# Removable Partial Denture Design: A Need to Focus on Hygienic Principles?

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**Purpose:** The purpose of this study was to critically analyze important hygienic/secondary prophylactic and biomechanical aspects of removable partial denture (RPD) design. **Materials and Methods:** The literature related to traditional biomechanical design and open/hygienic design of RPDs was discussed by the authors at a 2.5-day workshop. The written report was circulated among the authors until a consensus was reached. **Results:** There is little scientific support for most of the traditional design principles of RPDs, nor has patient satisfaction shown any correlation with design factors. However, there is evidence that an open/hygienic design is more important than biomechanical aspects for long-term oral health. The biomechanical importance of some components is questioned, eg, indirect retention and guiding planes. Alternative connector designs that reduce risks of tissue injury are described. Direct retainers and pontics are discussed in relation to the possibilities they offer for gingival relief. **Conclusion:** Greater attention should be paid to RPD design principles that minimize the risks of tissue injury and plaque accumulation in accordance with modern concepts of preventive dentistry. *Int J Prosthodont 2002;15:371–378.*

Traditionally, removable partial denture (RPD) design has focused on biomechanical aspects such as stability, retention, loading of supporting tissues, and mechanical durability. However, in addition to these considerations, it is of fundamental importance that RPDs be designed so that they interfere as little as possible with plaque control and do not damage the oral tissues. Such design parameters are termed the secondary prophylactic aspects by Marxkors.[1] They are also called hygienic principles.

Several studies of the outcomes of RPD treatment have been performed in different parts of the world. There appears to be, however, no unanimous opinion on RPD design principles, although one national survey demonstrated that many principles receive the support of a majority of prosthodontic specialists.[2] The RPD design principles are not based on clinical research and therefore are not evidence based. However, there are a number of reports of adverse effects on the oral tissues and a high frequency of patient dissatisfaction.

The aim of this article is to critically analyze, in the light of current preventive concepts, some important hygienic and related biomechanical aspects of RPD design.

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## Materials and Methods

The literature on the biomechanical aspects and hygienic requirements of RPD design was reviewed by an international group of prosthodontists, the authors, at a workshop in Copenhagen, Denmark, in June 1999. Attention was paid in particular to possible conflicts of interest between these two approaches to design. The discussions leading to a preliminary agreement were written down and circulated among the authors until consensus was achieved. Literature brought forward during the discussions was included in the report, as was as any new literature that appeared during the writing period.

## Results

It was concluded from the discussions that the open/hygienic aspects of RPD design should be collected and documented in a form suitable for coherent presentation to the prosthodontic community.

### *Success with RPD Treatment*

RPD treatment can be evaluated with regard to various parameters, such as denture survival, patient satisfaction, functional efficiency, and effects on oral health.

### *Survival of RPDs*

Metal-framework RPDs have been shown to have a relatively short survival time. Vermeulen[3] reported a 50% survival time of about 10 years for clasp-retained metal-framework RPDs, and a very short 50% survival time, about 3 years, for acrylic resin RPDs without metal frameworks. That study did not give any details about design or adverse effects of RPDs, but it did underline the need to focus on the long-term effects. A large study of metal-framework RPDs concluded that with a simple design and regular monitoring of the patient, the results are predictably successful.[4] The term "simple design" was, however, not defined.

### *Patient Satisfaction*

Patient satisfaction with RPDs is relatively low.[5–14] The figures in these studies are similar even though they originate from different countries with different design philosophies. Constructional or design aspects that can explain the low success rates have, however, not been identified. This combination of frequent rejection of RPDs and high risk of adverse effects provides a strong motive to consider new approaches.[6] One way to reduce the oral health risks from RPDs is not to prescribe them and to adopt the shortened dental arch concept whenever acceptable.[6,15,16] Alternatively, other treatment options may be employed, such as fixed partial dentures (FPD).[17,18]

### *Open Design/"Hygienic Design"*

The basic principle of open hygienic RPD design is presented in a German standards document that states in translation, "If the base elements of the RPD do not contact either teeth or periodontium, it cannot cause any injuries to these stuctures."[19] Open design for gingival and periodontal health is frequently mentioned in the literature, and its advantages have been demonstrated in a number of publications.[20,21]

Jacobson[22] presents guidelines for designing RPDs and states that, "Although some patients can maintain meticulous levels of home care regardless of the prosthesis design, partial dentures should be fabricated along guidelines that benefit the majority of patients, including those who demonstrate less-than-ideal levels of plaque control." He also stated, regarding traditional RPD construction, that, "Such designs incorporate many framework components and result in the undesirable coverage of hard and soft tissues."[22] The conclusion was that, "The emphasis in contemporary RPD design should be placed on minimal tooth coverage by framework components and on the elimination of components whenever possible without compromising biomechanical requirements."[22]

