A comparative study between thermoplastic and conventional removable partial denture designs

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Keywords

- Partially edentulous
- Acrylic removable partial denture
- Cobalt – chromium removable partial denture
- Non-metal clasp removable partial denture
- Removable partial denture design
- Support
- Retention
- Stability
- Indirect retention
- Cross – arch stabilization

Abstract

A comparative study between thermoplastic and conventional removable partial denture designs

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Aim: The aim of this study was to assess if a sample of clinical thermoplastic NMCDs, acrylic and metal-frame RPDs comply with biological and biomechanical design principles.

Methods: Three dental laboratories in the Cape Town Metropole that were known to fabricate "flexible" or NMCDs for dental practices were identified and were invited to participate in the study. Their participation consisted of emailing photographs of completed metal-frame, acrylic and flexible RPDs and their casts prior to sending them to the practices for delivery to patients. Specimens were collected until a total of 20 metal-frame, 20 acrylic resin and 20 flexible RPDs were received. A design was drawn for each submitted RPD. For each RPD, an "ideal" design was drawn, using the image of the cast. This was done by two observers, who are experienced members of staff in the Department of Restorative Dentistry (Prosthetics), independently. The designs from both observers were later compared for similarity. Where differences existed in the designs, these were resolved by means of discussion until agreement was reached. Each ideal design served as the control for each clinical design.The number of rests, their configuration, the type of support, number of clasps, the presence of indirect retention, cross-arch stabilization, the number of teeth whose periodontal tissues were covered by design components for each design among the different denture type groups, and corresponding control designs were identified and reported. The ratios of teeth replaced/teeth covered per denture type groups and per classification, and corresponding control designs were compared.

Results: The results reported the following: The clinical designs had a total of 33 designs with no rests at all, 8 had only 1 rest, 8 had 2 rests, 4 had 3 rests and 7 had 4 or more rests. The clinical designs that had no rest configurations were 41, 8 had a configuration in a line, 4 in a triangle and 7 in a square. A total of 33 clinical designs were soft tissue supported, 21 were of

mixed support and 6 had hard tissue support. A total of 35 clinical designs required indirect retention of which in only 14 designs it was provided. The total number of clasps in the clinical designs was 120 clasps compared to the 167 clasps of the control designs. For the number of teeth covered versus the number of teeth replaced, the ratio of clinical designs was 7.03 compared to the 3.31 of the control designs. Cross – arch stabilization in the clinical designs had 13 out of the 60 designs that were unilateral.

Conclusion: Within the limitations of this pilot study it may be concluded that: None of the groups of RPDs (acrylic, metal or NMCDs) in this sample were acceptable regarding biological and biomechanical principles. The metal-frame RPDs had higher compliance rates for type of tissue support (mostly hard and mixed), number of clasps and cross-arch stabilization. The acrylic partial dentures were compliant in providing cross-arch stabilization but were non-compliant in all other aspects. Except for clasp numbers, the NMCDs were not compliant with any of the biological and biomechanical criteria assessed in this study.

November 2018

DECLARATION

I hereby declare that this dissertation "*A comparative study between thermoplastic and conventional removable partial denture designs*" are my own work, that it has not been submitted for any degree or examination in any other university, and that all sources I have used or quoted have been indicated and acknowledged by complete references.

Warren Emile Farao

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Dedications

This paper is dedicated to my family for their continuous support, unconditional love and sacrifice.

- To my wife **Zylia**, my ‘research partner’ for your understanding, constant support, motivation and for keeping the fire burning at home.
- My mother, **Estelle** for your prayers, support and love.
- My son **Noah**, for his understanding, unconditional love and for sharing me with dentistry.
- My supervisor, **Prof. G Geerts**, for the advice, guidance, and availability.

Abbreviations

NMCD : Non-metal clasp denture

RPD : Removable partial denture

Co – Cr : Cobalt-chromium

PMMA : Poly methyl methacrylate

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Chapter 1: Literature review

1.1. Introduction

Due to an ageing population and a shift from total to partial edentulism, the need to replace missing teeth for partially edentulous patients increases (Campbell *et al.*, 2017). Patients may seek tooth replacements to improve appearance, mastication and phonetics. Dentists may want to prevent movement of teeth due to drifting, tilting and overeruption of remaining teeth and to protect or restore occlusion. There are several options available to manage the partially edentulous mouth as part of a comprehensive treatment plan. These options include removable partial dentures (RPDs), tooth-supported fixed partial dentures, implant-supported or -retained prostheses or no intervention. Each approach has its advantages and disadvantages. Removable partial dentures may be indicated as provisional or transitional prostheses, to facilitate oral hygiene, in situations of long edentulous spans when fixed prostheses and dental implants are not indicated (Mcgarry *et al.*, 2002), to support orofacial structures when hard and soft tissue need to be replaced (Bohnenkamp, 2014) and in situations of budgetary constraints (Ramsay *et al.*, 2015). Because of the association between complete and partial edentulism and lower socio-economic status of populations, RDPs will remain a prominent treatment option (Campbell *et al.*, 2017).

1.2. Consequences of treatment with removable partial dentures

Since the research project reported in this mini-thesis deals with the assessment of RPDs, this literature review will be limited to discussing the consequences of treatment of partial edentulism with RPDs.

Wearing RPDs may have adverse effects on the health of oral tissues (Mojon *et al.*, 1995). In a retrospective study, Behr *et al. (*2012) found that the most common complications of clasp retained RPDs were caries, loss of abutment teeth and fracture of clasps (Behr *et al.*, 2012). Removable partial dentures promote plaque accumulation not only on teeth in contact with the denture but also on other teeth (Vermeulen *et al.*, 1996). It is generally accepted that adverse effects of RPDs on oral tissues is related to the type of denture. A cobalt-chromium (Co-Cr) denture is considered more hygienic than an acrylic RPD, even though the ability of the patient to remove plaque remains crucial in maintaining oral health, regardless of the type of RPD the patient wears. This is evident from a report by Bergman *et al.* (1995) who found that with a high level of patient cooperation and motivation, the number of lost teeth, the number of new decayed and filled surfaces and the increased number of endodontically treated teeth were few. They also reported that no apparent changes took place regarding the periodontal condition during the 25-year follow-up period (Bergman *et al.*, 1995). Yeung *et al*. (2000) report a high prevalence of plaque, gingivitis and recession in close proximity to Co-Cr RPDs (Yeung *et al.*, 2000).

do Amaral *et al.* (2010) examined the periodontal condition of RPD-wearers, comparing abutment teeth and teeth not involved in the denture design before and after denture placement. They found that plaque index values were significantly higher after 1 year of denture use. They also found that abutment teeth suffered more periodontal effects associated with RPD-use when compared with non-abutment teeth. This confirmed earlier findings by Zlatarić *et al.* (2002) who measured higher plaque, gingival and calculus indices, probing depth, gingival recession and tooth mobility for abutment teeth as compared to non-abutment teeth. This association is attributed to RPDs that retain plaque (Vermeulen *et al.*, 1996).
Emami *et al*. (2012), in a systematic review, found an association between denture stomatitis and the wearing of RPDs (Emami *et al.*, 2012).

Root caries was found to be associated with Co-Cr RPDs, but not coronal caries (Yeung *et al.*, 2000). Hence, Yeung *et al.* (2000) recommended that exposed root surfaces should not be covered by RPD components.

Properly placed occlusal rests prevents movement of the RPD towards the tissues and reduces trauma to the underlying soft tissues. RPDs may increase the amount of stress on natural abutment teeth due to transmission of occlusal load from the denture teeth (Rissin *et al.*, 1985),(Zlataric *et al.*, 2002).

While accidental aspiration and swallowing of dental prostheses appear to be rare, they may have severe consequences. It is associated with undersized or fractured RPDs. The main reasons for these incidents are maxillofacial trauma, dental treatment, intoxication and dementia. Radiography assists in exposing swallowed or inhaled foreign objects. Hence, a radio-opaque RPD material may assist in its location (Goodacre, 1987),(Olak and Jeyasingham, 1991),(Cooke and Baxter, 1992),(Rajesh and Goiti, 1993).

1.3. Removable partial denture design

1.3.1. Introduction

While RPDs have been linked to harmful effects to teeth and supporting tissues, studies reported that these risks may be partly due to poorly designed RPDs (Zlataric *et al.*, 2002),(Preshaw *et al.*, 2011). Wilson (2009) argues that even acrylic RPDs can be considered a definitive prosthesis, provided that proper patient selection and the principles of RPDs are followed. Hence, it is the clinician's responsibility to plan custom designs for each patient to preserve health of oral tissues (Davenport *et al.*, 2000) (Wilson, 2009). Ezawi *et al.* (2017) stated in their systematic review, that most investigators suggested that RPD design improvements with overall good oral hygiene may reduce harmful impact of RPDs on soft and hard tissue (Ezawi Aae *et al.*, 2017). Kapur *et al.* (1994) concluded that a satisfactory treatment modality will be achieved if RPD designs are well designed-and-constructed, contains favourable abutments and is followed by regular prosthetic maintenance programs. According to Davenport *et.al*. (2000) creating an optimal RPD design depends on: clinical and technical knowledge, thorough patient examination and diagnosis, appropriate treatment planning including any mouth and tooth preparations, and knowledge of dental materials (Davenport *et al.*, 2000).

To optimize the advantages and minimize possible disadvantages of RPDs, several biological and biomechanical considerations need to be kept in mind when designing RPDs.

