissue support should therefore engage as large a surface area as possible as detailed below.

Support for each saddle

As a rule, each denture saddle should be supported by the same number of teeth that would be used for a bridge with the same number of pontics (Figure 7); this includes rests for anterior saddles as seen in Figure 8. This rule is simple for saddles that have a tooth at each end (bounded saddles).

RPDs with free-end saddles are more complex. A significant part of the support will have to come from the soft tissues. Common to all is optimum extension of the saddle base over the edentulous ridges. In the upper jaw this means extension back and around the tuberosities (Figure 9). In the lower jaw the saddles must extend back and on to the firm part of the retromolar pads (Figure 10). In addition, the palate (Figure 11) and mandibular buccal shelves offer valuable and stable non-dental bone support.

Support for the overall design

The RPD Figure 7 has two saddles. The saddles have a rest at each end. This equates to support for bridges with two abutments and two/three pontics. Overall, the RPD has four rests, one in each corner of the design. This design is fully tooth-supported.

The RPD in Figure 12 has

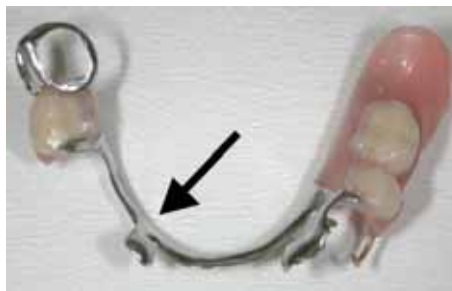


Figure 12. This RPD has optimum support for each saddle. LR7 and LR5 support the right saddle. The free-end saddle is supported by LL3, LL4 and the retromolar pad. In addition a rest is needed at LR3 (arrow) to ensure support in all corners of the design.

optimum support for each saddle: LR7 and LR5 support the right saddle and LL3, LL4 and optimum extension support the left free-end saddle. In addition, a rest is needed at LR3 to provide support in all corners of the design. This design is part tooth-, part tissue-supported.

■ **Rigid major connector**

The major connector is the backbone of an RPD. In some cases it also provides support for the RPD (see above). It must be strong and rigid. Delicate designs can flex and will not fulfil the major connector's role.

In the upper RPD in Figure 8 the major connector is a palatal plate. It is placed high in the vault of the palate and thereby curves in more than one plane. This



Figure 13. The rigid sublingual bar has a teardrop cross-section. Its shape and size is based on a functional impression of the lingual sulcus.



Figure 14. This dental bar gains its strength and rigidity from the curvature of the bar over and around composite rests (see also Figure 27).

gives it strength and rigidity.

The lower RPD in Figure 13 has a rigid sublingual bar of teardrop cross-section with dimensions of 5 x 5mm; a functional impression of the lingual sulcus allows the width to be increased.¹³ Alternatively, the dental bar in the RPD in Figure 14 gains its strength and rigidity from the curvature of the bar over and around the composite rests.

All connectors shown (Figures 2, 6, 8, 11, 12, 13, 14, 21, 23 and 28) fulfil

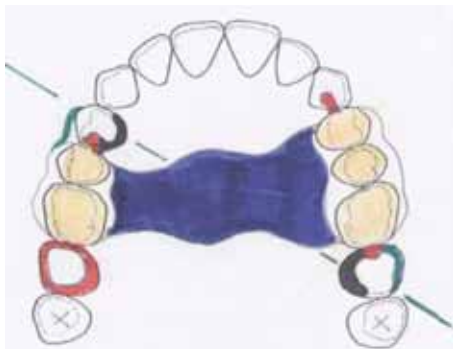


Figure 15. Fully tooth supported RPD: the clasp axis bisects the design. Active retention at UR4 and UL7 combined with anti-rotation from the supporting rests on UR7 and UL3 means this denture is unable to move until the clasps are released. The clasps are reciprocated by the black sections palatally on UR4 and UL7.

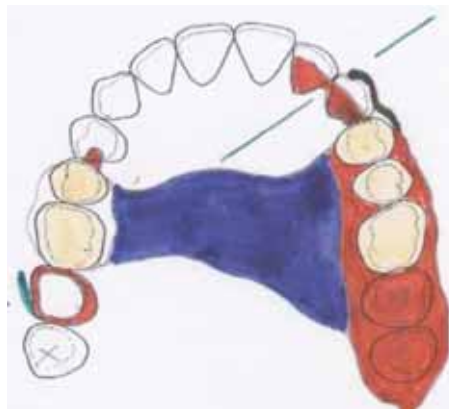


Figure 16. Part tooth, part tissue supported RPD: there is a difference in movement between the teeth and the soft tissues, in spite of the optimum extension of the free-end saddle and assistance from the palate. In this situation the RPD can rotate around the clasp axis to allow for the soft tissue resilience.