Longitudinal studies of RPD patients found that those who did not use their dentures had better periodontal conditions than those who did.[23–25] Remarkably good long-term periodontal and gingival conditions were, however, maintained in controlled studies of RPD patients where the patients were wearing RPDs of the open hygienic type and were on a regular maintenance program[26–29] or were wearing RPDs of the open hygienic design.[30]

Yeung et al[21] examined 87 patients who had been treated with cobalt chromium RPDs 5 to 6 years previously. Significantly more tooth sites adjacent to narrow embrasures with RPDs harbored plaque than those adjacent to wide embrasures. The same was true for gingival bleeding and loss of periodontal attachment, measured as loss of 4 mm or more of marginal attachment. The association between root caries and narrow embrasures was also statistically significant. The authors concluded that RPD components should be designed to uncover the gingival margins as often as possible.[21]

Severe gingival reactions have been observed when the gingiva is covered, whereas an open design of minor connector is less conducive to an increase in crevicular temperature, plaque formation, gingival inflammation, and pocket depth.[31–33] "Therefore, as a general rule, the design of removable partial dentures should be as simple as possible with denture bases, major connectors, and minor connectors avoiding contact with the free gingiva and contacting the alveolar ridge or the palate at least 3 mm from tooth surfaces . . ."[34] In a survey of prosthodontic specialists, the majority supported use of the open design when plaque control was poor.[2]

Spiekermann and Gründler,[35] when discussing periodontal prophylaxis in RPD design, emphasize that clasps should be placed as far as possible from gingival margins and that the number of minor connectors should be kept to a minimum. They suggest direct minor connectors approaching from the base areas, with open proximal spaces, instead of palatally or lingually approaching minor connectors and mention that gingival relief can be further achieved by designing the first replacement tooth of a base as a pontic.[35]

Adopting a simple shape for the prosthesis and keeping the number of components to a minimum have major advantages as far as hygiene is concerned.[36] A survey of expert prosthodontic opinion showed that the majority are in favor of a maximum of two direct retainers and a major connector of simple shape.[37] There is significant support in the literature for the view that gingival/periodontal health is favored by the open/hygienic design.

### *Risk Factors in Traditional Design*

The majority of prosthodontic textbooks have concentrated on the RPD design principles of force distribution, support, stability, and retention. The most widely disseminated general design rules are the ones described and advocated in McCracken's textbook of removable partial prosthodontics.[38,39] The basic principles are, however, founded on ideas that are not scientifically proven.

### *Direct and Indirect Retention*

Direct and indirect retention feature prominently in the relevant design principles. The distal extension denture is assumed to rotate around a fulcrum line when bases are subjected to forces directed toward or away from the residual ridge.[38]

Indirect retainers are "rigid units of the partial denture framework that are located on definite rest seats on the opposite side of the fulcrum line from the distal extension base" and "should be placed as far as possible from the distal extension base affording the best possible leverage advantage against the lifting of the distal extension base."[38] For indirect retention to operate, the rests on the fulcrum line must be held in their seats so that rotation about an axis occurs. If total displacement of the direct retainer occurs, there will be no rotation about the fulcrum and so no indirect retention.[38] However, it has not been demonstrated that occlusal rests are held in their seats during function, rather the opposite.

There are divided opinions regarding the value of indirect retention. For example, Grant and Johnson[40] stated that, "The improved stability which can be achieved in a partial denture by placement of indirect retainers needs to be weighed against their possible disadvantages. The latter include the biological disadvantages arising from increased coverage of soft and hard tissues of the mouth, and the fact that they may give rise to irritation of the tongue or other oral tissues." Similarly, Marxkors[41] questioned the overall benefit of indirect retention, as the indirect retainer lifts off the abutment tooth and becomes a potential source of irritation when the distal extension base is loaded.

