

Conformity of removable partial denture designs from three laboratories to a set of design principles

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ABSTRACT

Purpose. The purpose of this study was to assess and to compare the technical quality of removable partial dentures (RPDs) servicing both public and private sectors, in relation to biomechanically acceptable principles.

Materials and Methods

A convenience sample of work carried out in three commercial dental laboratories servicing both the private and government sectors was used to provide a descriptive study of the laboratory stage of fabrication of RPDs over a 3-month period. Prescription sheets, master casts and completed dentures of 114 cases were evaluated and procedural and design-related information data were captured for each case.

Results

The results were disappointing in that not one of the RPDs evaluated conformed to commonly accepted principles. Not one dentist prescribed the design of the denture. Only one cast was surveyed to determine the path of insertion and any undercuts for the placement of clasps, yet 119 clasps were placed. Although 81 rests were used (in only 25 of the dentures), only 11 of those rests were pre-prepared on the teeth. Only 8 of the 95 acrylic-based dentures had any rests, making the remainder entirely mucosa-borne and therefore potentially iatrogenic.

Conclusions

The study suggests that principles of RPD design taught during undergraduate training are not being adequately practised in both private and public sectors; and if practised the RPDs are not designed, nor constructed to requirements guided by design principles. Further training of dental technicians and clinicians is clearly indicated,

and consideration should be given to a system of clinical audit to identify and prevent the malpractice observed in this study. In addition, ethical and legal guidelines emphasising the roles of clinicians and technicians in the prescription and design of RPDs in South Africa should be developed; and the mandatory comprehensive completion of laboratory work authorisation forms by dental clinicians should be considered.

Keywords: removable partial dentures; design principles.

INTRODUCTION

In developing countries, increasing numbers of patients are seeking treatment for partial tooth loss.¹ Possible treatment options include removable partial dentures (RPDs), fixed partial dentures, and implant-supported prostheses. As technology and materials advance, treatment options such as implants and fixed prostheses have increased, but their costs are high, making them unaffordable to most patients. Conventional acrylic resin or metal framework based RPDs remain the most cost effective option for the majority of patients.^{2,3}

RPD design principles have evolved since 1711, when partial dentures were first carved from a block of bone to replace missing teeth.⁴ As the years progressed, with the aid of technology, as well as observations with regards to outcomes, RPD designs have changed considerably. Designing RPDs may pose a challenge, as it has been estimated that there are 65,534 possible presentations of partial edentulism for each dental arch, if the only variable accounted for is the presence or absence of teeth.⁵ There appears to be no single universally used set of guidelines or principles for designing RPDs,^{6,7} although a study conducted in the UK demonstrated that there was general consensus amongst a majority of prosthodontic specialists for a number of principles.⁸ A local study⁹ used designs agreed to by two prosthodontists to enable comparisons with actual designs observed in commercial laboratories.

A questionnaire study on RPD designs in South Africa reported a distinct disparity between principles and methods taught and practised routinely applied after graduation.¹⁰ The study reported that 82% of dentists instructed the laboratory technicians to design the RPD; casts were not surveyed by 64% of dentists, and 55% were not mounted on an articulator. A more recent local study of RPDs produced in three commercial laboratories found that 55% of the designs had no rests; 65% of the acrylic RPDs had no rests and 85%

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had no clasps; and metal RPDS had more clasps than necessary.⁹

To date, no published studies have been carried out in South Africa that have compared the designs observed in commercial laboratories to a set of design principles, nor have any comparisons been made between RPDs made for the private or public sectors.^{11,12} The aim of this study was therefore to assess the designs of RPDs being produced in three commercial laboratories supplying both the public and private sectors against a set of design principles derived from the literature.

MATERIALS AND METHODS

This was a cross sectional, descriptive study conducted on RPDs during the laboratory stage of fabrication, using a convenience sample of work carried out in three dental laboratories in one district (Ekurhuleni, Gauteng province) for both private and public sectors over 3 months. All acrylic and metal based RPDs were included.

