UNIVERSITY OF THE WESTERN CAPE

Comparison of Occlusal Rest Seat Preparations to Cast Metal Rests

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Dedication

This is dedicated to my parents, brother, sister, their families, wife Masooda, and children Ayesha and Khadija who each in their own way made it possible.

Comparison of Occlusal Rest Seat Preparations to Cast Metal Rests.

Keywords:

Metal-Based removable partial dentures

Partial dentures

Occlusal rest seat preparations

Occlusal rest seat

Cast metal rest

SUMMARY

A well designed metal-based removable partial denture (MBRPD) is a cost-effective and a conservative method of rehabilitating a partially edentulous mouth. The MBRPD demands that the abutment tooth provides support and/or retention while the abutment tooth, in turn, expects the MBRPD to transmit the forces axially and to be passive when fully seated. For vertcal forces to be transmitted axially, occlusal rest seats have to be prepared on the abutment teeth to receive a cast metal rest of the MBRPD. **Objective:** 1- To compare occlusal rest seat preparations for metal-based removable partial dentures (MBRPD) prepared by dental students at the UWC Oral Health Centres, to the corresponding cast metal rests. 2- To determine action taken in response to discovered discrepancies between the rest seat preparation depth and the cast metal occlusal rest thickness. **Materials and methods:** Stone models and the corresponding metal frameworks of MBRPD were examined for the depth, width and length of occlusal rest seat preparations and the thickness of the cast metal rests respectively. Models were measured for the maximum bucco-lingual (B-L) width of the tooth between the maximum curvatures of these surfaces and the mesio-distal (M-D) length was obtained from the marginal ridges of the teeth. Measurements were made with a modified digital calliper, under magnification of 1.5X, by a pre-calibrated observer. The B-L width and M-D length of the rest preparation was measured and compared with the recommended one

third B-L width and one third M-D length of the tooth, respectively. The depth of the rest preparation was compared to the minimum recommended depth (1mm) and the thickness of the cast metal rest. The cast metal rests were measured after the try-in and delivery stages and the results were correlated with the responses provided to the questionnaire given to the students to record any changes made to the cast metal rests. Data were analysed using a pair-wise comparison (Wilcoxon signed-rank test) at $p<0.05$. **Results:** The occlusal rest seat preparations (B-L width, M-D length and depth) were significantly less ($p<0.05$) than the recommended preparation dimensions. The cast metal rests were thicker than the corresponding rest seat preparation in 75% of the cases. 72% of the rest seat preparations were irregularly shaped. 62.5% of the remaining triangularly shaped rests were supervised by full-time specialists. The students responded by grinding the thicker metal rests in 25% (17) of the cases and by grinding the opposing tooth in 9% (6) of the cases where the cast metal rest opposed natural teeth. Where the cast metal rests opposed dentures or an edentulous space no action on the rest was taken. **Conclusions:** Dental students tend to be overly conservative when preparing occlusal rest seats for MBRPD. However, the fabricated metal rests (75%) were thicker than the depth of the preparations, suggesting overcompensation by the technicians. The guidelines for preparing rest seats are rarely followed and need to be re-evaluated in the light of this study.

DECLARATION

I declare that *Comparison of Occlusal Rest Seat Preparations to Cast Metal Rests is* my own work, that it has not been submitted before for any degree or examination in any other university, and that all the sources I have used or quoted have been indicated and acknowledged as complete references.

Shabir Cassim June 2007

Signed: ……

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Chapter 1 – Introduction

The designing of metal-based partial dentures is taught to dental students as a two week block course at the beginning of their fourth academic year of study at The University of the Western Cape. Thereafter they are expected to treat patients requiring metal-based partial dentures. Each student is required to design and commission at least two metal-based partial dentures as part of their clinical training for the BChD degree. While supervising students, inconsistencies were noted in the size and shape of the occlusal rest seats that were being prepared. This inspired further investigation into the preparation of rest seats for metal-based partial dentures by dental students at the Oral Health Centres of the University of the Western Cape.

The need for tooth support for removable partial dentures has long been recognised. Dentures without adequate tooth support exact a severe biological price in the long term with loss of attachment and gingival recession around the abutment tooth, destruction of the underlying alveolar bone and even the ultimate loss of the abutment tooth (McCracken 1956). The first person to describe occlusal rests was Bonwill in 1899 and since then many authors have described occlusal rests and rest seat preparations in natural teeth and restorations (Zarb, Bergman, Clayton and MacKay 1978; McGiveney and Carr, 1999; Phoenix, Cagna and DeFreest 2003). These descriptions have largely been based on

anecdotal evidence and clinical experience (Goodkind, Smith and Taylor 1984)

The Dental students, as part of their training, are taught that an occlusal rest seat preparation should be spoon-shaped and triangular in outline. The base of the triangle being at the marginal ridge, and the apex towards the centre of the tooth. The width should be one third the bucco-lingual width of the tooth or one half the distance between the cusp tips. The length should be one third to one half the mesio-distal length of the tooth. The depth at the marginal ridge should be one to one and a half millimetres with a deeper reduction towards the centre of the tooth, giving the rest seat preparation a sloping inclination towards the centre of the tooth (Stratton and Wiebelt 1988; Rudd, Bange, Rudd, and Montalvo 1999; Phoenix, Cagna and DeFreest 2003)

Inconsistencies in the preparation of rest seats have been reported in the literature in terms of size, shape and depth of preparation (Culwick, Howell and Faigenblum (2000); Dunham, Brudvik, Morris, Plummer, *et al,* (2006). Therefore the aim of the study was to evaluate occlusal rest seat preparations for metal-based removable partial dentures (MBRPD) provided by dental students at the UWC Oral Health Centres in Mitchells Plain and Tygerberg.

Chapter 2 – Literature Review

2.1- Introduction

With decreasing rates of complete edentulism and increasing life expectancy, the demand for partial prosthesis is on the increase (Owen, 2000; Mojon, Thomason and Walls, 2004). A metal-based removable partial denture (MBRPD) is a relatively cost-effective and biologically accepted method of rehabilitating a partially edentulous patient. However, the preferred method of replacing missing teeth would be with the use of an implant supported prosthesis or a fixed partial denture (FPD) (Szentpetèry, John, Slade and Setz 2005; Wöstmann, Budtz-Jorgensen, Jepson, Mushimoto, *et al,*, 2005; Henry, 1998) as the use of removable partial dentures has not been totally without problems. The presence of removable partial dentures has been associated with an increased risk of caries, particularly root surface caries and periodontal disease (Jepson, Allen, Moynihan, Kelly, *et al,* 2003). In one study, teeth adjacent to edentulous spaces restored with a removable partial denture have a significantly lower survival rate compared with teeth adjacent to edentulous spaces that were not restored or that were restored with a fixed partial denture (Aquilino, Shugars, Bader and White, 2001).