Indirect retainers are often connected to the denture base by minor connectors that, if they make contact "with axial tooth surfaces, aid in stabilization against horizontal movement of the denture. Such tooth surfaces, when made parallel to the path of placement, may also act as auxiliary guiding planes."[38] Indirect retainers and their minor connectors make the denture more complex, and as the minor connectors cross the gingival margins, they increase the risk of damage to the gingiva. Therefore, a modified, more hygienic design has been introduced by extending the minor connector around the lingual aspect of the abutment tooth and onto the next tooth, thus avoiding the need to cross the gingival margin.[22,42–44]

An indirect retainer is supposed to reduce the risk of the denture base moving away from the mucosa.[45,46] However, clinical studies do not confirm that this happens in practice. A cineradiographic study of the movements of bilateral distal extension mandibular RPDs during chewing showed lifting of the bases even though indirect retainers were provided.[47]

It has been argued that there is a risk of lever action on the clasped mesial tooth in extension base RPDs if a direct retainer is placed on the opposite side of the fulcrum line.[38,39,44] Most design philosophies indicate that such constructions are inappropriate, and this seems to be a common worldwide view found in textbooks.[34,35,43,48–50] In the textbook by Bergman et al,[43] this principle is named the "Cummer rule."[49,50] However, examples that do not conform to the Cummer rule can be found.[37,51] In fact, a critical analysis of the literature did not find any evidence that a reduction of torquing forces transmitted to abutment teeth is necessary.[52]

In spite of the fact that there is little or no scientific evidence for most of the basic biomechanical design principles described above, there is a high level of agreement about many of them among prosthodontic experts from dental schools in the United Kingdom.[37] For example, all agreed that indirect retention should be used for distal extension bases.

### *Guiding Planes/Surfaces*

Guiding planes are believed to increase retention by increasing the efficiency of the direct retainers. They are used differently throughout the world. If employed, the gingival relief is reduced. Guiding planes are frequently advocated in the US,[38,39,53,54] and sometimes extensively.[55]

The European literature recommends the preparation of planes less strongly than in the US. It tends to suggest specific justifications for the recontouring of abutment teeth, eg, to eliminate occlusally high survey lines.[1,43,44,51,56] British textbooks seem to be of the opinion that guiding surfaces are advantageous from a mechanical viewpoint, but that there are often contraindications to their use.[40,48,57–59] When abutment teeth are to be crowned, a German textbook recommends that distinct guiding planes be incorporated into the restoration, but a more conservative approach is advised when removal of natural tooth substance is involved.[35]

The conclusions from the London International Prosthodontic Symposium 1982 still hold true: "It is clear that all partial dentures encourage a severe ecological change, but until studies are conducted on larger samples of subjects having both similar needs for prosthetic replacement and measured assessment of response to previous periodontal disease, the significance of guiding planes cannot readily be assessed."[60]

## Clinical Examples and Recommendations

The open/hygienic design principles that emphasize simplicity and uncovering of gingival margins have mostly been presented in national publications, not always easily available. Some illustrative examples are therefore discussed below.

### *Mandibular Major Connector*

Alternatives to the lingual bar are the sublingual bar, dental bar, and linguoplate. It is clear that the choice is geographically related.[61–64] Many authors consider the linguoplate disadvantageous from a hygienic and gingival health viewpoint.

The dental bar has been described by several authors.[20,30,65–70] Limiting factors mentioned are short clinical crowns, diastemas (in situations where esthetics may be compromised), lingually inclined teeth, and long dental arches, as the rigidity of the connector may be unsatisfactory. The dimensions recommended are 4-mm height and 1.5- to 2.5-mm thickness.[34,70] The dental bar has a long history, although the early use was not motivated by gingival health considerations.[71,72]

The sublingual bar, which maximizes the clearance of the gingival area, has also been described by a number of authors.[69,73–76] Food trapping has been reported and is made worse if the superior border of the bar is in contact with the mucosa.[76–78] Therefore, clearance between the alveolar mucosa and the sublingual bar is now suggested.[22,34,44] The recommended cross-sectional dimensions of the sublingual bar are 4 mm × 2 mm.[34]

### *Minor Connectors*

Minor connectors can, in most situations, be extended directly from the base onto the proximal aspect of the abutment tooth, allowing an open embrasure to be created. The direct minor connector principle is easily accomplished for the mandibular dental bar by continuing it directly into the connector (Figs 1 and 2). In molar regions, the minor direct connector can be extended and shaped similarly to a sanitary pontic in an FPD. Where a minor connector has to enter a dental arch without any replacement tooth or denture base, it can cross the gingival margin at the midpoint of the lingual/palatal tooth surface.[35,38,39,65,66,68,70,79–81]

### *Pontics*

The use of pontics in RPD design is described by a number of authors. McGivney and Castleberry[38] mention that replacement teeth can be abutted to the residual ridge for better esthetics, and Davenport et al[57] show the use of a "cleansable" pontic. The pontic was introduced into the hygienic RPD design concept by Karlsen.[30,65] It was later advocated and described in other publications.[41,66–68,82] The pontic is not very often presented in the literature and is therefore exemplified in Figs 1 to 4.