Ethical clearances was obtained from the Ekurhuleni Ethics Committee and the Human Research Ethics Committee of the University (No. M190314). Prior to delivery, each RPD prescription sheet, master cast and final denture was digitally photographed by the dental technicians in a way that allowed the number of existing teeth, the class of partial edentulism, support and retentive components to be identified. In addition, the technicians participating in the study were asked to record a variety of technical aspects of the RPDs: the choice of primary impression materials used, whether special trays were requested, materials used in secondary impressions, use of occlusion rims, types of articulators requested / type of articulators available, try-in procedures and if any dentures were sent back to the lab post-recall for adjustments to be made. A separate column for design and surveying was also completed by the technician. Where possible, at the master cast and prior to delivery stages, close-up photographs were taken by RD.

The photographic records of the casts were then examined and any additional aspects that may have been missed were recorded. They were also examined by an experienced prosthodontist in order to assess/verify technical quality, using the selected design principles. In the event that there was any disagreement in interpreting the images and data capture sheet, an additional prosthodontist assessed the data.

The design principles were derived from a number of sources.^{6,-9,13-29} These were:

- Evidence of casts having been surveyed by the dentists and/or dental technicians;
- The presence of articulated diagnostic casts;
- Written or verbal technical instructions given to the technician;
- Provision of denture design drawings by dentists and/or dental technicians;
- The presence or absence of tooth support in the form of rests in the final denture;
- The presence or absence of prepared rest seats

on the master casts;

- The presence or absence of clasps in the final denture; and
- The presence or absence of prepared tooth guide planes on the master cast.

A brief explanation for these is as follows:

Surveying and design by the clinician: the design of the RPD is the responsibility of the dentist and a dental surveyor is necessary in order to determine the path of insertion, height of the contour line and to measure undercuts for clasp design.^{6,25,29} Diagrammatic and written instructions should include framework design and saddle area extensions, occlusal rests, direct and indirect retention and reciprocation.³⁰ If wrought wire is to be used for clasps the dimensions of the wire and the depth of undercut in which the clasp should rest should be indicated as well.^{29,31}

Importance of articulated diagnostic casts: Articulated diagnostic casts aid in assessing spatial requirements of the dentures when placing rests and designing the framework, ensuring no unplanned occlusal vertical dimension increase occurs.²¹

Tooth support: The purpose of a rest seat preparation is to direct forces axially along the tooth,^{23,29} to prevent movement of the denture in an occlusal direction, reducing trauma to the mucosa, and distributing occlusal forces. Rests should be prepared on the occlusal surface of posterior teeth, or on the cingulum area of anterior teeth by a clinician before recording a secondary impression. Rest seat design will vary according to the denture base material (metal or acrylic) or the component used (such as half-round wire for acrylic-based RPDs).²⁹ Patients who had adequate and sufficient rest seats, were overall more satisfied with their dentures than those whose dentures had inadequate support;²⁶ and adequate support was one of the few criteria that correlated with successful wearing of mandibular Kennedy Class I RPDs.³²

Clasps: Clasps should be flexible enough to allow the RPD to be repeatedly seated and removed without permanently deforming the clasp and without damaging the tooth.^{29,31,33-37} Although clasps aid in retention, they should not be considered the prime objective of the design. Well adapted and extended denture bases, accurate framework fit, and properly prepared guide planes positively influence RPD retention independently or in combination with clasps.^{6,28}

Guide planes and guiding surfaces: The guide plane on the prepared surface of a tooth adjacent to an edentulous saddle, and the guiding surface of the denture provide guide plane retention, by increasing frictional resistance, limiting the path of insertion/removal. In addition they provide stabilisation against horizontal rotation and help to eliminate food traps between the abutment teeth and RPD components.^{16,23,28}

Apart from these design principles, there are other factors that contribute to the successful use of RPDs.

Designs should incorporate minimal gingival coverage by major connector components and elimination of redundant components without compromising biomechanical requirements.^{7,14,15} In addition, it is not always clear as to what features correlate with patient satisfaction. Frank et al (2000)³² reported that patients were most dissatisfied with ill fit of partial dentures (76%), followed by iatrogenic damage caused by the partial denture (63%), but found no statistical correlation with rest form, base extension, force control, framework fit, base support, occlusion, stress distribution and retention. However, gingival inflammation was twice as likely when rest seats lacked positive preparation form, the base was under-extended, insufficient rests were placed adjacent to a distal extension, and there was poor fit of the framework.