2.2- Metal-Based Removable Partial Dentures

Long span edentulous areas in a partially dentate mouth are ideally restored with dental implants (Misch, 2005). However, in patients, where dental implants are contra-indicated, or not an option due to financial constraints, a metal-based removable partial denture (MBRPD) is a viable and a cost-effective alternative (Wöstmann, Budtz-Jorgensen, Jepson, Mushimoto, *et al,* 2005). A well designed and accurately constructed MBRPD will adequately restore form and function that is subsequent to the loss of natural teeth (Owen, 2000). Thus it should restore masticatory efficiency, appearance and speech, whilst maintaining the integrity of the dental arches, by preventing drifting and over-eruption of the teeth into the edentulous spaces. (Fenn, Liddelow and Gimson, 1974).

Amongst the disadvantages of removable partial dentures is the fact that being a foreign body it would be more conducive to accumulating plaque especially in a poorly maintained mouth which could create an increased risk for dental caries and/or periodontal disease. This is substantiated in a study that gathered evidence on an association between the use of removable partial dentures and root surface caries in the elderly (Wöstmann, Budtz-Jorgensen, Jepson, Mushimoto, *et al,* 2005).

Partial dentures not supported by teeth can have detrimental effects on the underlying soft tissue (McGiveney and Carr, 1999). Masticatory forces

on a denture that finishes adjacent to or over the gum margin and cervical to the suprabulge area of the tooth will have an effect of stripping the gum away from the tooth over time, causing irreversible damage to the periodontium (Davenport, Basker, Heath, Ralph, *et al,* 2000). Dentures that do not finish against adjacent natural teeth will have food impacting in and stagnating between the denture and the adjacent natural tooth with resultant periodontal problems (McGiveney and Carr, 1999). Poorly designed dentures can loosen natural teeth by leverage where forces acting on the tooth are non-axially directed, rather than vertically along the long axis of the tooth (Fenn, Liddelow and Gimson, 1974).

2.3- Components of Metal-Based Removable Partial Dentures

The metal-based removable partial denture is made up of a metal framework with components for support, retention and stability, to which acrylic flanges are attached. The metal framework of the MBRPD is a single piece casting from a base metal alloy of chrome, cobalt and nickel. This alloy was originally of chrome and cobalt only and was developed by Haynes for the use in automobiles. Originally referred to as Haynes satellites they are known as Stellite alloys. These alloys are light, stiff, strong in thin sections, and can be cast to a high degree of accuracy (Owen, 2000; Van Noort, 2002; Wataha, 2002).

Guidelines are available in the literature as to the design of the denture and the preparation of the mouth to accommodate the various components of the MBRPD as per design. The components of the metal-based removable partial denture are classified as the major connector, minor connector, rests, direct retainers, reciprocal components and in some instances indirect retainers when the prosthesis has one or more distal extension bases. The major connector connects the parts of the prosthesis located on one side of the arch with those on the opposite side. It is that unit of the partial denture to which all other parts are directly or indirectly attached. This component, being a rigid structure, also provides the cross-arch stability that is needed to resist displacement of the denture, during function (Johnson and Stratton, 1980; McGiveney and Carr, 1999).

The minor connector is that component of the MBRPD that serves as the connecting link between the major connector or base of the removable partial denture and the other components of the prosthesis such as the clasp assembly, indirect retainers, occlusal rests, and cingulum rests.

The rest is that part of a partial denture that rests on a tooth surface, providing vertical support for the removable partial denture. It also transmits some or all of the forces from the saddle area of a denture to the adjacent tooth rather than to the underlying soft tissue. An indirect retainer is also a rest, but its function is that of providing retention for the

denture. The indirect retainer is placed anterior to the fulcrum line that passes through the anterior most rigid component of clasp assemblies of a distal extension partial denture. This prevents the rotation of the major connector along the fulcrum line. Therefore the indirect retainer will help prevent the dislodging of the distal extension base away from the underlying mucosa and posteriorly, and anteriorly, it will prevent the major connector from impinging and digging into the underlying soft tissue (McGiveney and Carr, 1999).

The success of especially the MBRPD depends on the support and retentive features that are incorporated into the design features of the denture (McGiveney and Carr, 1999). Support (withstanding occlusal forces) is derived from the remaining teeth and the underlying soft tissue. Retention (resisting dislodging forces) is derived from the clasp assembly that engages the existing teeth and the guide planes that are the parallel surfaces along the sides of the teeth and the soft tissue (Fig. 2.1) (Zarb, Bergman, Clayton and MacKay, 1978; McGiveney and Carr, 1999; Phoenix, Cagna and DeFreest, 2003; Owen, 2000).

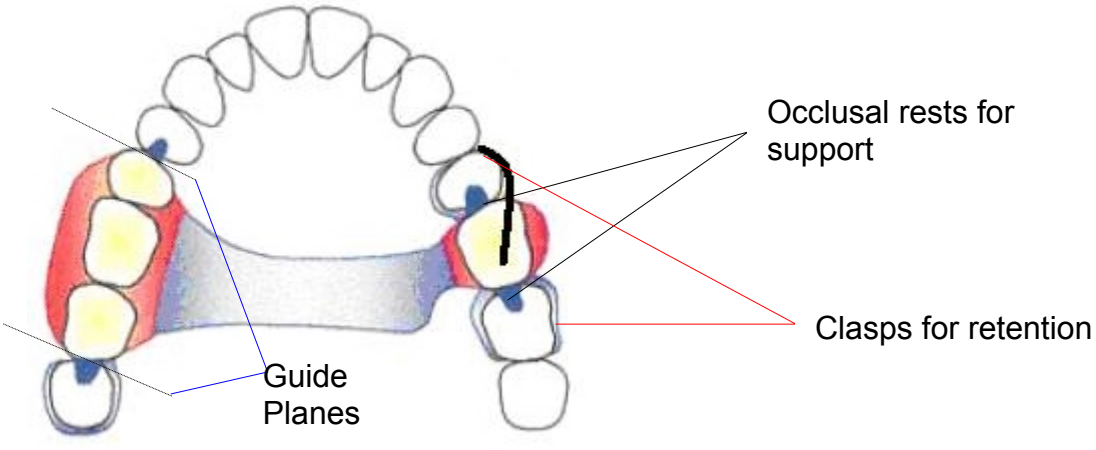


Figure 2.1: Support and retention of MBRPD. (Adapted from Davenport, Basker, Heath, Ralph, *et al, 2000*)