### *Direct Retainers*

Occlusally approaching retainers minimize the risk of physical injury to the gingival tissues. They may, however, have drawbacks related to esthetics. A common alternative is a gingivally approaching bar retainer, but this creates a risk of irritation to the facial gingival margin and, in cases of shallow sulci, to the mucosa.[82] An alternative retainer design is a buccal/facial retentive

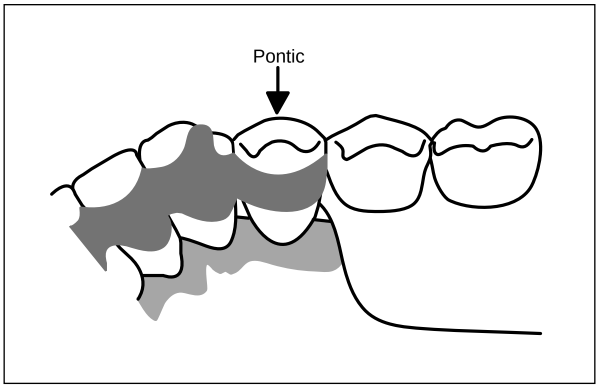



**Fig 1** Dental bar can continue distal of the abutment tooth and be designed to retain a pontic.

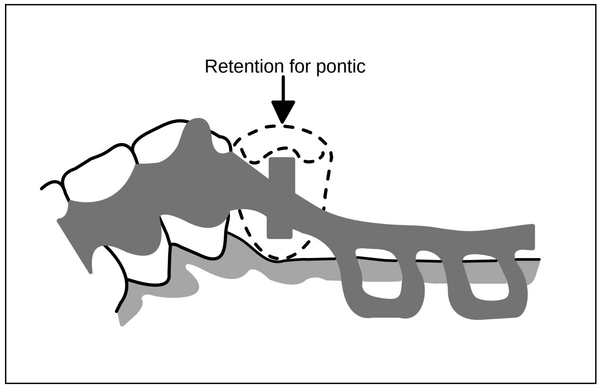



**Fig 2** Alternative retention for acrylate.[30,65]

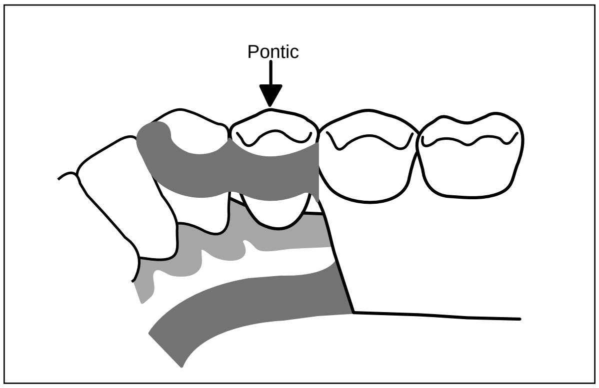



**Fig 3** Lingual (or sublingual) bar can extend distal of the first replacement tooth and a pontic placed in the junction area.