1.3.2. Biological considerations

In the section "Consequences of treatment with removable partial dentures", biological consequences of placing RPDs were given. Numerous authors have published papers on the importance of designing RPDs to reduce the risk of developing these biological complications. The most frequent recommendation is to follow hygienic or open design principles by not covering marginal gingiva. A clinical study by Ogunrinde *et al.*, (2014) indeed revealed that, with similar plaque levels, better gingival tissue health was maintained by patients wearing an RPD with a lingual bar major connector as compared to a lingual plate (Ogunrinde *et al.*, 2014). A clinical study by Akaltan & Kaynak (2005) found that plaque accumulation was higher for lingual plates as major connectors for distal extension RPDs as compared to a lingual bar, although tooth mobility (TM) improved with the lingual plate-type RPDs (Akaltan and Kaynak, 2005). Orr *et al.* (1992) found that even if plaque indices (PI) remained the same, gingival indices (GI) increased after placement of acrylic resin baseplate connectors (Orr *et al.*, 1992). This was confirmed by Zlatarić *et al.* (2002) who found that covering the gingival margin was harmful to gingival health. They also found that calculus index (CI) was highest for Kennedy Class I RPDs. The highest PI and CI were found for lingual plate RPDs and probing depth (PD) was higher for acrylic dentures. Tooth and tooth-mucosa supported dentures had significantly lower GI, CI and PD than mucosa supported dentures. With more clasps higher PI and TM scores were recorded, with no difference between occlusally or gingivally approaching clasps. Within this context, it is important to note that retention of RDPs was shown to be improved in vitro by incorporating guide planes on teeth and guiding surfaces on tooth-bounded saddles of RPDs (Mothopi-Peri and Owen, 2018). Hence, the number of clasps may be reduced and may ultimately have a positive effect on PI and TM in vivo. With more occlusal rests, lower GI, TM and gingival recession were recorded (Zlataric *et al.*, 2002). Kapur *et al.* (1994) compared the circumferential clasp assembly with the RPI system for distal extension dentures and found that the two designs did not differ significantly in terms of success rates and effects on abutment teeth.

1.3.3. Biomechanical considerations

1.3.3.1. Biomechanical basis of support

All support is ultimately derived from bone, as all forces are transmitted to it via mucosa and periosteum or teeth and periodontal ligament. For RPDs, vertical support should *always* be provided via rests on some of the remaining teeth (Owen, 2000). Rests should transmit vertical forces to and along the long axes of abutment teeth (Carr and Brown, 2011). Besides support, rests resist movement toward the tissue and prevent iatrogenic damage. For Kennedy Class I, II and some Class IV RPDs, partial support from the mucosa cannot be avoided. For stability in support, the selection of at least 3 rests is advised, widely spaced (Owen, 2000).

1.3.3.2. Biomechanical basis of retention

Retention provides resistance against forces that tend to dislodge a denture. There are different ways to provide retention: 1) *Direct, or active, retention* (retainers or clasps) exert a force on abutment teeth when the RPD is lifted away from the teeth (Owen, 2000). The efficiency of direct retainers to resist movement is influenced by the prosthesis' stability and support from its other components: major and minor connectors, rests, and tissue bases (Carr and Brown, 2011); 2) *Passive retention* is provided by components of the denture that exert a force whenever the denture is dislodging in a direction other than that of its path of withdrawal (Owen, 2000). Guide planes are an example of providing passive retention. 3) The *indirect retainer* prevents the denture from tipping around a horizontal axis and is valuable with distal extension partial dentures and those with anterior saddles. Rests or any contact of the RPD against hard tissue or hard palate on the opposite side of the horizontal axis may act as indirect retainer (Mccord *et al.*, 2002).

1.3.3.3. Cross-arch stabilization

Forces on RPDs are not purely vertical but have a horizontal component as well. *Major connectors* connect RPD components of both sides of the arch to not only create cross-arch stability but also spread loading forces and reduce torque on abutment teeth. A horizontal force

on one side of the arch, will be resisted by a clasp and/or rest on the other side of the arch and contribute to stability (Owen, 2000). Major connectors should be rigid to effectively perform these functions (Gad, 2017).

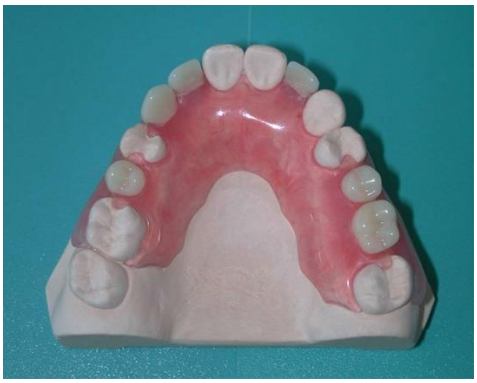
1.4. Removable partial denture materials

Frameworks for RPDs are commonly made from metal or polymer. Metals most often used are cobalt-chromium and, more recently, also titanium (Becker *et al.*, 1994),(Au *et al.*, 2000),(Ohkubo *et al.*, 2008) . The benefits of metal bases include their strength, stiffness, good thermal conductivity, accuracy, durability, reduced bulk and weight (titanium), and resistance against corrosion (Ohkubo *et al.*, 2008). The disadvantages of metal base RPDs are their high fabrication cost, aesthetics, galvanism, biofilm formation and difficulty to repair (Ohkubo *et al.*, 2008) (Suwal P *et al.*, 2017). Suwal *et al.* (2017), in a prospective trial, established that metal cast RPDs provided better retention, stability, masticatory efficiency, comfort and periodontal health of abutment teeth over a period of 1 year. Even though metal bases are still considered to be the best material for RPDs, some studies reported that over time, direct retainers distorted under stress and eventually did not fit the abutment correctly anymore (Keltjens *et al.*, 1997),(Mahmoud *et al.*, 2007).

Acrylic resin RPDs are popular in developing countries (Akinyamoju *et al.*, 2017). Acrylic RPDs with or without the incorporation of metal clasps and rests, have advantages over metal: aesthetics because of their colour and translucency, cost, light weight, easy to work with and their repairability. Their disadvantages include poor thermal conductivity, brittleness, lower strength than metal, low durability, thermal expansion, and cytotoxicity due to leaching of chemicals. Another disadvantage is that key design features such as rests and clasps are often not incorporated in their designs (Campbell *et al.*, 2017). This is currently changing due to the development of a polyetheretherketone (PEEK) polymer frame that can be combined with conventional acrylic resin bases and denture teeth (Zoidis *et al.*, 2016),(Schwitalla *et al.*, 2015).

As an alternative to conventional PMMA, “thermoplastic” or “flexible” materials for RPDs have been developed. Dentures made from these materials are also known as “non-metal clasp

dentures" (NMCDs), since all components of the denture (except the denture teeth), are fabricated from the same material excluding the need to incorporate metal clasps.



Dental art lab, *Valplast Dentures*, accessed 02/11/2018,
http://www.dentalartlab.in/material.php

Dental Nesbit, *Flexi Dentures*, accessed 02/11/2018,
https://dvine-dental-arts-llc.business.site/

The option of NMCDs has attracted considerable interest from practitioners, even though clinical guidelines for their use have been lacking (Fueki, 2016). This led to the development of a "position paper" based on "expert opinion" by the Japan Prosthodontic Society, wherein NMCDs were not recommended as definitive prostheses, except e.g. in case of metal allergy or when rigidity can be provided by incorporating a metal framework (Fueki, 2016). No well-designed prospective studies with medium to long-term follow-up periods have been published on NMCDs. This lack of information makes it difficult to formulate guidelines for the use of flexible or NMCDs. In the meantime, the following disadvantages of NMCDs have been

identified by Fueki *et al*, (2014 part I): "Clasps" of NMCDs cover the cervical area of the tooth, marginal gingiva and mucosa - as opposed to metal clasps who don't come into contact with the gingival margin - hence may cause caries and periodontal disease; When no (metal) rests are incorporated, the resin clasps traumatise marginal gingiva (Fueki *et al.*, 2014a).

Materials used for these NMCDs include a variety of polymers: polyethylene glycol, methyl methacrylate, aryl-ketone polymers (Campbell *et al.*, 2017), polyamide resins, polycarbonate resins, polyethylene terephthalate resins (Takabayashi, 2010). While clinical studies are largely lacking, several studies looked at their mechanical and physical properties.

Takabayashi (2010) compared thermoplastic resins with PMMA for dentures and found that thermoplastic resins have lower flexural strength (but still acceptable by ISO standard – except the polyamide resins) and although there was some plastic deformation, the thermoplastic resins did not fracture during *in vitro* flexural strength testing. The acrylic resin did. Because of their fracture resistance and low modulus of elasticity, thermoplastic materials are tough compared to acrylic resins (Takabayashi, 2010). Hence, these materials make it possible for larger undercuts to be engaged for retention as compared to acrylic resin. Most thermoplastic materials had lower water sorption and solubility than the acrylic resin, offering hygienic advantages over PMMA. Takabayashi (2010) warns against displacement of soft tissue due to denture flexibility. He also reported that staining may occur on polyamide and polyethylene terephthalate resins. Vojdani & Giti (2015) did a literature review on polyamide resins and found that the material could be an alternative to conventional acrylics, under certain conditions such as in case of severe soft/hard tissue undercuts, allergy to PMMA, and microstomia. However, they warned that limited knowledge exists in terms of their clinical performance and a careful recall protocol is advised (Vojdani and Giti, 2015). This warning confirms an earlier report by Fueki *et al.* (2014b) who reported great variability in physical and mechanical properties of thermoplastic materials and found that studies related to material properties, treatment efficacy and follow-up are insufficient to provide definitive conclusions at this time (Fueki *et al.*, 2014b).

1.5. Conclusions

The need to treat partial edentulism by means of RPDs will continue to exist, especially in regions of low socioeconomic conditions.
From retrospective studies, a well-designed and -constructed RPD supported by favorable abutments and accompanied by a regular recall program may offer a satisfactory treatment modality for partial edentulism. However, well-designed long-term randomized controlled clinical trials investigating outcomes of RPDs are lacking.

Cobalt chromium and PMMA are still popular materials used for RPDs, but new materials have been developed and are used to fabricate RPDs. In the absence of retrospective and prospective clinical studies, the use of NMCDs is recommended in exceptional circumstances only.

Conventional PMMA RPDs and newer NMCDs don’t seem to adhere to the same design principles as metal-frame RPDs do.

Chapter 2: Aims and objectives

2.1. Aim

The aim of this study was to assess if a sample of clinical flexible NMCDs, acrylic and metal-frame RPDs comply with biological and biomechanical design principles.