The clasp assembly (Fig. 2.2), also called an extra-coronal retainer is composed of a rest and two arms that encircle the abutment tooth for a total of more than 180 degrees. The tip of one arm, the retentive arm engages the under-cut area cervical to the bulge of the tooth while the other opposing arm, the reciprocal arm is positioned occlusal to the maximum convexity of the tooth. The retentive arm provides the retention through its tip that engages the undercut area of the tooth while the reciprocating arm has a bracing action. (Dykema, Cunningham and Johnston, 1969; Sato, Shindoi, Koretake and Hosokawa, 2003).

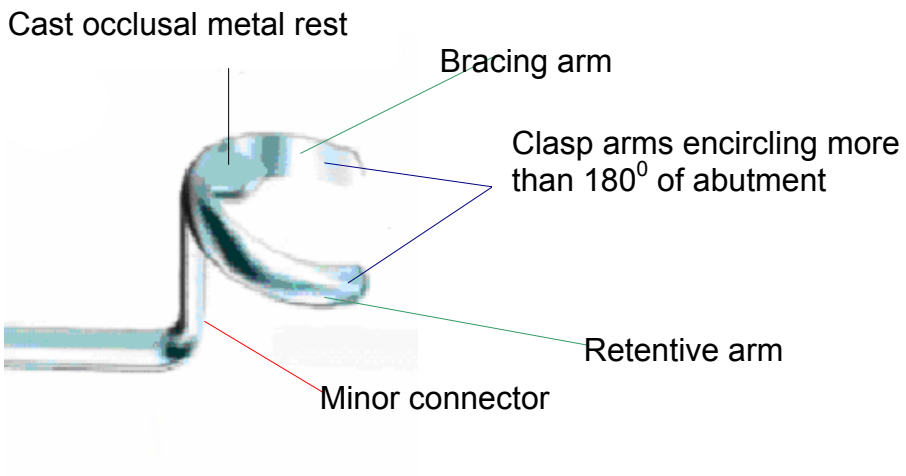


Figure 2.2: Clasp Assembly (Sato, Shindoi, Koretake and Hosokawa, 2003)

2.4- Occlusal Rests

Teeth that are used for support are called abutment teeth and rest seats should be prepared on these teeth, or on the restorations covering these teeth (McGiveney and Carr, 1999), to receive a cast metal occlusal, incisal or lingual rest of a metal-based removable partial denture (Stratton and Wiebelt, 1988). The function of the cast occlusal rest is to transfer forces of mastication apically along the long axis of the tooth (Schuyler, 1953). These forces are atraumatically absorbed by the periodontal ligament fibres. The cast rest also serves as a vertical stop for the denture thus preventing gingival displacement (McCracken, 1956).

According to Zarb, Bergman, Clayton and MacKay (1978); Lewis (1978); McGiveney and Carr (1999); Culwick, Howell and Faigenblum (2000);

Owen, (2000); and Phoenix, Cagna and DeFreest (2003), an occlusal rest seat is prepared to receive a cast occlusal rest so that the occlusal rest:

1. can transmit forces along the vertical axis of the tooth;
2. has adequate thickness so that it does not distort or fracture under load;
3. does not interfere with the occlusion and restores the topography of the tooth existing before the rest seat preparation;
4. has a positive location in the tooth, preventing the denture from moving when in function.

2.5- Shape of the Rest Seat Preparation

Occlusal rest seat preparations are expected to be saucer or spoon-shaped depressions with no sharp edges, line angles or vertical walls (Stratton and Wiebelt, 1988). The shape of the rest seat preparation should be triangular, with the base at the marginal ridge and the apex of the triangle towards the centre of the abutment tooth, following the mesial or distal fossa of the abutment tooth (Zarb, Bergman, Clayton and MacKay, 1978; McGiveney and Carr, 1999; Phoenix, Cagna and DeFreest, 2003).

2.6- Width of the Rest Seat Preparation

The buccolingual width of the occlusal rest seat preparation should be one third of the buccolingual width of the crown of the tooth or one half the distance between the cusp tips (Fig. 2.3) (Stratton and Wiebelt, 1988; Phoenix, Cagna and DeFreest, 2003; Sato, Shindoi, Koretake and Hosokawa, 2003). Due to the occlusal wear that may affect the cusp tips, a more clinically appropriate guideline for the preparation of occlusal rest seats is to make it one third the buccolingual width of the tooth. Dykema, Cunningham and Johnston (1969) recommend that the occlusal rest seat preparation be 2.0mm wide.

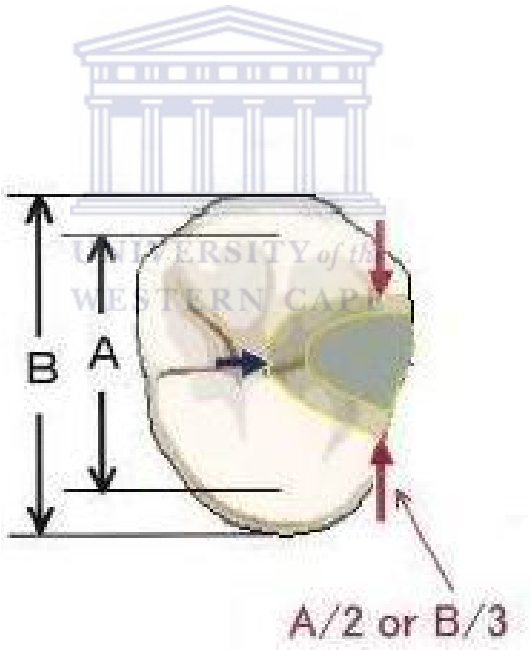


Figure 2.3: Recommended width of occlusal rest is one half of A - cusp tip to cusp tip; or a one third of B - buccolingual width of the tooth. (Sato, Shindoi, Koretake and Hosokawa, 2003).