RESULTS

Types of dentures and sector

There were 114 removable partial dentures recorded, 79 of which originated from the private sector, and 35 from government clinics (Table 1).

Table 1. Numbers and types of RPDs and their origin. Mand = mandibular; Max = maxillary.							
PRIVATE				GOVERNMENT			
METAL-BASED		ACRYLIC-BASED		METAL-BASED		ACRYLIC-BASED	
Mand	Max	Mand	Max	Mand	Max	Mand	Max
14	5	14	46	0	0	15	20
19		60				35	

Extent to which the RPDs met minimal principles of design

- Evidence of the casts having been surveyed by the dentists and/or dental technicians.* Only one case had been surveyed by one dentist, but the remaining 113 cases had no evidence of having been surveyed at all.
- The presence of articulated diagnostic casts.* No articulated diagnostic casts were found.
- Written or verbal technical instructions given to the technician.* The laboratories reported 3 cases where they had received verbal instructions from the dentists, 1 from the private sector for a maxillary metal-based RPD, and 2 from the government sector, for a maxillary and a mandibular acrylic-based RPD. Written instructions comprised the completion of a form supplied by the laboratories and were absent in only 6 cases. However, none of the completed forms contained any design instructions.
- Provision of denture design drawings by dentists and/or dental technicians.* No cases had any drawings by either the dentists or the technicians.
- The presence or absence of rests in the final denture.* None of the dentists had specifically requested rests to be included in the design and the decision for their placement was entirely left to the technician's discretion. The type of rest (anterior or posterior) was not recorded, but 25 of the RPDs did have rests, 17 metal-based and 5 acrylic-based dentures for the private sector and 3 acrylic-based dentures for the government sector.

- The presence or absence of prepared rest seats on the master casts.* Four of the casts had evidence of prepared rests on the teeth, 3 metal-based dentures from the private sector and 1 acrylic-based denture from the government sector.
- The presence or absence of clasps in the final denture.* Despite there being no designs from the dentists, 54 (47%) of the dentures did have clasps, 40 for the private sector and 14 for the government sector. Of these, 19 dentures were metal-based and 35 acrylic-based. The types of clasps were not recorded other than to note that when a wrought wire clasp was used, the laboratories used a variety of stainless steel clasp of diameters from 0.7 mm to 1.0 mm.
- The presence or absence of guide planes on the master cast.* No evidence could be found of any prepared guide planes on the teeth on any of the casts.

Design Principles Met

The most number of design principles met was 3, but that was only in 3 of the dentures out of 114. Twenty three (20%) met 2 principles and 28 (25%) met one. This meant that 54 (47%) did not conform to any of the principles.

DISCUSSION

Removable partial dentures are a viable and cost effective treatment option that can improve the oral health related quality of life of partially dentate patients, particularly in developing countries,³⁸ as well as in underserved communities in developed countries.³⁹ In a South African study, patients reported an improved function, satisfaction and oral health-related quality of life after prosthetic treatment with RPDs.⁴⁰

Rehabilitation of the partially dentate patient requires the clinician to be cognisant of mechanical and biological factors. A biologically acceptable design must take into account factors such as the periodontal condition, number and status of remaining teeth, the nature of the opposing teeth (artificial vs natural), hygienic principles and aesthetics. An ideal RPD is customised for the patient, integrating the clinical findings into a design that widely distributes the occlusal load to include tooth and mucosal support when necessary, with the teeth providing most of the support. Retention from active elements such as clasps and passive elements such as guide planes/guiding surfaces contribute to the overall retention and stability of the RPD. Eliminating redundant components and covering excessive mucosa should always be avoided, and in so doing optimal hygienic principles are incorporated into the RPD and the design is thus simplified.¹ Lower failure rates have been observed when the emphasis on biologically acceptable designs, regular maintenance visits and oral hygiene education was reinforced.^{15,41} This study evaluated the design of removable partial dentures fabricated within three dental laboratories serving the private and public sectors, in Ekurhuleni, South Africa, and using a set of principles derived from the literature. The results revealed that not one of the RPDs evaluated conformed to these principles.