To assess biomechanical requirements, *support* was assessed by counting the number of rests, establish their configuration and identifying the type of support; *retention* was assessed by counting the number of clasps and presence of indirect retention where applicable. To assess for biological requirements, natural teeth whose gingival tissue and neck areas were covered by RPD components, were counted and related to the number of teeth replaced by the RPD.

2.2. Objectives

The objectives of this study were:

- To capture the number of rests and their configuration for each RPD and its corresponding ideal design (control)
- Compare the number of rests and their configuration among the different denture type groups and among classifications including the ideal designs
- To identify the type of support as being soft tissue, hard tissue or mixed soft and hard tissue support for each denture type group and classification including the ideal designs
- To compare the types of support among denture type groups and classifications including the ideal designs
- To capture and compare number of clasps among denture type groups and classifications including the ideal designs
- To capture the presence of indirect retention for each clinical RPD and corresponding ideal design

- To count the number of teeth whose periodontal tissues are covered by RPD components for each clinical RPD and corresponding ideal design
- To count the number of replaced teeth for each RPD and corresponding ideal design
- To compare the ratios teeth replaced/teeth covered per denture type groups and per classification including the ideal designs
- To establish horizontal stability by counting the number of teeth that are being replaced related to the number of teeth that are touching the framework of the RPDs including the ideal designs
- To establish cross-arch stability by noting if the design crosses the midline or not for all RPDs including the ideal designs
- To determine if any of the above features comply with design principles for RPDs, among types of denture groups and classifications.

2.3. Null -hypotheses

The null-hypotheses of this study were

- There is no difference among RPDS made from different materials in complying to biological principles
- There is no difference among RPDS made from different materials in complying to biomechanical principles

Chapter 3: Methodology

3.1. Introduction

The research proposal was approved by the Biomedical Research Ethics Committee of the University of the Western Cape (Date: 24 November 2016; Project registration number: BM/16/5/12 – Addendum 1).

Informed consent was received from participating laboratory owners. The name of the laboratory was not recorded. De-identification of laboratory specimens was done by using numbers on specimens and data sheets instead of patients' names.

3.2. Research Design

This project was a cross-sectional study making use of a convenience sample.

3.3. Sampling and data collection

Three dental laboratories in the Cape Town Metropole that were known to fabricate "flexible" RPDs for dental practices were identified and were invited to participate in the study. Their participation required of them to email photographs of completed metal-frame, acrylic and flexible RPDs and their casts prior to sending them to the practices for delivery to patients. The following views of the RPDs were requested: occlusal, left lateral, right lateral, frontal and any other view to enable the researchers to identify all RPD components on the photographs. Specimens were collected until a total of 20 metal-frame, 20 acrylic resin and 20 flexible RPDs were received.

For each RPD, an "ideal" design was drawn, using the image of the cast. This was done by two observers, who are experienced members of staff in the Department of Restorative Dentistry (Prosthetics), independently. The designs from both observers were later compared for

similarity. Where differences existed in the designs, these were resolved by means of discussion until agreement was reached. Each ideal design served as the control for each clinical design.

The features of the clinical and ideal designs were assessed and entered using a standard data collection sheet (Addendum 2).

For the sake of consistency, the following agreements were made prior to designing the ideal RPDs:

- If major connector covered cingulum of anterior teeth of clinical RPDs, a rest was considered to be present. If cingulum was visible, it was considered that no rest is present
- Mandibular lingual major connector for control design was always the same as the clinical RPD design (plate vs bar)
- Number of replaced teeth on ideal denture were kept the same as number of teeth replaced on the clinical RPDs
- No mesially approaching C-clasps on maxillary anteriors, 4s and 5s were designed for ideal RPDs.

For the sake of consistency, the following agreements were made prior to recording data from the RPD and ideal designs:

- The number of rests was counted and was given as a numerical value: 1, 2, 3, 4, >4. The configuration of rests was given as 0: no configuration because there were no rests or only 1 rest; 2: line; 3: triangle; 4: at least a quadrangle.
- Type of support for the RPD was indicated as hard (H) (exclusively tooth-born), soft (S) (exclusively mucosa-born) or mixed hard-soft (M) (both tooth and mucosa support).
- Number of clasps was counted and was given as a numerical value: 1, 2, 3, 4, >4.
- Presence of indirect retention was given as Yes, No or Not applicable.
- Number of teeth with periodontal tissue cover was given as a numerical value 1, 2, 3, ….
- Number of replaced teeth was given as a numerical value 1, 2, 3, ….
- Horizontal stability: ratio replaced teeth/teeth touched by RPD components.

- Presence of cross-arch stability: Yes or No.

Compliance to the ideal design was rated as *Acceptable* or *Not acceptable* according to the following general rules:

- For support, for Class II, III and IV RPDs a minimum of 3 rests in a triangle configuration was considered to be acceptable, less than 3 rests or 3 rests not in a triangle configuration was considered not acceptable. For Class I RPDs a minimum of 2 rests was considered to be acceptable, less than 2 rests were considered not acceptable. Soft tissue support was not acceptable for any of the classifications. Mixed support was accepted for Class I, II RPDs and where long saddles covered arch corners; for all other designs, mixed support was not acceptable.
- Absence of indirect retention for designs where it was indicated was scored as not acceptable
- Absence of cross-arch stability was scored as not acceptable.

Acceptability was rated by two observers independently. Where differences occurred, these were debated until consensus was reached.

3.4. Analysis

Results are presented descriptively using frequency tables and cross-tabulations. Because of the nature of the data and the large differences among groups, statistical analysis was not indicated.

Chapter 4: Results

4.1. Introduction

The results will report on the following:

1. The **number of rests** and their **configuration** for each design among the different denture type groups, and corresponding control designs

2. The **type of support** whether soft tissue, hard tissue or mixed soft/hard tissue support for each design among the denture type groups and classification, and corresponding control designs

3. The number of **clasps per design** among denture type groups and classifications, and corresponding control designs

4. The presence of **indirect retention** for each design and corresponding control design

5. The number of teeth whose periodontal tissues are **covered** by design components for each design among denture type groups and corresponding control designs

6. The comparison of the ratios of teeth replaced/teeth covered per denture type groups and per classification, and corresponding control designs

7. The presence of **cross-arch stability** by noting if the design crosses the midline or not for all designs among groups and the corresponding control designs

8. If any of the above features comply with generally accepted requirements for designing RPDs, among denture type groups and classifications.

The sample of 60 dentures was collected over a period of 18 months.

4.2. Summary of the findings

The features of all clinical and control designs are summarized in Table 1. The raw data are presented in Addendum 4.

Table 1: Summary of different features of the RPD designs according to material groups

	Acrylic	Contr acrylic	Metal	Contr metal	NMCD	Contr NMCD
Number	**20**	**20**	**20**	**20**	**20**	**20**
Kennedy Class I	3	3	2	2	1	1
Class II	2	2	4	4	3	3
Class III	14	14	14	14	16	16
Class IV	1	1	0	0	0	0
Mandibular	5	5	9	9	4	4
Maxillary	15	15	11	11	16	16
Total no. of rests	**12**	**88**	**57**	**78**	**0**	**80**
No of RPDs without rests	13	0	0	0	20	0
RPDs with 1 rest	6	0	2	0	0	0
RPDs with 2 rests	0	1	8	1	0	1
RPDs with 3 rests	0	1	4	4	0	2
RPDs with 4 or more rests	1	18	6	15	0	17
RPDs with no rest configuration	19	0	2	0	20	0
RPDs configuration in line	0	1	8	1	0	1
RPDs configuration of rests in triangle	0	1	4	4	0	2
RPDs configuration of rests in square or more	1	18	6	15	0	17
Support soft tissue	13	0	0	0	20	0
Mixed support	6	5	15	6	0	4
Support hard tissue	1	15	5	14	0	16
Total no. of clasps	**6**	**51**	**71**	**64**	**43**	**52**
RPDs without clasps	17	0	0	0	0	0
RPDs with 1 clasp	0	0	0	0	1	0
RPDs with 2 clasps	3	11	2	4	16	9
RPDs with 3 clasps	0	7	5	8	2	10
RPDs with 4 clasps	0	2	13	8	1	1
Bilateral design	20	20	20	20	7	20
Number of teeth covered	159	71	85	71	81	63
Number of teeth replaced	87	87	93	93	45	45
No. of teeth covered & (replaced) Kennedy Class I	19 (21)	16 (21)	9 (10)	9 (10)	8 (5)	8 (5)
No. of teeth covered & (replaced) Kennedy Class II	12 (12)	5 (12)	13 (19)	13 (19)	24 (12)	20 (12)
No. of teeth covered & (replaced) Kennedy Class III	120(50)	42 (50)	63(64)	39 (64)	49 (28)	33 (28)
No. of teeth covered &(replaced) Kennedy Class V	8 (4)	0 (4)	-	-	-	-

NMCD = non-metal clasp denture; contr = control

The majority of the 60 RPDs was for the maxilla (n=42; 70%).