2.7- Length of the Rest Seat Preparation

The recommended mesiodistal length of the occlusal rest seat preparation should be one third to one half of the crown mesiodistally. (Fig. 2.4) (Stratton and Wiebelt, 1988; Phoenix, Cagna and DeFreest, 2003; Sato, Shindoi, Koretake and Hosokawa, 2003). According to Stratton and Wiebelt (1988) molars that are mesially tilted into the adjacent edentulous space should be prepared with a longer length rest seat preparation to receive a longer cast occlusal rest that will transfer forces more axially, preventing further mesial tilt of the molar tooth. Long rest seat preparations are also recommended where there is a rotational path of insertion of the partial denture. In partial dentures with a rotational path of insertion, the number of clasps are reduced and the long rest together with the minor connecter serves for both support and retention (Jacobson, 1994).

Some authors prefer to specify actual dimensions, suggesting that a rest seat preparation should be as wide as it is long and at least 2.5mm. for both premolars and molars (Dykema, Cunningham and Johnston, 1969; McGiveney and Carr, 1999; Zarb, Bergman, Clayton and MacKay, 1978).

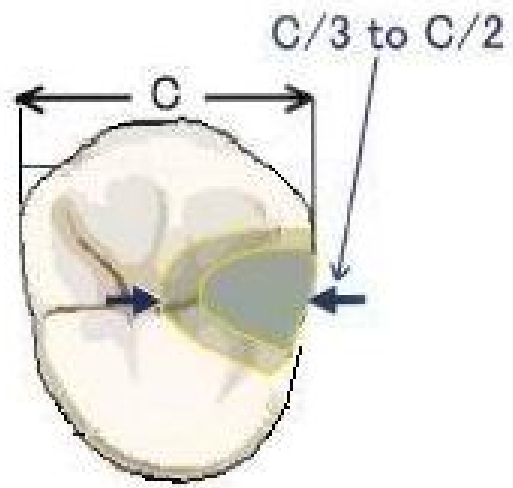


Figure 2.4: Recommended length of the occlusal rest is one half to one third mesio-distal length of the tooth (C). (Sato, Shindoi, Koretake and Hosokawa, 2003)

Osborne and Lammie (1974) explained the need for extending the length of the cast rest from one third to one half the mesio-distal length of the tooth, by comparing the tooth to a cone. The top wide area of the cone represents the occlusal surface and the narrow bottom area represents the root area. They postulated that if a force was applied to the entire top surface of the cone the resultant force would be an uncomplicated vertical downward movement along the long axis of the cone (Fig. 2.5).

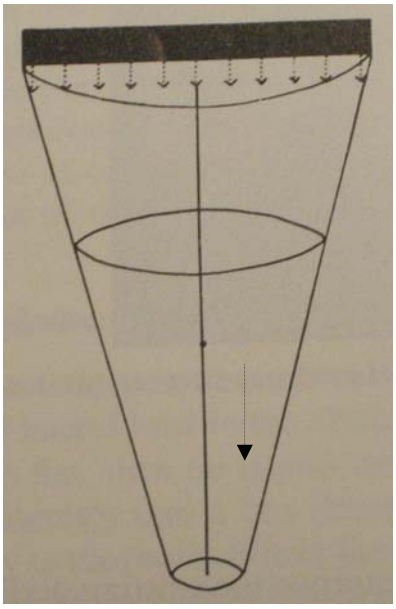


Figure 2.5: (Osborne and Lammie, 1974) Force applied to the entire top surface of the cone results in an axial downward movement.

However, if vertical pressure was applied at the periphery of the top surface of the cone, the downward movement would be complicated by a torque being placed on the tooth with a resulting tilting of the cone (Fig. 2.6). To prevent this torquing effect the force on the top surface of the cone should be extended to at least the middle of the top surface of the cone (Fig. 2.7). Similarly an occlusal rest on the contiguous surface of the abutment tooth should extend to at least the middle of the tooth to prevent any damaging tilting force.

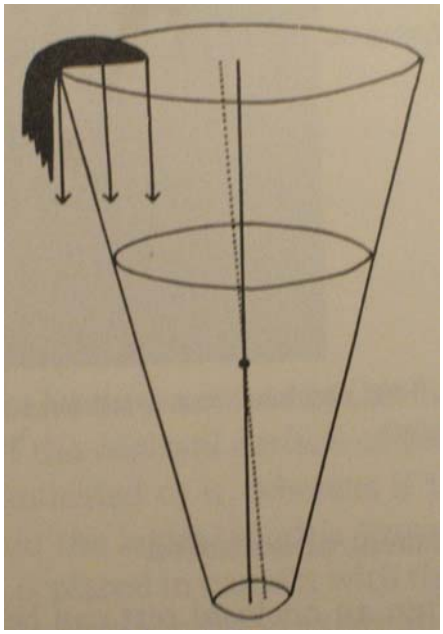


Figure 2.6: (Osborne and Lammie, 1974) A torque is present when a load is placed on the surface of the cone that is limited to the periphery of the cone only.

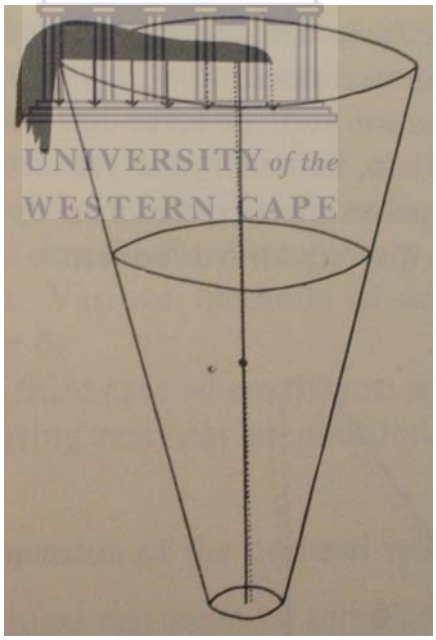


Figure 2.7: (Osborne and Lammie, 1974) Torque is reduced if the force on the surface of the cone is extended to beyond the centre of the cone.