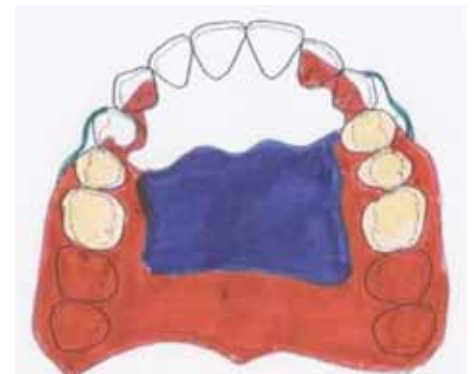


Figure 17. Mostly tissue supported. The clasps (and axis) are placed on the teeth adjacent to the saddles. This allows for the resilience of the soft tissues. The clasp tips engage mesially to resist distal movement.

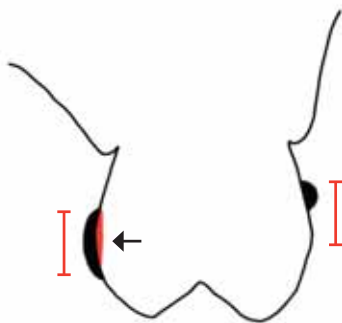


Figure 18. As the clasp (on the right) deflects on its way out of the undercut the reciprocal (on the left) needs to stay in contact with the opposite side of the tooth throughout; a small tooth modification may be needed to achieve this (arrow to red area).



Figure 19. The inter-proximal spaces below the contact points allow free access for saliva and interdental brushes around the necks of the teeth at all times. The spaces imitate the natural adjacent spaces.



Figure 20. The pontic design of these supported RPD teeth (UL3 and UL4) can improve aesthetics and access for hygiene.

the requirements for a hygienic design: the connectors enter directly into the saddles and thereby avoid unnecessary proximity with the teeth used for support.

Retention

Clasps are the most common form of retention for RPDs. Traditionally, RPDs have several clasps. Two clasps are sufficient but they need to be placed strategically and used in combination with anti-rotation to be effective (Figures 15–17). The same principles apply to other forms of retention as well, for example custom and precision attachments.

Anti-rotation (also referred to as indirect retention)

Two clasps form a clasp

axis between them. When this axis is strategically placed (Figures 15–17), the movement of the RPD is limited to rotation around this axis. If support is already present in all corners of the design, it will act as anti-rotation and minimal movement will take place.

Reciprocation

A clasp deflects when it is pulled out of an undercut on a tooth. It is the degree to which the clasp resists this deflection that dictates its effectiveness. The

resistance of the clasp puts a lateral force on the tooth. Unless the tooth is braced against this force, the tooth will move. This bracing is referred to as reciprocation. Figure 18 shows how a minor tooth modification may be needed for the reciprocator to stay in contact with the tooth throughout the distance where the clasp is deflecting.

Hygienic principles

Hygienic principles are aimed at:

- Avoiding unnecessary coverage of the gingival tissues;
- RPDs that are easy for the patient to clean and maintain (Figures 2, 6, 8, 13, 14, 19, 21, 23 and 28).

RPD components should never come closer than 3 mm to a gingival margin. This applies to major and minor connectors and the necks of denture teeth/ base of denture flanges. Figures 8, 11



Figure 21. There is too much recession of the lingual gingival margins on LR4 and LR3 to allow a sublingual bar to rest safely on keratinized tissue at 3mm's distance. In this situation the dental bar offers a better solution as well as making full use of the remaining teeth for support.

and 14 show examples of hygienic major connectors: all avoid proximity with the adjacent natural teeth. In the same way, the minor connectors exit the saddles directly to the rests; there is no unnecessary 'wrap around' coverage often seen in traditional designs.

The inter-proximal spaces below the contact points in Figure 19 are ideal. They allow free access for saliva and interdental brushes around the necks of the teeth at all times. When inter-proximal spaces are visible in the smile their size needs to be in keeping with aesthetics; in Figure 20 imitation of adjacent inter-proximal spaces gives a natural appearance as well as hygienic clearance.