Kennedy Class III designs occurred most frequently with a total of 44 (73%) designs out of the 60 clinical designs. There was only 1 Class IV design, belonging to the acrylic RPD group. (Table 1)

The group of 20 acrylic RPDs consisted mainly of Kennedy Class III (n=14; 70 %) RPDs, followed by Class I (n=3; 15%), Class II (n=2; 10%) and Class IV (n=1; 5%). (Figure 1)

The NMCD group, consisted also mainly of Kennedy Class III designs (n=16; 80%), followed by Class II (n=3; 15%), Class I (n=1; 5%) and no Class IV dentures. (Figure 1)

The metal group consisted again of a majority of Kennedy Class III designs (n=14; 70%), followed by Class II (n=4; 20%), Class I (n=2; 10%) and no dentures in Class IV. (Figure 1)

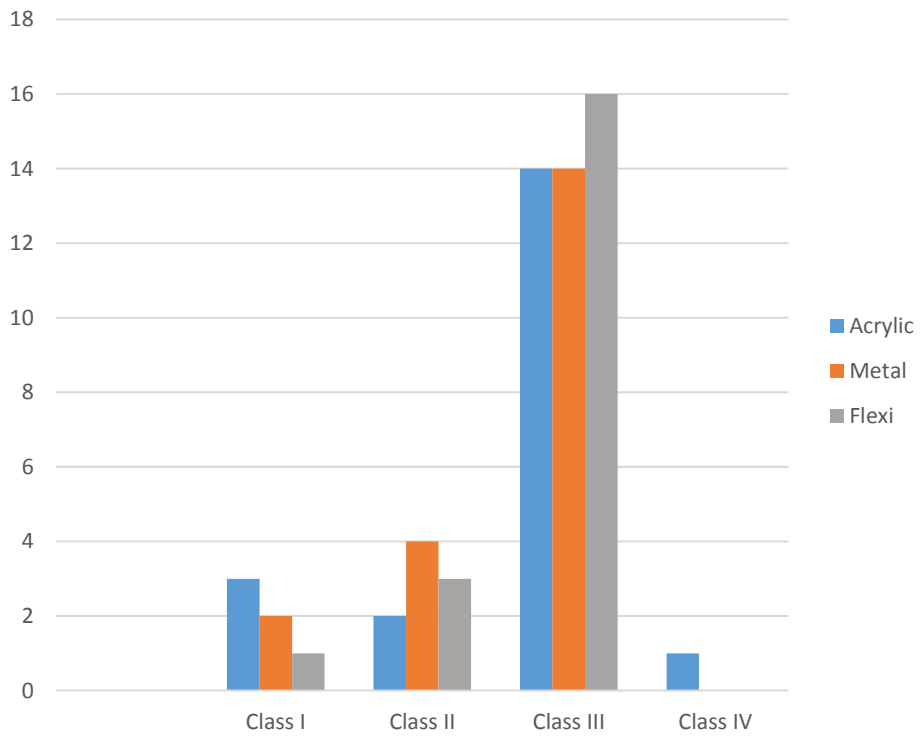


Figure 1: Bar chart of number of RPDs per Kennedy classification for each material group. Flexi = NMCD

For each clinical design, a corresponding control design was drawn. Hence, the numbers according to Kennedy classification and upper/lower jaw are the same as for the clinical designs.

4.3. Biomechanical considerations for support

4.3.1. Number of rests

The number of rests as well as their configuration was recorded for each design and its corresponding control design. A total of 33 clinical designs had no rests at all, 8 had only 1 rest, 8 had 2 rests, 4 had 3 rests and 7 had 4 or more rests. The control designs all had rests, with 57 designs having at least 3 rests. Figure 2 shows number of dentures according to their number of rests for each denture material group and the controls.

In the acrylic group, 13 designs had no rests, 6 designs had 1 rest, none had 3 rests and only 1 design had at least four rests. For the corresponding control designs, 1 RPD had 2 rests, 1 had 3 rests and 18 RPDs had at least 4 rests. There were no control designs with 1 or zero rests.

All designs in the NMCD group had zero rests, while for their control designs 17 RPDs were given at least 4 rests, 2 designs had 3 rests and 1 design had 2 rests. There were no control designs with 1 or zero rests.

For the metal group, 2 designs had 1 rest, 8 had 2 rests, 4 had 3 rests and 6 had at least 4 rests. The control had one design with 2 rests, 4 designs with 3 rests and 15 with 4 or more rests. There were no control designs with 1 or zero rests.

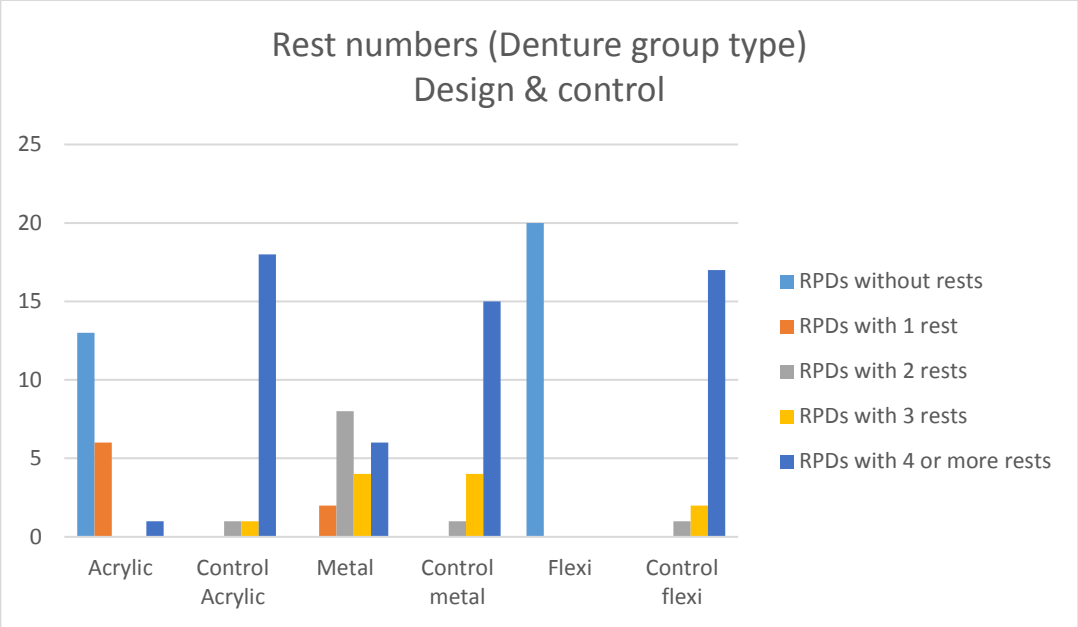


Figure 2: Chart of number of dentures according to number of rests of the design and their corresponding control group for each denture type group. Flexi = NMCD

4.3.2. Configuration of rests

Figure 3 shows the number of RPDs according to different rest configurations per denture group and the corresponding control designs. When there were only 1 or zero rests, this was considered absence of configuration, 2 rests were considered to have a "line" configuration and the other configurations are self-explanatory.

The acrylic group had mostly no rest configurations in its designs and only 1 square configuration. Its control designs had 1 line, 1 triangle and 18 square configurations.

The metal group had 2 designs with rests without configuration, 8 designs had rest in a line configuration, 4 in a triangle configuration, and 6 designs in a square configuration. Its control group had 1 design with rests in line configuration, 4 in a triangle and 15 in a square.

All 20 NMCD designs had no rest configurations. The control designs had 1 line -, 2 triangle – and 17 square configurations.

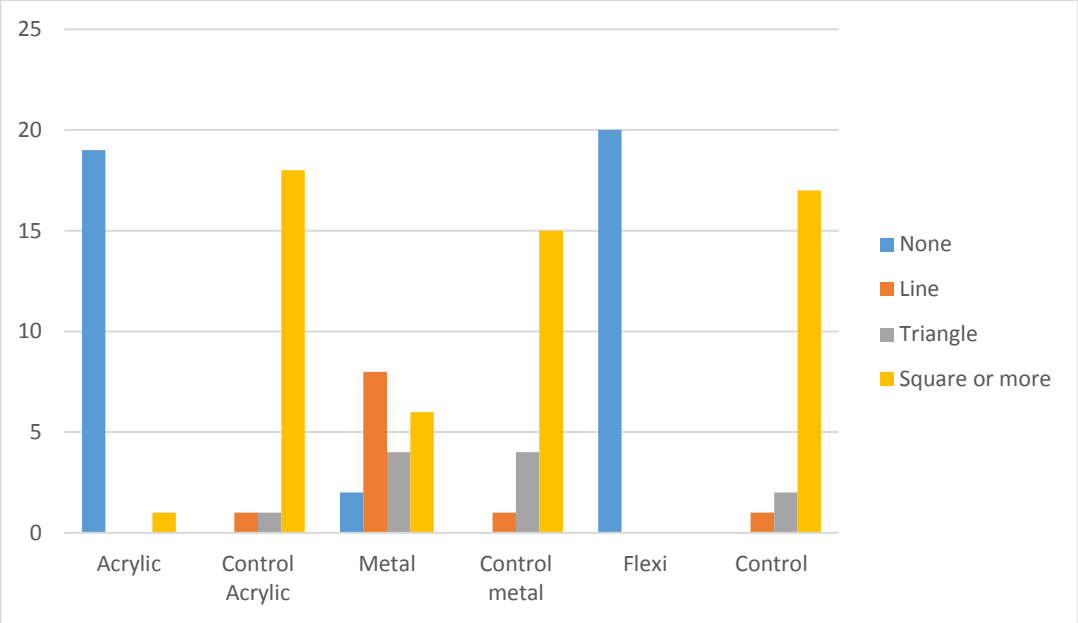


Figure 3: Chart of number of dentures according to their rest configurations for each group and corresponding control group. Flexi = NMCD

4.3.3. Tooth, tissue or mixed support

A total of 33 clinical designs were soft tissue supported, 21 were of mixed support and 6 had hard tissue support. All the control designs had hard tissue (n=45) or mixed support (n=15).

Figure 4 shows the number of RPDs according to type of support per material group.

The RPDs in the acrylic group were mostly soft tissue supported (n=13; 65%), one RPD being hard tissue supported and 6 were mixed hard and soft tissue supported. The control designs in the group were all hard tissue (n=15; 75%) and mixed support (n=5; 25%).

The RPDs in the metal group were predominantly of mixed support (n=15; 75%). The rest was hard tissue support (n=5; 25%). The control designs were predominantly hard tissue supported (n=14; 70%) and the rest (n=6; 30%) were of mixed support.

In the NMCD group all designs were soft tissue supported (n=20; 100%). Their controls were all hard (n=16; 80%) and of mixed support (n=4; 20%).

None of the control designs were soft tissue supported.