If only a short length rest can be used, then from the analogy of the cone (Fig. 2.8) another rest must be placed on the opposite side of the tooth to prevent tourquing forces (Fig. 2.8).

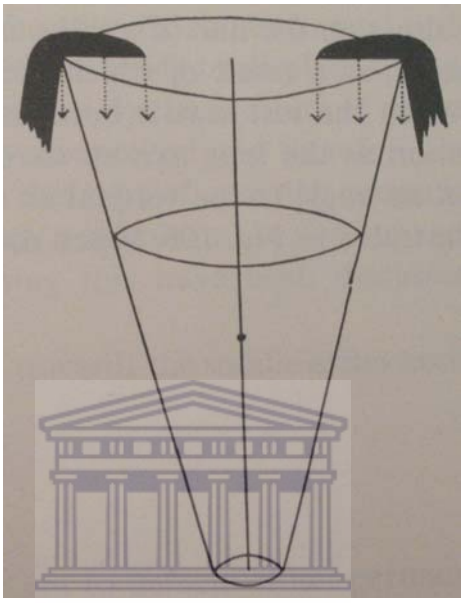


Figure 2.8: (Osborne and Lammie, 1974) Counteracting the torquing force produced, by an additional occlusal rest on the other side of the cone.

Yet another possibility is to place the rest away from the saddle area adjacent to a contiguous standing tooth to help resist the rotatory movement (Fig. 2.9)

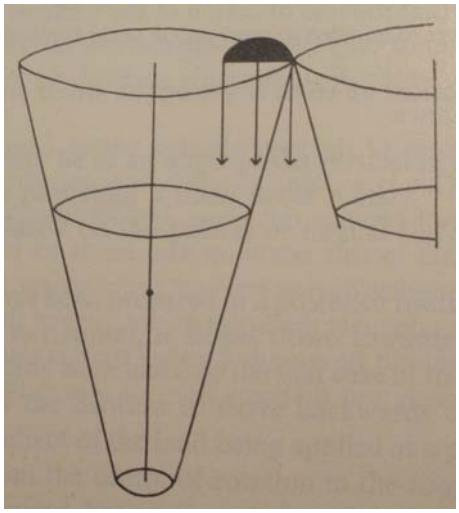


Figure 2.9: (Osborne and Lammie, 1974) Effect of a contacting contiguous tooth in resisting a torquing force.

2.8- Depth of the Rest Seat Preparation

As regards the depth of the occlusal rest seat preparation, the literature reviewed, recommend a reduction of between 1.0mm and 1.5mm at the marginal ridge (Fig. 2.10). The middle of the occlusal rest seat preparation should be deepened so as to provide an inclination of the horizontal axis of the cast occlusal rest of less than 90 degrees (Fig. 2.11) (Dykema, Cunningham and Johnston, 1969; Zarb, Bergman, Clayton and MacKay, 1978; Stratton and Wiebelt, 1988; McGiveney and Carr, 1999; Rudd, Bange, Rudd and Montalvo, 1999; Owen, 2000; Phoenix, Cagna and DeFreest, 2003; Sato, Shindoi, Koretake and Hosokawa, 2003).

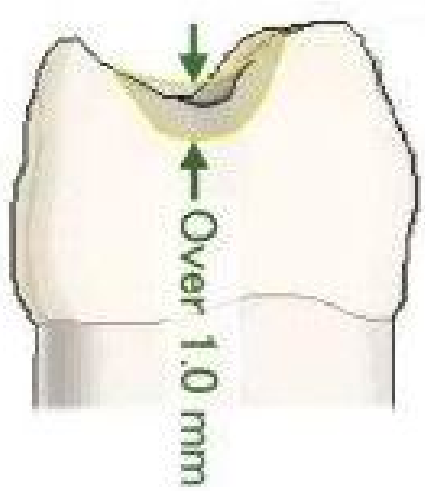


Figure 2.10: Recommended depth of occlusal rest: 1.0mm to 1.5mm at the marginal ridge (Sato, Shindoi, Koretake and Hosokawa, 2003).

Owen (2000) does not specify the reduction of the tooth in millimetres to receive a cast rest, but does, as do other authors (McCracken, 1956; Zarb, Bergman, Clayton and MacKay, 1978; Rudd, Bange, Rudd and Montalvo, 1999; Phoenix, Cagna and DeFreest, 2003), recommend the use of a number 6 round bur for the preparation of the occlusal rest seat. Other authors have suggested the use of a number 6 round bur and then a number 4 round bur to deepen the central part of the rest seat preparation to achieve the less than 90 degree horizontal plane incline (McCracken, 1956; Stratton and Wiebelt, 1988; Rudd, Bange, Rudd, and Montalvo, 1999). Phoenix, Cagna and DeFreest, (2003) warn that using a round bur without sufficient care can create undercuts at the periphery of the preparation and suggest the use of a diamond bur with rounded ends and

tapering sides. The use of round burs could also result in rest seat preparations that are round rather than triangular in outline form.

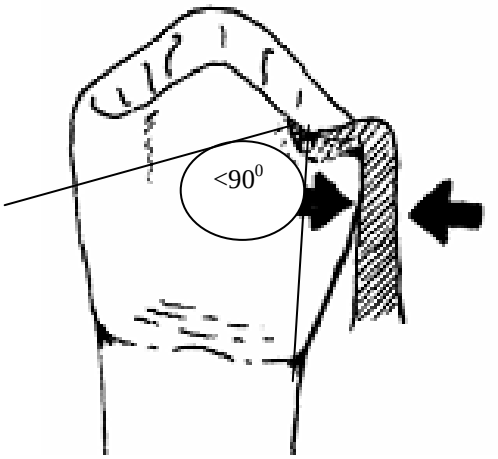


Figure 2.11: Horizontal inclination of the occlusal rest is less than 90 degrees. (Rudd, Bange, Rudd and Montalvo, 1999)

In addition to the occlusal rest, the inclination of the horizontal plane of the occlusal rest seat preparation towards the centre of the tooth ensures that occlusal forces are directed vertically along the long axis of the tooth when occlusal loads are placed on the prosthesis. If the horizontal plane of the occlusal rest seat preparation is not inclined towards the centre of the tooth, occlusal loads will cause wedging or slippage of the cast rest against the tooth, resulting in detrimental lateral orthodontic forces being transmitted to the tooth (McGiveney and Carr, 1999; Rudd, Bange, Rudd and Montalvo, 1999). The spoon-shape of the cast occlusal metal rest has the additional benefit of transmitting occlusal forces to the deepest part of the prepared rest seat (Owen, 2000).