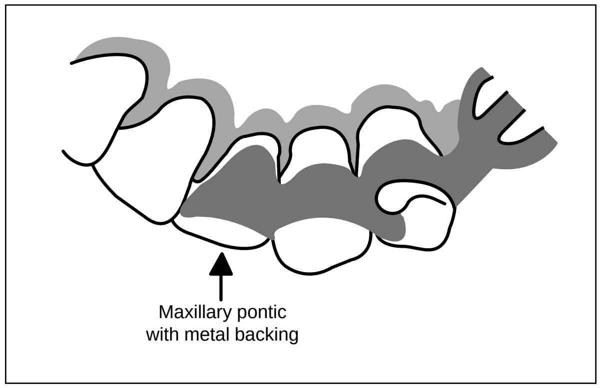


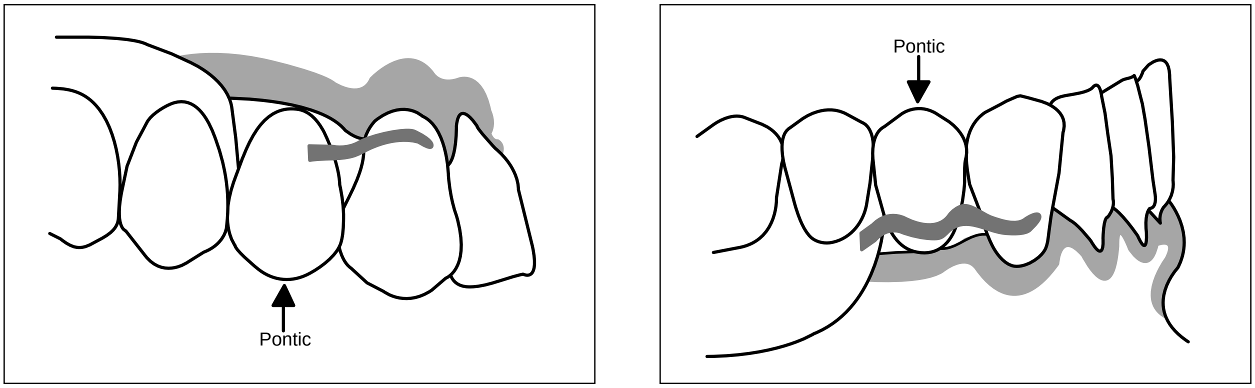

**Fig 4** In a situation of high risk for breakage or wear, the whole lingual and/or occlusal surface should preferably be metal.

arm approaching horizontally and proximally directly from the denture base or pontic across the embrasure and well relieved from the gingival tissue (Figs 5 and 6).[81]

## Discussion

From the outset, when planning the workshop on which this article is based, it was decided that the topic should be RPD design, with a particular emphasis on prevention. The participants very quickly came to the unanimous opinion that there was a need to critically analyze traditional RPD design concepts in the light of contemporary preventive dentistry. It was apparent that most RPD literature focused primarily on design related to biomechanical aspects, while design approaches related to hygiene and prevention were mostly described as "alternative" constructions, if at all.[37–40,48] A coherent presentation of hygienic/preventive aspects could thus be beneficial to the prosthodontic community.

A critical analysis of the literature revealed that no clinical studies provide evidence to support the well-established "biomechanical" design principles. However, adverse effects from RPDs are common.[21,23,25] In addition, patient satisfaction with RPDs is low[5–14] in spite of the constructions being designed for biomechanics, which basically aims at patient comfort and denture function. Although these problems have been known for many years, they do not seem to have influenced RPD design much, when judged from recent textbooks.[39] It was, however, clear that the evidence for the benefits of open/hygienic design was also weak and indirect. There seemed, though, to be reason enough to question some generally accepted design rules, and to stimulate clinical studies about alternative constructional principles that could reduce risk factors. The group was aware of the possibility of being considered revolutionary, but found good grounds to promote the open/hygienic designs found in the recent literature. It was also apparent that these design




**Figs 5 and 6** Wrought-wire S-bar retainer[83] approaches the retentive area directly from the base or pontic without crossing the gingival margin. In cases of long clinical crowns and shallow sulci, it is especially indicated. The length relates to the depth of the undercut and the flexibility needed. It is free from the pontic buccal surface. Rest seats at cingulum or as incisal hooks.

aspects can be applied without invariably compromising the requirements of biomechanics.

## Conclusion

The literature indicates that gingival coverage and a close relationship between parts of the RPD and the gingival tissues are risk factors for the long-term success of an RPD. The RPD components that especially need to be considered from a hygienic viewpoint are direct retainers, indirect retainers, guiding planes, minor connectors, and mandibular major connectors. A critical analysis of RPD design carried out in the light of modern concepts of preventive dentistry favors open/hygienic design principles rather than biomechanical considerations. There is accordingly a need to focus on minimizing risks of oral tissue injury in RPD treatment and design.

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*Literature Abstract*

**No association between incisal tooth wear and temporomandibular disorders.**

This study investigated the relation between anterior tooth wear and TMD; 208 TMD patients and 172 asymptomatic control subjects were selected. Individuals with more than one missing premolar or molar in opposite arches and subjects with missing or extensively restored anterior teeth were excluded. There were 154 TMD patients and 120 control subjects included (age 31.2 ± 13.4 years). Anterior tooth wear was assessed on dental casts with a 0 to 5 scale. A multiple logistic regression analysis was performed to study the association between tooth wear and TMD. Incisal tooth wear was not significantly associated with TMD when the influence of age and gender was controlled. Substantial tooth wear, which might be regarded as a sign of bruxism, does not yield a higher risk for the development of TMD. Based on the presented evidence, a clinically relevant risk for TMD from incisal tooth wear can be excluded. The findings of this investigation do not support the notion that treatment of incisal tooth wear is indicated to prevent TMD.

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