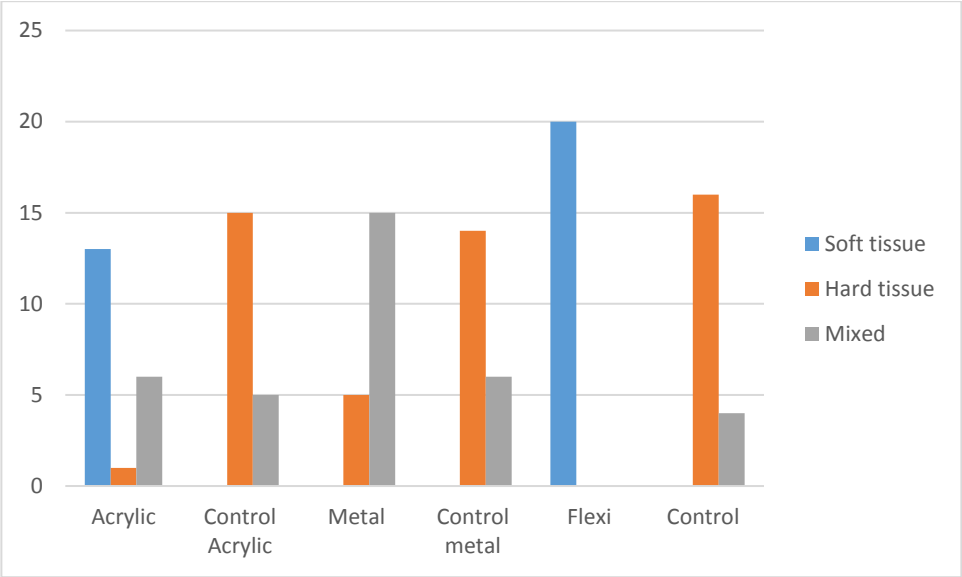


Figure 4: Bar chart of frequencies of support for each denture material group and its corresponding control group. Flexi = NMCD

In table 2, the different types of support are shown for the different Kennedy classification groups.

Table 2: Type of support according to Kennedy Classification for the clinical designs

Kennedy Class	Number of designs	Hard tissue support	Hard & soft tissue support	Soft tissue support
I	6	0	3	3
II	9	0	4	5
III	44	6	14	24
IV	1	0	0	1

Table 3: Type of support according to Kennedy Classification for the control designs

Kennedy Class	Number of designs	Hard tissue support	Hard & soft tissue support	Soft tissue support
I	6	0	6	0
II	9	0	9	0
III	44	43	1	0
IV	1	0	1	0

4.4. Biomechanical considerations for retention

4.4.1. Indirect retention

A total of 35 designs required indirect retention and in only 14 designs was indirect retention provided. This is a 40% compliance rate. For the 25 other designs, indirect retention was not applicable.

Per denture materials group the results in terms of compliance to indirect retention requirements were as follows: were as follows:

For acrylic RPDs 16 of the designs required indirect retention and only 1 design provided this, representing a 6.25% compliance rate.

For the NMCD group, 7 designs required indirect retention and only 3 designs provided this, representing a 42.86% compliance rate.

For the metal group, 12 designs required indirect retention and 10 designs provided it, representing an 83.33% compliance rate.

Figure 5 shows the number of times indirect retenion was provided per denture material group (red bars) against the times it was required (blue bars = control).

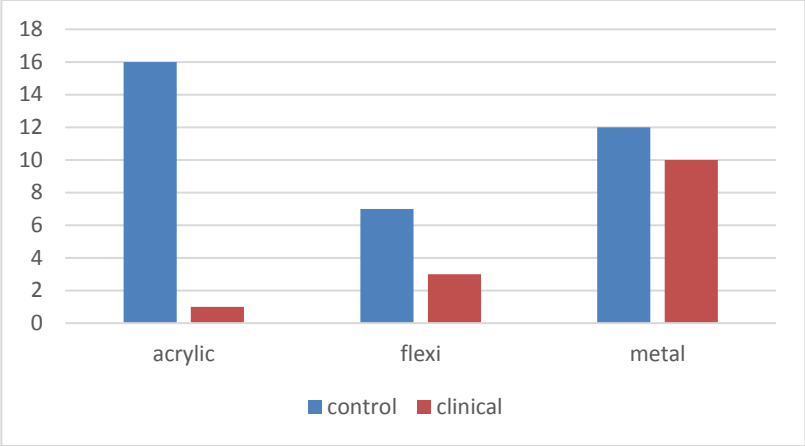


Figure 5: Bar chart of indirect retenion provided per denture material group and its control designs. Flexi = NMCD

4.4.2. Direct retention

The total number of clasps for each clinical denture design group and its corresponding control designs are shown in table 4.

Table 4: Number of clasps in clinical and control designs

Denture type group	Total number of designs	Clinical designs – Total number of clasps (mean per group)	Corresponding control – Total number of clasps (mean per group)
Acrylic	20	6 (0.30)	51 (2.55)
NMCD	20	43 (2.15)	52 (2.60)
Metal	20	71 (3.55)	64 (3.20)

The number of clasps among the different Kennedy classification groups, as well as its corresponding control design clasp numbers is depicted in table 5.

Table 5: Number of clasps for clinical and control designs per Kennedy Classification

Kennedy Class	Number of designs	Clinical designs: Total clasp number	Control designs: Total clasp number
I	6	10	12
II	9	20	26
III	44	90	127
IV	1	0	0

4.5. Biological consideration

4.5.1. Number of teeth covered per teeth replaced according to denture material group

The number of teeth whose gingival tissue was covered versus the number of teeth replaced in the clinical designs and corresponding control designs is shown in table 1 and the ratios are shown in table 6.

Table 6: Ratios of teeth covered versus teeth replaced per denture type group.

Denture group	Clinical designs (Covered vs Replaced)	Control designs (Covered vs Replaced)
Acrylic	3.71	0.96
NMCD	2.33	1.46
Metal	0.99	0.89

4.5.2. Number of teeth covered per teeth replaced according to Kennedy classification

The mean ratio of teeth covered vs teeth replaced for all Kennedy Classifications are shown in table 7.

Table 7: Ratio covered vs replaced teeth per Kennedy Classification for the clinical designs & control designs

Kennedy classification	Clinical designs	Control designs
I	1.13	0.72
II	1.45	1.30
III	1.83	1.02
IV	2	0

4.6. Cross – arch stabilization

Figure 6 shows the number of RPDs per denture material groups who had bilateral designs. All control designs had cross-arch stabilization, as had the acrylic and metal groups. The NMCD group only had 7 out of 20 designs with cross-arch stabilization.

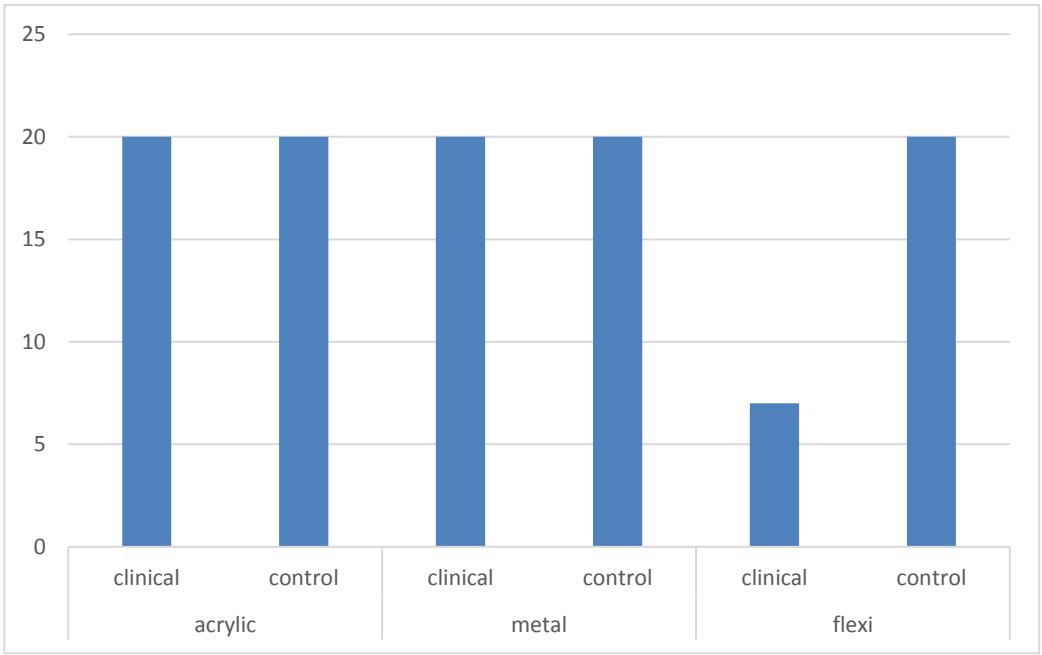


Figure 6: Chart showing the number of RPDs per denture material group who had bilateral designs. Flexi = NMCD

4.7. Compliance of designs with the control designs according to denture materials groups

Table 8 shows acceptance rates for different features of RPD designs for the clinical designs of the 3 denture materials groups when compared with their corresponding control designs.

Table 8: Number of acceptable clinical RPD designs and compliance scores in % per design feature for each material group.

No. of RPDs with acceptable:	Acrylic (Control)	%	NMCD (Control)	%	Metal (Control)	%
Number of dentures with rests (Min. 2 rests)	1 (20)	5%	0 (20)	0%	18 (20)	90%
Support	7 (20)	35%	0 (20)	0%	20 (20)	100%
Rest configurations	1 (20)	5%	0 (20)	0%	20 (20)	100%
Indirect retention	1 (16)	6.25%	3 (7)	42.86%	10 (12)	83.33%
Direct retention	3 (20)	15%	9 (20)	45%	20 (20)	100%
Teeth covered	159 (71)	92 extra teeth covered	81 (63)	18 extra teeth covered	85 (71)	14 extra teeth covered
Ratio teeth covered/teeth replaced	3.71 (0.96)		2.33 (1.46)		0.99(0.89)	
No. of RPDs with acceptable ratios	3 (20)	15%	3 (20)	15%	9(20)	45%
Cross-arch stabilization	20 (20)	100%	7 (20)	35%	20 (20)	100%

4.8. Compliance of designs with the control designs according to denture classification

Table 9: Number of acceptable clinical RPD designs and compliance scores in % per design feature for each Kennedy classification.