A common error when preparing a rest seat is not reducing the marginal ridge of the tooth adequately, resulting in an extremely thin cast rest that is prone to fracture (Lewis, 1978; Phoenix, Cagna and DeFreest, 2003). The depth of the rest seat preparation can be verified in the mouth by asking the patient to bite into a piece of red utility wax and then measuring the imprint of the rest seat preparation in wax with a thickness measuring gauge (Rudd, Bange, Rudd and Montalvo, 1999; Davenport, Basker, Heath, Ralph , *et al,* 2000).

The recommendation of a 1 to 1.5mm reduction of the marginal ridge area of the abutment tooth is to provide sufficient bulk of metal at the junction of the minor connector and the cast rest. If the cast rest is to be contoured to restore the occlusal morphology of the tooth, then rest seat preparations of a shallower dimension would not provide sufficient space to cast a metal rest of adequate bulk (Sato, Shindoi, Koretake and Hosokawa, 2003; Gapido, Kobayashi, Miyakawa and Kohno, 2003). To achieve a sloping inclination towards the centre of the abutment tooth and a spoon-shape of the cast metal rest, greater reduction in the centre of the proposed rest seat preparation is needed compared to the marginal ridge area (Fig. 2.1). Therefore it can be expected that the reduction of the abutment tooth at the deepest part of an optimal rest seat preparation can approach 1.5 to 2.0mm.

2.9- Problems Associated with Rest Seat Preparations

With the reduction of tooth structure in an unrestored abutment tooth to receive a cast metal rest, there is a greater possibility of perforating the enamel-dentine junction with resultant exposure of dentine. The risk of tooth sensitivity and caries would be low as long as the rest seat preparations are in sound enamel, or in superficial dentine at the deepest, and provided good oral hygiene is maintained (McGiveney and Carr, 1999). Severely exposed dentine requires the restoration of the tooth with the rest seat subsequently prepared within the restoration (Dykema, Cunningham and Johnston, 1969; Zarb, Bergman, Clayton and MacKay, 1978; McGiveney and Carr, 1999; Phoenix, Cagna and DeFreest, 2003). In older individuals, where the dentine has been exposed for some time and in the presence of good oral hygiene, a rest seat preparation can be placed without fear of caries or sensitivity developing in the abutment tooth. The deposition of secondary and peritubular dentine obliterates the lumen of the dentinal tubules, and renders it impermeable to fluids and toxins with minimal risk of post-operative sensitivity (Jones, Goodacre, Brown, Munoz, *et al,* 1992).

Rest seat preparations can be placed in composite resin restorations, amalgam alloy restorations and in indirect cast restorations (Firtell, Kouyoumdjian, and Holmes, 1986; Culwick, Howell and Faigenblum, 2000). Although, it has been stated that a well condensed amalgam

restoration is capable of supporting a cast metal occlusal rest (Holmes 1986), large multiple surface amalgam restorations are less suitable compared to cast restorations as amalgam restorations tend to deform under a sustained load and are susceptible to fracture (Phoenix, Cagna and DeFreest, 2003).

2.10- Studies Related to the Preparation of Rest Seats

Ideally the rest seat preparation in a cast restoration, should be carved into the wax pattern (McGiveney and Carr, 1999; Phoenix, Cagna and DeFreest, 2003) and a deeper and a more positive rest seat preparation should be used (Robinson,1970). Cecconi (1974) showed in a laboratory study that rest seat preparations placed in abutment teeth as deep as the gingival level were as effective as intracoronal precision attachments in terms of directing the occlusal forces vertically with minimal lateral displacement. The conclusion was that shallower rest seat preparations resulted in greater lateral displacements under load compared to deeper rest seat preparations that resulted in apically directed forces.

In a study conducted by Jones, Goodacre, Brown, Munoz, *et al,* (1992), that comprised a survey of laboratory and clinical phases, canine and premolar rest seat preparations were evaluated. The survey was

conducted amongst prosthodontists. The laboratory study evaluated the width, depth, length and dentine exposure resulting from the rest seat preparations on extracted human teeth. The clinical study examined dentine exposure and tooth sensitivity following rest seat preparation at the time of preparation, within one to six months of rest seat preparation and six months to seventeen years after rest seat preparation. The following observations were noted from both the laboratory and the clinical studies:

- Although 69% of those surveyed, recommended a depth of 1.0mm or more for canine ledge reduction, the mean depth reduction measured only 0.74mm.
- Rests that were visibly judged to be excessively deep, were within the recommended depth suggested in the literature.
- Dentine was exposed in 55% and 61% of the occlusal rest seat preparations on premolars in the laboratory study and clinical study respectively.
- The bucco-lingual width of the occlusal rest seat preparations were within the recommendations of one third or one half the bucco-lingual width of the tooth or the distance between the cusp tips respectively.
- The mesio-distal length of the rest seat preparations was within the recommended one third to one half the mesio-distal length of the tooth.

From this study, it was concluded that clinically, the bucco-lingual and the mesio-distal dimensions of the rest seat preparations were within the recommended guidelines. However, due to the high rate of dentine exposure during the rest seat preparations, the depth of the preparations in the clinic may be compromised due to patient sensitivity during the procedure.

Another study by Culwick, Howell and Faigenblum, (2000) used a laser profilometer to compare the size and shape of occlusal rest seats prepared on plastic teeth by general dental practitioners, postgraduate students and their academic teachers. They found that there was a marked difference in the dimensions of the rest seat preparations of the different groups.

The post graduate students and their academic teaching staff prepared occlusal rest seats that were closer to the ideal as recommended in the literature in terms of width, length and shape. The general dental practitioners however, prepared occlusal rest seats that were narrower and shorter than the recommendations in the literature, and lacked the triangular shape with smoothed edges that were found in the preparations of the post graduate students and the academic teachers. It appeared as though the rest seats prepared by the general dental practitioners were cut

by a single application of a round bur placed on the marginal ridge of the abutment tooth (Culwick, Howell and Faigenblum, 2000).