The maximum number of principles encountered in the designs was 3, and only for 3 of the dentures. Almost half (47%) showed no conformity to any of the principles. Not one dentist prescribed the design of the denture. Only one cast was surveyed to determine the path of insertion and any undercuts for the placement of clasps, yet 119 clasps were placed, which implies that they were either placed in the wrong undercut or not in any undercut at all. Although 81 rests were used (in only 25 of the dentures), only 11 of those rests were pre-prepared on the teeth. Only 8 of the 95 acrylic-based dentures had any rests, making the remainder entirely mucosa-borne and therefore potentially iatrogenic.

Such findings, although tantamount to malpractice on the part of both the dentists and the technicians, are sadly not unique. For example, a variety of studies have reported some similar findings: more than 88% of dental laboratories reported that the dentist's communication to them was lacking and that the majority (77.9%) of RPDs were designed by the technicians and not the dentists;⁴² 51% of RPD casts were submitted to laboratories without specifying the design or providing written instructions;³⁸ more than 80% of dentists communicated through generic laboratory scripts only, with 90% rarely or never giving additional details regarding RPD design;⁴³ and only 46% of laboratory technicians indicated prescriptions were completed accurately.⁴⁴

Mandatory comprehensive completion of laboratory work authorisation forms by dental clinicians is required, prior to RPD fabrication in the United States. The laboratory script is considered a legal document, and is duplicated and included in patient records.⁴⁵ Similar legal and ethical guidelines have been included in Medical Devices Directive (European Union) and the British Society for the Study of Prosthetic Dentistry.⁴³ No such prescripts have been published in South Africa.

The finding here that all the government clinic RPDs were acrylic-based is probably because in the public sector costs are generally kept as low as possible so metal-based RPDs are not routinely made, but the majority of RPDs from the private sector were also acrylic-based. There is no doubt that these are a more cost-effective option, but nevertheless there is no excuse for not providing at least tooth support for these dentures.

Apart from the lack of tooth support, only one cast was surveyed, by one of the private dentists. Not one of the technicians reported surveying a cast, making it impossible that such aspects as the path of insertion, undercut identification and measurement, hard and soft tissue analysis, guide plane analysis and so on can be carried out, leading to potentially iatrogenic consequences. It has been reported that there may be a belief by dentists that the technician has more experience and dentists elect to delegate this responsibility but that this is unethical, as the diagnosis, prognosis and treatment planning are the responsibility of the dentist.^{29,38}

A further example of the malpractice observed in this study is the placement of clasps. A recent study has pointed out the necessity to provide the correct material and form relative to the curvature of the tooth, the length of the clasp, and the undercut present, yet none of these appear to have been considered in this study, as inferred from the lack of surveying.³¹ It has also been pointed out that guide plane retention especially in acrylic-based RPDs may be sufficient if carried out correctly to obviate the need for clasps.²⁸ Not one of the RPDs evaluated in this study showed any evidence of this having even been considered.

LIMITATIONS

There were some limitations to this study: only conformity to design principles was recorded, and not every aspect of design so that no analysis of the overall design could be carried out. It was not possible to follow up the dentures to see if in fact the patients for whom they were intended were wearing, and using them. Although the standards investigated are derived from an extensive literature, there is no universally accepted set of standards.

CONCLUSION

Within the limitations of this study, it can be concluded that none of the participating clinicians and technicians adhered to principles of partial denture design, even though these are extensively taught and adequately practised during undergraduate training.

The RPDs evaluated were neither designed nor constructed to satisfy the principles of partial denture design, and the majority of dentures are likely to be potentially iatrogenic. There is therefore a clear need for further education and training for both dentists and dental technicians and eventually for a system of clinical audit to be put into place to identify and prevent the malpractice observed in this study, as well as ethical and legal guidelines emphasising the roles of clinicians and technicians in the prescription and design of RPDs in South Africa. Finally, the mandatory comprehensive completion of laboratory work authorisation forms by dental clinicians should be considered.

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