No. of RPDs with acceptable:	**Class I (Control)**	**%**	**Class II (Control)**	**%**	Class III (Control)	%	Class IV (Control)	%
Acceptable rest nrs	1 (6)	16.67	2 (9)	22.22	6 (44)	13.64	0 (1)	0
Acceptable rest configuratio ns	0 (6)	0	2 (9)	22.22	4 (44)	9.09	0 (1)	0
Acceptable tissue support	2 (6)	33.33	4 (9)	44.44	15 (44)	34.10	0 (1)	0
Acceptable indirect retention	1 (6)	16.67	3 (7)	42.86	NA	NA	NA	NA
Acceptable direct retention	5 (6)	83.33	5 (9)	55.56	14 (44)	31.82	0 (1)	0
Acceptable tissue coverage (Control)/ Nr of teeth replaced/	36(33) /36	Ratio – 1 (0.92)	49 (38) / 43	Ratio – 1.45 (1.23)	232 (114) / 142	Ratio – 2.7 (1.02)	8 (0) / 4	Ratio – 2 (0)

There is thus no statistically significant agreement between acceptable status of the clinical designs and control designs for rest numbers, support, rest configurations, dentures or clasp numbers.

Chapter 5: Discussion

5.1. Introduction

Studies reported that RPDs have been linked to harmful effects to teeth and supporting tissues and that these effects have been attributed to poorly designed RPDs (Zlataric *et al.*, 2002),(Preshaw *et al.*, 2011). In the Western Cape, partial edentulousness is often treated by means of acrylic resin and metal frame RPDs and more recently also NMCDs. It is the impression that design principles for these RPDs are not consistently adhered to, hence could lead to harmful effect on teeth and supporting tissues. This study was undertaken, with the following aim in mind: to assess if a sample of clinical NMCDs, acrylic and metal-frame RPDs to the same extent, comply with biological and biomechanical design principles.

A convenience sample of 60 RPDs fabricated for patients, 20 for each type of material, was collected from commercial dental laboratories. The investigator then compared the designs of these dentures with an "optimal" design agreed on by two professionals experienced in the field of prosthetic dentistry.

To assess for biological requirements, natural teeth whose gingival tissue and neck areas were covered by RPD components, were counted and related to the number of teeth replaced by the RPD; The type of support (hard, soft or mixed) provided by the design was also assessed.

For the biomechanical requirements, support was assessed by counting the number of rests, establishing their configuration and identifying the type of support; retention was assessed by counting the number of clasps and presence of indirect retention where applicable.

5.2. Biological considerations

Plaque index values were found to be higher on abutment teeth that were covered by RPD components (Do Amaral *et al.*, 2010). Orr *et al*. (1992) found that gingival indices increased after placement of acrylic resin baseplate connectors. This was confirmed by Zlatarić *et al*. (2002) who found that covering the gingival margin was harmful to gingival health. Augustin *et al,* (2016) concluded in their study that RPDs' gingival coverage and its close relationship with gingival tissues increases the risk of complications (Augustin *et al.*, 2016). An 'hygienic design principles' was emphasised by Marxkors (1984), by designing an RPD that controls dental plaque and thus preventing dental caries and periodontal disease (Marxkors, 1984). Dula *et al.* (2015) also advised on an RPD design that does not cover marginal gingiva (Dula *et al.*, 2015).

Hence, for this study, coverage of the periodontal tissues of the remaining natural teeth by RPD components was used as a bench mark for rating the biological acceptability of each denture.

In addition, it is generally accepted that properly place occlusal rests on abutment teeth prevents movement of the RPD towards the tissues and reduces iatrogenic damage to the underlying soft tissues (Owen, 2000),(Carr and Brown, 2011). Hence, a minimum number of rests in an appropriate configuration was also considered to be a benchmark for assessing the biologic acceptability of the designs.

The null-hypothesis related to the assessment of biological considerations was as follows:

- There is no difference among RPDs made from different materials in complying to biological principles.

Based on the results of this investigation, the answer to the null-hypothesis is as follows:

- Differences were found among RPDs made from different materials in complying with biological principles. Therefore, this null-hypothesis is rejected.

These following results are presented to motivate this answer:

The group of acrylic RPDs had the highest ratio of teeth covered by components, being higher than their control group (table 5) and was also higher than the metal frame and NMCDs. Therefore, in terms of this design feature, it was concluded that the RPDs were not biologically acceptable because of excessive coverage of periodontal tissues.

The group of NMCDs (flexi) had the second highest ratio of periodontal tissues covered and was higher than the group of control designs. Hence, their designs were also regarded as not being biologically acceptable (table 5).

The group of metal-frame RPDs had the lowest ratio of covered periodontal tissue among the 3 groups, but the ratio was still higher than their control designs. Hence it was decided that these designs were also not biologically acceptable although their ratio scored very close to their "ideal" design controls (table 5).

The vertical support for both the acrylic RPDs and NMCDs was problematic. Only one of the acrylic RPDs had enough rests in an appropriate configuration to be judged acceptable (table 7). All the other acrylic RPDs had either 1 or no rests, hence, had soft tissue or mixed type of support. Therefore, it was decided that acrylic resin RPDs designs in this sample were not acceptable regarding vertical support and potentially harmful to the supporting tissue of the remaining natural teeth. None of the NMCDs had any rests. The result is that all the NMCDs were considered to be soft tissue supported and all 20 designs in this sample were not acceptable regarding support (table 7). In contrast with the acrylic and NMCDs, none of the metal-frame RPDs were soft tissue supported. Fifteen clinical metal-frame RPDs had mixed tissue support where there should only have been 6 with mixed support according to the control deigns. It was concluded that only 9 (45%) of the metal-frame RPDs were acceptable in terms of tissue support.

5.3. Biomechanical considerations

According to Owen (2000) vertical support should always be provided via rests on some of the remaining natural teeth. These rests should transmit chewing forces from the denture along the long axis of abutment teeth.

Direct or active retainers or clasps are vital components in an RPD which exerts a force on abutment teeth when the RPD is lifted away from the teeth (Owen, 2000). If adequate retention is not provided, the RPD might be dislodged. More clasp assemblies lead to higher PI and TM scores (Zlataric *et al.*, 2002).

Indirect retention prevents dislodging of the RPD around a horizontal axis (Mccord *et al.*, 2002).

The null-hypothesis related to the assessment of biomechanical considerations was as follows:

- There is no difference among RPDs made from different materials in complying to biomechanical principles.

Based on the results of this investigation, the answer to the null-hypothesis is as follows:

- Differences were found among RPDs made from different materials in complying with biomechanical principles. This null-hypothesis is rejected.

As already mentioned in the section 5.2. 'Biological consideration', the metal-frame group of RPDs performed best in complying with the principle of support to prevent harm to the soft tissues of the remaining natural teeth. For stability and support, the selection of at least 3 rests, widely spaced, is advised (Owen, 2000). In this regard, the designs of the metal-frame RPDs complied on 10 occasions as compared to 19 occasions among the control designs. Hence, for half of the metal-frame designs, there was no compliance regarding transfer of loads to abutment teeth. For the acrylic RPDs, there was only 1 design with more than 3 rests. The other dentures had either no or only 1 rest. This would not allow transmission of chewing forces along the long axis of the abutment teeth. Therefore, it was concluded that the acrylic resin RPD group did not conform to this biomechanical requirement. No decision could be made on NMCDs since no transmission of chewing forces could take place via abutment teeth, since there was a 100% absence of rests. The clinical consequence of these findings is that for the metal-frame and acrylic RPDs, the integrity of the abutment teeth is at risk due to inadequate transfer of occlusal forces along abutment teeth.

For the acrylic group, a total of 6 clasps were provided, as compared to 51 for the corresponding control designs. This is a mean of 0.3 clasps per design. For the control the mean number of

clasps per design was 2.6. Based on these results, it was concluded that the provision of direct retention was generally inadequate for acrylic RPDs.

The NMCDs group had a total of 43 clasps (mean 2.2 per RPD) compared to the 52 (mean 2.6 per RPD), of the control. Based on these results, it was concluded that in terms of retention, most NMCDs are acceptable in the provision of direct retention.

For the metal-frame RPDs, a total of 71 clasps were given (mean 3.6) against their control designs of 64 clasps (mean 3.2). It was therefore decided that in terms of direct retention, this group was acceptable. This is the only group where the clinical designs were given more clasps than their control group. The slightly higher number of clasps may have a negative effect on PI and TM scores (Mothopi-Peri and Owen, 2018).

The clinical consequence of these findings is that NMCDs and metal-frame RPDs would be retentive, but that the retention of acrylic RPDs in this sample of dentures would not be adequate.

Where applicable and needed, the presence or absence of indirect retention was recorded for the sample of RPDs in this study. Sixteen of the acrylic resin RPDs required the incorporation of indirect retention, with only 1 design complying (6.25%). In the flexi group 7 needed indirect retention with only 3 complying (42.9%). The metal group had 12 designs that needed indirect retention with 10 complying (83.33%). The indirect retainers are there to prevent tipping of the denture around a horizontal axis (Mccord *et al.*, 2002). The metal group had the highest compliance rate. Poor compliance was noted in the acrylic group, followed by the flexi group. It should be noted that the sizes of the samples differ considerably. The clinical significance of these findings is that the retention of the majority of the acrylic RPDs and half of the NMCDs are compromised in providing acceptable retention.

In assessing if the designs of the different denture groups had cross-arch stabilization being unilateral or bilateral, the following findings were made: All the designs in the acrylic and metal-frame RPD groups were bilateral and acceptable. The flexi group only had 7 bilateral designs. Hence, it was decided that this group was 65% non-compliant in terms of cross-arch stability. In a unilateral RPD design with no cross-arch stabilization the denture may dislodge

easily and cause some additional complications, even with the advantage of such a restoration that avoids extensive coverage of the palatal or lingual major connector (Goodacre, 1987).

Looking at the different denture material types and how they've performed in complying with the minimum requirements and compared to their controls, the following findings were made:

The *acrylic RPD designs* were compared with their corresponding control designs: 1) Poor compliance with the acceptable amount of rests, rest configurations, provision of indirect retention, acceptable clasp numbers and with the number of teeth covered. 2) Partial compliance with support requirements with regards to tooth and mixed tooth-and-tissue support. 3) Compliant with cross-arch stabilization as all 20 designs in the group were bilateral.