The depth of the rest seat preparations was less than the recommended 1mm in all three groups. The mean depth recorded for the post graduate students and their academic teachers was 0.68mm and 0.65mm respectively. The general dental practitioners prepared the occlusal rest seats to a mean depth of 0,78mm.

The salient feature of this study was that the academic staff and the postgraduate students failed to prepare occlusal rest seats to their minimum recommended depth of 1mm. It would be expected that this group would be most familiar with the guidelines of occlusal rest seat preparations, yet their rest seat preparations were shallower compared to those prepared by general dental practitioners.

The 1 to 1.5mm depth recommendations of rest seat preparations by most authors (Dykema, Cunningham and Johnston, 1969; Zarb, Bergman, Clayton and MacKay, 1978; Stratton and Wiebelt, 1988; McGiveney and Carr, 1999; Rudd, Bange, Rudd and Montalvo, 1999; Phoenix, Cagna and DeFreest, 2003) have recently, been questioned (Meining, 1994; Dunham, Brudvik, Morris, Plummer, *et al,* 2006). Meining (1994) initiated the debate on the need for prepared rest seats that has gone unchallenged ever since

rest seats were first recommended by Bonwil in 1899. However, this has not been substantiated by any other studies.

The need for tooth support for removable partial dentures is understandable, for the protection and preservation of the underlying soft tissue. Recent clinical findings by Dunham, Brudvik, Morris, Plummer, *et al,* (2006) revealed that 38 out of 50 cast rests in a clasp assembly did not contact the depth of the rest seat preparation when in function. Their results showed that the metal-based removable partial denture was supported by the clasp arms that were in contact with the suprabulge area of the abutment tooth, rather than the cast metal rest that was supposed to be seated within the rest seat preparation.

Following the study by Culwick, Howell and Faigenblum (2000), where the average depth of the rest seat preparations was 0.78mm by general dental practitioners, Gapido, Kobayashi, Miyakawa and Kohno (2003) used a 0.8mm thick cast chrome cobalt occlusal rest to test for fatigue resistance in a clinically simulated study based in a laboratory over a 3 year period. They found that the fatigue resistance of a 0.8mm thick cast chrome cobalt occlusal rest was adequate as a support for a MBRPD in their study.

Meining (1994) studied 32 patients wearing a total of 39 removable partial dentures without occlusal rests over a period of seventeen years. All the clasps and frames were cast in chrome cobalt, except two that had clasps

of gold wrought wire with an acrylic base. The partial denture comprised bounded saddles as well as distal free-end saddles. He found that none of these dentures caused any damage of any kind to the underlying soft tissue or alveolar bone. This is anecdotal evidence however; the recent findings by Dunham, Brudvik, Morris, Plummer, *et al,* (2006) also reported that support for a MBRPD came from the contact of the clasp assembly with the suprabulge area of the tooth rather than from the cast occlusal rest in the rest seat preparation. This may only offer some explanation for the Meining (1994) study.

Not all authors recommend that occlusal rest seats have to be prepared for all cases. Patterson (2002) in a pocket reference book of clinical dentistry states that tooth preparation is only required if the position of the rest will interfere with the occlusion. Implying that if there is no opposing tooth or if there is a space between the abutment tooth and the opposing tooth, then the need for a rest seat preparation does not exist.

2.11- Consequences of inadequately prepared rest seats

The consequences inadequately prepared rest seats can be grouped into three main categories. Firstly, placing the cast occlusal rests on surfaces unprepared or inadequately prepared to receive them can result in the cast rest not restoring the topography of the tooth thus becoming a conduit

for accumulating plaque. Secondly, it can interfere with the occlusion, creating discomfort for the patient that could lead to grinding of the opposing tooth or the occlusal rest, thus weakening the cast rest and making it prone to fracture. Thirdly, a rest not located in a positive rest seat can transmit non-axial forces on the tooth because of the slippage effect of inclined planes resulting in the abutment tooth being displaced from the cast rest when a load is applied to the denture (Dykema, Cunningham and Johnston, 1969; Zarb, Bergman, Clayton and MacKay, 1978; Stratton and Wiebelt, 1988; McGiveney and Carr, 1999; Rudd, Bange, Rudd and Montalvo, 1999; Phoenix, Cagna and DeFreest, 2003).

Chapter 3 – Aims and Objectives

3.1- Aim

1. To compare occlusal rest seat preparations for metal-based removable partial dentures (MBRPD) prepared by dental students at the UWC Oral Health Centres, to the corresponding cast metal rests.

2. To determine action taken in response to discovered discrepancies between the rest seat preparation depth and the cast metal occlusal rest thickness.

The research questions to be answered include:

1. Do dental students prepare occlusal rest seats according to the guidelines recommended in the literature?
2. What is their response in the event of an inadequately prepared rest seat?

3.2- Objectives

The objectives of the study are to:

1. Compare the bucco-lingual (B-L) width of the rest seat preparation to the recommended one third B-L width of the tooth

2. Compare the mesio-distal (M-D) length of the rest seat preparation to the recommended one third M-D length of the tooth
3. Compare the depth of the rest seat preparation to the recommended minimum depth of 1mm.
4. Compare the rest seat depth with the actual thickness of the cast metal rest.
5. Measure the cast metal rest before and after the metal try-in.
6. Record, by means of a questionnaire, how discrepancies (if any) between the preparation and the casting are managed.

Chapter 4 – Materials and Method

4.1- Study Design

This is a descriptive study assessing rest seat preparations for MBRPD by undergraduate dental students after being exposed to a pre-clinical techniques course in Removable Partial Denture Construction in the fourth academic year of study.

4.2- Study Sample and Inclusion Criteria

1. All MBRPDs constructed at the Mitchells Plain and Tygerberg Oral Health Centres of the Dental Faculty of the University of the Western Cape during March and April 2007 by undergraduate students in their fourth year of study.
2. All students involved in this study would have attended a pre-clinical techniques course in removable partial denture construction.

4.3- Exclusion Criteria

Acrylic based partial dentures.

4.4- Methodology

Stone models at the metal try-in stage in the construction of the MBRPD were examined for the depth, width and length of the occlusal rest seat preparations. All models were poured in “Fuji Rock” (G C Belgium)

The corresponding metal framework was assessed for the thickness of the cast metal rests.