In the lower jaw, recession of the lingual gingival margins can be so advanced that gingival clearance is impossible. In this situation (Figure 21) a different major connector may be necessary.

Additional elements

There are additional elements that may apply with specific indications or enhance the performance of the core elements:

- Guide surfaces

These define the path of insertion and removal of the RPD. They give the RPD a friction fit. This precludes rotation and reduces the need for strategic positioning of the clasp axis.

- Provision for future additions

The deliberate backing behind UL5 (Figure 22) now allows this tooth to be



Figure 22. The backing behind the UL5 anticipated loss and now provides tacking for addition.

added to the RPD.

- Precision attachments

These avoid the need for unsightly clasps. They require careful planning and assessment of number, position and status of the teeth proposed to anchor them.

- Semi-permanent periodontal splints

Figure 23 shows an example of an RPD that acts successfully as a semi-permanent splint for a shortened dental arch (SDA) whilst also providing the option for additions.

- Over-denture abutments

These are very useful for both support and retention (Figure 24). Ideal candidates are root-filled, heavily restored or broken teeth. Reduction of a tooth with bone loss to gingival level can also eliminate unfavourable leverage. Molars can be divided to allow one or two roots to be kept for strategic support and bone preservation in the arch.

Preparation

When the clinician has put together a design proposal it needs to be checked against a surveyed cast. This can be done in conjunction with the technician. The surveying determines the most suitable path of insertion; it indicates tooth modifications required to achieve this path of insertion and it confirms suitable undercuts for clasps.

Correctly planned and prepared rest-seats and guide surfaces make a significant difference to an RPD. The addition of composite rests,¹⁴ as well as preparation of the tooth surfaces, are proven measures that should be used



Figure 23. Semi-permanent periodontal splints: this RPD acts successfully as a semi-permanent splint for an SDA whilst also providing the option for additions.



Figure 24. Over-denture abutments are very useful for both support and retention. This abutment has a post retained cast coping. It also has a blank for use with a magnet inserted in the RPD.

routinely. A rest seat ensures that the force placed on the tooth by the RPD is transmitted favourably down the long axis of its root. For this to happen, the preparation of the rest seat must be designed so that the rest and seat stay together when the RPD is in place. Compare the occlusal rest and composite rest in Figures 25 and 26.

Tooth preparation for cast restorations must take into account space requirements for planned guide surfaces, rests, undercuts and precision attachments.

Hygienic 3 mm clearance needs to be drawn on the master cast as seen in Figure 27.

After careful preparation of rest seats and guide surfaces, the fitting surfaces of the cast framework should be hand finished (Figure 28); electropolishing is an expedient way of achieving a shiny finish but reduces the accuracy of the fit disastrously.



Figure 25. Composite rests have proven value and reliability. They require optimum acid-etch technique and must be aligned with the RPD path of insertion. These are shaped like lingual cusps on a lower premolar.



Figure 26. A rest seat prepared within an existing filling. The rest seat ensures that the force placed on the tooth by the RPD is transmitted favourably down the long axis of its root.



Figure 27. The pink wax block-out, distal to LR3, on this master cast corresponds to a future 3mm inter-proximal space below the contact point to the first RPD saddle tooth.

The key to successful RPDs is a systematic approach that allows the RPD to be tailored to the individual. With the aim of improving standards in provision of RPDs a systematic approach is suggested as a way to increase clinician confidence and understanding.

Maintenance

RPD patients are dentally vulnerable people. Their dentition is already depleted and it is imperative to seek to preserve what remains. Individual motivation and skill will vary. The hygienic principles should reduce the outright risk to the root surfaces and gingival tissues but patients need help with looking after the remaining teeth and the RPD on a daily basis. They will also need regular professional contact for reinforcement of the advice and assistance with maintaining health. Hygienists can teach patients to use the interproximal brushes in the spaces for gingival clearance seen in Figure 21. They can also disclose the RPD to demonstrate presence of plaque. A three-monthly recall during the first year of use should reveal the frequency of follow-up needed thereafter.

Conclusion

RPDs continue to have an important role as a prosthodontic solution in today's Britain. RPDs are a difficult subject within dentistry but they must be presented and compared fairly with other prosthodontic solutions. Patient choice rather than the ideal is suggested as the minimum standard of care.¹⁵

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Figure 28. To increase the accuracy of fit the fitting surface of this cast framework has been hand finished. Electropolishing it gives a more shiny finish but also sacrifices significant microns of fit.