The *metal RPD designs* were compared with their control designs: 1) Poor compliance with teeth covered versus teeth replaced, as 14 extra teeth were covered in the clinical designs, compared to the controls. 2) Partial compliance with the minimum number of rests needed, adequate rest configurations and in providing indirect retention. 3) Compliant with incorporating hard or mixed support, acceptable clasp numbers and cross-arch stabilization, suggested by the control designs.

The *NMCDs designs* were compared with their control designs: 1) Poor compliance with provision of rests, rest configurations, providing hard tissue support and with number of teeth covered. 2) Partial compliance with acceptable clasp numbers, providing indirect retention and cross-arch stabilization.

Dentists/technicians appear to pay more attention to designing metal-frame partial denture as compared to acrylic resin and NMCDs. This may be explained by the fact that the latter two types of RPDs are considered to be "temporary".

5.4. Limitations and recommendations

- There is widespread consensus that a well-designed and constructed RPD contributes to a satisfactory treatment outcome. However, there is little published evidence based on clinical trials of what these design criteria are (Kapur *et al.*, 1994). Biological and

biomechanical criteria were identified and applied for the methodology of this study but are not validated and supported by clinical trials.

- Clinical trials should be carried out on what the short- and long-term effects are, of what are considered to be a lack of acceptable biological and biomechanical design features, on tissue health.
- Only a few commercial laboratories in the Western Cape region provide all 3 types (acrylic, metal and NMCDs) of RPDs. Sampling was limited to these commercial laboratories. Sampling was not randomized because of the limited numbers of acrylic and NMCDs fabricated in these laboratories and a convenience sample was used. Hence, the sample evaluated in this study might not be representative of the total RPDs service delivered in the Western Cape. This study should be regarded as a pilot for further investigation into the quality of the designs associated with RPDs treatment.
- The reason why limited numbers of NMCDs and acrylic RPDs were manufactured at the 3 commercial laboratories may be due to the costing structure and durability of the material. NMCDs are expensive and acrylic RPDs are not considered to be permanent even though Wilson (2009) reported that well designed acrylic RPDs supported with an appropriate recall protocol may be considered a definitive treatment modality.
- Laboratories agreed to provide all RPDs designs until a number of 20 designs for each material group reached the investigator. Since the investigator relied on commercial laboratories to provide the designs, the sample may have been biased based on selection of designs by the laboratory technician. It is assumed that selection was biased towards the "better" designs.
- Only the presence and location of clasps was assessed. The type of material and design of clasps was not recorded. It was noted during the assessments of the designs that, on occasions, cast clasps were used on premolar teeth.
- The presence of guide planes on teeth and guiding surfaces on tooth-bound saddles was not assessed in this study. These features may reduce the need for direct retention. Hence, the decision on adequacy of direct retention may have been influenced by this limitation.
- Because of the nature of the data, no statistical analysis could be performed, and the presentation of results is limited to a descriptive analysis.

- Only information based the end-product was collected. The process of designing in terms of communication and identity of the RPD designer (dentist or technician) was not requested.
- The effect of the presence or absence of specific design characteristics on patient-based outcomes could be researched.

5.5. Conclusions

Within the limitations of this pilot study it may be concluded that:

- None of the groups of RPDs (acrylic, metal or NMCDs) in this sample were acceptable regarding biological and biomechanical principles.
- The metal-frame RPDs had higher compliance rates for type of tissue support (mostly hard and mixed), number of clasps and cross-arch stabilization.
- The acrylic partial dentures were compliant in providing cross-arch stabilization but were non-compliant in all other aspects.
- Except for clasp numbers, the NMCDs were not compliant with any of the biological and biomechanical criteria assessed in this study.

Addenda

Addendum 1: Ethics approval

Office of the Deputy Dean
Postgraduate Studies and Research
Faculty of Dentistry & WHO Collaborating Centre for Oral Health

UNIVERSITY OF THE WESTERN CAPE
Private Bag X1, Tygerberg 7505
Cape Town
SOUTH AFRICA

Date: 07th December 2016

For Attention: Dr W Farao

Dear Dr Farao

STUDY PROJECT: A comparative study between thermoplastic and conventional removable partial dentures designs

PROJECT REGISTRATION NUMBER: BM/16/5/12

ETHICS: Approved (Permission to access the laboratories must be requested)

At a meeting of the Senate Research Committee held on Thursday 24th November 2016 the above project was approved. This project is therefore now registered and you can proceed with the study. Please quote the above-mentioned project title and registration number in all further correspondence. Please carefully read the Standards and Guidance for Researchers below before carrying out your study.
Patients participating in a research project at the Tygerberg and Mitchells Plain Oral Health Centres will not be treated free of charge as the Provincial Administration of the Western Cape does not support research financially.

Due to the heavy workload auxiliary staff of the Oral Health Centres cannot offer assistance with research projects.

Yours sincerely

Professor Lawrence Stephen

Tel -27-21-937 3131 (w); Fax -27-21-931 2287 e-mail: lstephen@uwc.ac.za

Addendum 2: Dental Laboratory permission letter

Oral & Dental Research Institute
Faculty of Dentistry and WHO Oral Health Collaborating Centre
University of the Western Cape
Cape Town

Dental laboratory information sheet

I, Dr Warren Farao am a qualified dentist involved in research and training at the University of the Western Cape, Faculty of Dentistry.

I am doing research on the partial denture design principles of flexi- partial dentures.

I would like to assess the flexi-partial denture designs which you fabricate, in order to determine to which extent they comply with standard design principles.

Giving permission to do the study at your laboratory is voluntary. Refusing to participate will not prejudice you or your laboratory in any way. The use of the dentures or designs will not be labelled, and names of patients as well as the laboratory will remain anonymous throughout the study. All laboratory, personal and patient information will be kept strictly confidential.

Participating in the study will contribute to the knowledge and current practices of thermoplastic RPD's.

Thanking you.

……

Dr. Warren E Farao

Researcher
Oral and Dental Research Institute
Oral Health Centre Tygerberg
Contact details:
Tel: (021) 937 – 3170
Mobile: 082 929 7475

I, (Participating Laboratory owner)…….fully understand the information supplied to me by Dr Warren Farao in this information sheet.

Signature: …… Date: ……..……20…….

Addendum 3: Data sheet

RPD (Metal-frame / Acrylic / Flexible / ideal)														
				Support			Retention				Major connector			Saddles
	Classification (I to IV)	Modif	Rests (nos.)	Rests (tooth ID)	Soft (S) Hard (H) Mixed (M)	Configuration (no. of corners)	Clasps (nos.)	Clasps (tooth ID)	Indirect retention (yes-no-NA)	Reciprocation Yes/no	Bilateral (Yes-no)	Unilateral (yes-no)	No. of teeth covered	No. of teeth replaced
1														
2														
3														
4														
5														
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Addendum 4: Raw data

Denture Type	Classification	Modif	Rests(Nr)	Tooth ID	Soft/HardTiss/Mixed	Config Nr of Corners	Clasp Nr	Tooth ID	Indir Reten(Y/N/NA)	Uni/Bilat	Nr teeth Covered	number of teeth replaced
A1	I	1	0	0	S	0	0	0	no	B	7	7
A2	III	0	0	0	S	0	0	0	NA	B	9	1
A3	III	1	0	0	S	0	0	0	no	B	7	5
A4	III	0	0	0	S	0	0	0	NA	B	11	1
A5	III	2	0	0	S	0	0	0	no	B	8	5
A6	III	2	6	37,35,33,43,45,47	H	>4	2	35,45	yes	B	6	6
A7	III	1	0	0	S	0	0	0	no	B	10	3
A8	III	0	1	13	M	0	0	0	no	B	9	1
A9	I	0	1	43	M	0	2	34, 44	no	B	8	4
A10	III	2	1	13	M	0	0	0	no	B	5	9
A11	III	2	0	0	S	0	0	0	no	B	10	3
A12	III	0	0	0	S	0	0	0	NA	B	11	1
A13	III	2	1	33	M	0	0	0	NA	B	10	4
A14	II	1	0	0	S	0	0	0	no	B	7	5
A15	I	3	0	0	S	0	2	15, 23	no	B	4	10
A16	IV	0	0	0	S	0	0	0	no	B	8	4
A17	III	1	1	43	M	0	0	0	no	B	8	4
A18	III	2	0	0	S	0	0	0	no	B	6	6
A19	III	0	1	21	M	0	0	0	no	B	10	1
A20	II	3	0	0	S	0	0	0	no	B	5	7
			12				6				159	87

Denture Type	Classification	Modif	Rests(Nr)	Tooth ID	Soft/HardTiss/Mixed	Config Nr of Corners	Clasp Nr	Tooth ID	Indir Reten(Y/N/NA)	Uni/Bilat	Nr teeth Covered	number of teeth replaced
M1	III	1	2	14,27	M	0	4	14,16,23,27	NA	B	5	5
M2	II	1	1	37	M	0	3	37,33,43	yes	B	6	7
M3	I	0	1	34	M	0	2	34, 45	yes	B	9	5
M4	III	1	3	17, 14, 25	M	3	4	17,14,25,26	yes	B	6	7
M5	III	1	4	15,16,25,26	M	2	4	15,16,25,26	yes	B	8	4
M6	III	2	2	16,26	M	0	3	16,26,24	NA	B	8	4
M7	III	1	4	14,15,24,25	M	2	4	14,15,24,25	yes	B	0	2
M8	II	1	2	45, 47	M	0	3	34, 45, 47	no	B	0	3
M9	III	2	2	37, 47	M	0	4	37, 35, 45, 47	NA	B	0	3
M10	III	1	4	38, 33, 43, 48	H	4	4	33, 43, 38, 48	NA	B	0	6
M11	III	2	2	16, 26	M	0	4	16, 14, 24, 26	yes	B	8	3
M12	III	2	2	17, 27	M	0	4	17, 14, 24, 27	yes	B	4	8
M13	I	0	2	33, 44	M	0	2	33, 44	no	B	0	5
M14	III	1	3	17, 14, 27	H	3	3	17, 14, 27	NA	B	9	4
M15	III	1	6	36, 35, 33, 43, 44	H	4	4	36, 35, 44, 47	yes	B	4	4
M16	III	1	2	37,46	M	0	4	37,34,44, 46	NA	B	8	3
M17	III	2	4	17,13,23,27	H	4	4	17,13,23,27	NA	B	2	7
M18	III	1	3	17,14,26	H	3	4	17,14,23, 26	NA	B	1	4
M19	II	1	5	16,15, 23, 25	M	4	4	16, 15, 25, 26	yes	B	0	5
M20	II	1	3	37, 34, 43	M	3	3	37, 34, 43	yes	B	7	4
			57				71				85	93

Denture Type	Classification	Modif	Rests(Nr)	Tooth ID	Soft/HardTiss/Mixed	Config Nr of Corners	Clasp Nr	Tooth ID	Indir Reten(Y/N/NA)	Uni/Bilat	Nr teeth Covered	number of teeth replaced
F1	III	3	0	NA	S	0	2	17,27	no	B	6	7
F2	III	0	0	NA	S	0	2	23,25	NA	U	2	1
F3	III	0	0	NA	S	0	2	43,46	NA	U	2	2
F4	III	0	0	NA	S	0	2	13,15	NA	U	3	1
F5	III	1	0	NA	S	0	2	25,27	NA	U	3	2
F6	III	0	0	NA	S	0	2	14,16	NA	U	3	1
F7	II	0	0	NA	S	0	1	34	no	B	7	3
F8	III	0	0	NA	S	0	2	14,16	NA	U	3	1
F9	III	0	0	NA	S	0	2	13, 16	NA	U	2	2
F10	III	0	0	NA	S	0	2	23, 26	NA	U	2	2
F11	II	1	0	NA	S	0	3	37, 34, 45	yes	B	10	2
F12	II	1	0	NA	S	0	3	17,13,23	yes	B	7	7
F13	III	0	0	0	S	0	2	12, 21	no	B	7	1
F14	III	0	0	0	S	0	2	24, 26	NA	U	2	1
F15	III	1	0	0	S	0	4	12, 22, 23, 25	no	B	4	3
F16	I	0	0	0	S	0	2	34, 44	yes	B	8	5
F17	III	0	0	0	S	0	2	15, 13	NA	U	3	1
F18	III	0	0	0	S	0	2	23, 25	NA	U	3	1
F19	III	0	0	0	S	0	2	12, 14	NA	U	2	1
F20	III	0	0	0	S	0	2	24, 27	NA	U	2	1
							43				81	45

Denture Type	Classification	Modif	Rests(Nr)	Tooth ID	Soft/HardTiss/Mixed	Config Nr of Corners	Clasp Nr	Tooth ID	Indir Reten(Y/N/NA)	Uni/Bilat	Nr teeth Covered	number of teeth replaced
MAP A1	I	1	3	14,21,24	H	3	2	14,24	yes	B	7	7
MAP A2	III	0	4	13,15,24,26	H	4	2	15,26	NA	B	3	1
MAP A3	III	1	4	13,16,23,26	H	4	2	16, 25	yes	B	3	5
MAP A4	III	0	4	14,16,23,25	H	4	2	16, 25	NA	B	3	1
MAP A5	III	2	5	36, 34, 44, 45, 47	H	4	3	36, 45, 47	yes	B	7	5
MAP A6	III	2	6	47,45,43,37,35,33	H	>4 (6)	4	37,35,45,47	yes	B	6	6
MAP A7	III	1	5	17, 14, 21, 23, 27	H	4	3	17, 14, 27	yes	B	1	3
MAP A8	III	0	4	16, 13, 11, 26	H	3	2	16, 26	yes	B	0	1
MAP A9	I	0	2	34, 44	M	0	2	34, 44	yes	B	8	4
MAP A10	III	2	5	17, 14, 13, 23, 27	H	4	4	17, 14, 23, 27	yes	B	3	9
MAP A11	III	2	6	16, 13, 11, 23, 25,	H	>4	3	16, 25, 27	yes	B	1	3
MAP A12	III	0	4	15, 13, 25, 26	H	4	2	15, 26	NA	B	2	1
MAP A13	III	2	4	35, 34, 44, 46	H	4	3	35, 44, 46	NA	B	7	4
MAP A14	II	1	5	15, 13, 23, 26, 27	M	4	3	25, 26, 27	yes	B	1	5
MAP A15	I	3	4	15, 13, 21, 23	M	4	2	15, 23	yes	B	4	10
MAP A16	IV	0	4	16, 13, 23, 26	H	4	2	16, 26	yes	B	0	4
MAP A17	III	1	4	36, 33, 43, 46	H	4	2	36, 46	yes	B	6	4
MAP A18	III	2	6	16, 15, 13, 23, 25,	H	>4	3	16, 25, 27	yes	B	1	6
MAP A19	III	0	5	16, 14,21, 24, 27	H	>4	2	16, 27	yes	B	0	1
MAP A20	II	3	4	16, 14, 21, 25	M	4	3	16, 14, 25	yes	B	4	7
			88				51				67	87

Denture Type	Classification	Modif	Rests(Nr)	Tooth ID	Soft/HardTiss/Mixed	Config Nr of Corners	Clasp Nr	Tooth ID	Indir Reten(Y/N/NA)	Uni/Bilat	Nr teeth Covered	number of teeth replaced
MAP M1	III	1	4	14,16,23,27	H	4	4	16,14,23,27	NA	B	1	5
MAP M2	II	1	3	37,33,43	M	3	3	37,33,43	yes	B	6	7
MAP M3	I	0	3	34, 45	M	2	2	34,45	yes	B	9	5
MAP M4	III	1	4	14,17,24,26	H	4	3	14,17,26	yes	B	2	7
MAP M5	III	1	4	13,16,21,25, 26	H	4	2	16, 26	yes	B	3	4
MAP M6	III	2	5	14,16,21, 24,26	H	4	3	16,24,26	NA	B	4	4
MAP M7	III	1	4	14,16,24,26	H	4	2	16, 26	yes	B	0	2
MAP M8	II	1	3	34, 45, 47	M	3	3	34, 45, 47	yes	B	9	3
MAP M9	III	2	5	37, 35, 33, 45, 47	H	4	4	37, 35, 45, 47	NA	B	2	3
MAP M10	III	1	4	37, 33, 43, 47	H	4	4	37, 33, 43, 47	NA	B	2	6
MAP M11	III	2	5	16, 14, 11, 24, 25	H	6	3	16, 14, 25	yes	B	6	3
MAP M12	III	2	4	17, 14, 24, 27	M	4	4	17, 14, 24, 27	yes	B	2	8
MAP M13	I	0	2	33, 44	M	2	2	33, 44	yes	B	0	5
MAP M14	III	1	4	16, 14, 23, 27	H	4	4	16, 14, 23, 27	NA	B	1	4
MAP M15	III	1	4	36, 33, 44, 47	H	4	3	36, 44, 47	yes	B	6	4
MAP M16	III	1	4	37,34,44,46	H	4	4	37,34,44,46	NA	B	8	3
MAP M17	III	2	4	17,13,23,27	H	4	4	17,13,23,27	NA	B	2	7
MAP M18	III	1	4	17,14,23,27	H	4	4	17,14,23,27	NA	B	1	4
MAP M19	II	1	5	17,16,13,23,26	M	4	3	17,16,26	yes	B	0	5
MAP M20	II	1	3	37, 34, 33	M	3	3	37, 34, 43	yes	B	7	4
			78				64				71	93

Denture Type	Classification	Modif	Rests(Nr)	Tooth ID	Soft/HardTiss/Mixed	Config Nr of Corners	Clasp Nr	Tooth ID	Indir Reten(Y/N/NA)	Uni/Bilat	Nr teeth Covered	number of teeth replaced
MAP F1	III	3	6	13, 15, 17, 23, 24	H	4	4	14, 17, 25, 27	yes	B	4	7
MAP F2	III	0	4	14,16,23,25	H	4	2	16,25	NA	B	3	1
MAP F3	III	0	4	36, 34, 43,46	H	4	3	36,43,46	NA	B	8	2
MAP F4	III	0	4	13,15,23,26	H	4	3	13, 15, 26	NA	B	3	1
MAP F5	III	1	4	15,17, 23, 25, 27	H	4	3	17, 25, 27	NA	B	4	2
MAP F6	III	0	4	14,16,24,26	H	4	3	14, 16, 26	NA	B	2	1
MAP F7	II	0	3	34,46,44	M	3	2	34, 46	yes	B	9	3
MAP F8	III	0	4	14,16,24,26	H	4	3	14, 16, 26	NA	B	1	1
MAP F9	III	0	4	16, 13, 24, 26	H	4	3	16, 13, 26	NA	B	1	2
MAP F10	III	0	4	16.14.23.26	H	4	3	16. 23.26	NA	B	1	2
MAP F11	II	1	4	37, 35, 43, 45	M	4	3	37, 35, 45	yes	B	10	2
MAP F12	II	1	3	17,13,23	M	3	3	17,13,23	yes	B	2	7
MAP F13	III	0	4	13, 16, 21, 26	H	4	2	16, 26	yes	B	2	1
MAP F14	III	0	4	16, 14, 24, 26	H	4	3	16, 24, 26	NA	B	0	1
MAP F15	III	1	5	16, 13, 23, 25, 26	H	>4	2	16, 26	yes	B	5	3
MAP F16	I	0	2	34, 44	M	0	2	34, 44	yes	B	8	5
MAP F17	III	0	4	15, 13, 24, 26	H	4	2	15, 26	NA	B	0	1
MAP F18	III	0	5	17, 14, 23, 25, 27	H	4	2	17, 27	NA	B	0	1
MAP F19	III	0	4	16, 14, 24, 26	H	4	2	16, 26	NA	B	0	1
MAP F20	III	0	4	16, 14, 24, 26	H	4	2	16, 26	NA	B	0	1
			80				52				63	45

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