The models were surveyed (surveyor: Dentalfarm Italy) for the maximum bucco-lingual (B-L) width of the tooth (Fig. 4.1)

Figure 4.1: Model on dental surveyor - Dentalfarm Italy

The bucco-lingual width was measured from the maximum convexity of the tooth as identified by the dental surveyor (Fig. 4.2). The mesio-distal (M-D) length of the tooth was measured from the middle of the marginal ridge to mid-point of the opposing marginal ridge. The rest seat preparation was outlined in pencil (Fig. 4.3) and all measurements were made with a customised Digital Caliper (Mititayo, Japan) (Fig. 4.4, and 4.5), under magnification of 1.5X (optivisor: Donegan Optical USA) (Fig. 4.6 and 4.7), by a pre-calibrated observer. Intra-examiner calibration was achieved by repeating the measurements of 20 percent (13) of rest seat preparations. Each rest seat preparation used for the calibration purpose was examined twice, 24 hours apart. Intra-examiner reliability was greater than 90% to the nearest 0.05mm between the measurements.

Figure 4.2: Bucco-lingual width of the tooth measured with a digital calliper.

Figure 4.3: Rest seat on distal of 15

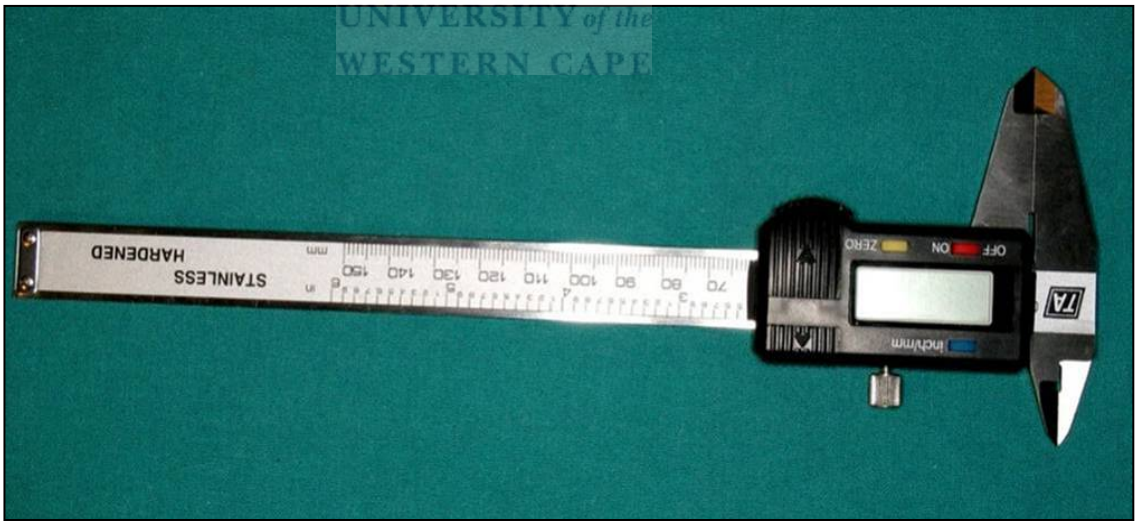
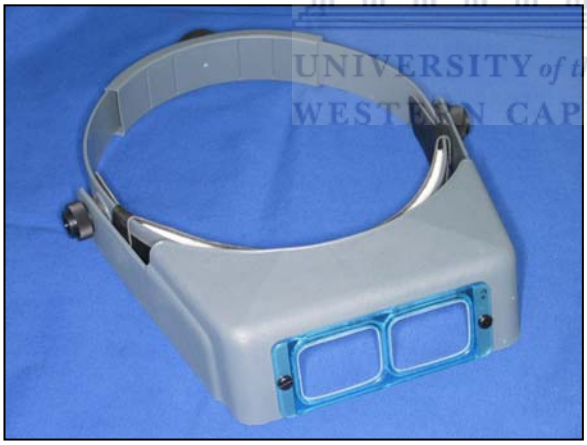


Figure 4.4: Digital Calliper (Mititayo, Japan)

Figure 4.5 Bucco-lingual width of the rest seat preparation being measured



Figures 4.6 and 4.7: Optivisor with a 1.5 magnification factor (Donegan Optical USA)

Measuring the depth of the rest seat preparation on the model was a challenge. The study by Jones, Goodacre, Brown, Munoz, *et al,* (1992) failed to mention how the rest seat preparations were measured. Culwick, Howell and Faigenblum (2000) used a laser profilometer that was capable of non-contact measurement of small height differences over a large vertical and horizontal range, to measure the depth of the rest seat preparations. For this study, not having access to a laser profilometer, the digital calliper was customised. The depth measuring end of the digital calliper was machined to a fine point so that the rest seat depth could be measured with accuracy. The fine point was placed in the deepest part of the rest seat preparation; and the adjacent flat edge contacted the occlusal surface of the tooth, closest to the rest seat preparation, towards the centre. The instrument was held perpendicular to the occlusal plane to overcome the effect of the tilt of the instrument. The measurements were repeated ten times on a single specimen to verify reproducibility of the method.

Figures 4.8 and to 4.9 show the end that was modified to measure the depth of the rest seat preparation and figure 4.11 shows the electronic reading accurate to a 100th of a millimetre.

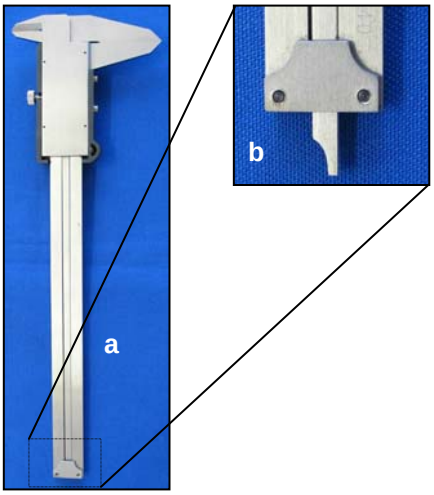


Figure 4.8 (a and b): Depth measuring end of digital calliper.

Figure 4.9: Customised part of the digital calliper

Figure 4.10: Electronic reading in 100th of a mm

The thickness of the cast metal rest of the MBRPD was measured using the digital calliper in the conventional way.

The measurements were recorded on a data collection sheet (Appendix I).

A questionnaire was issued to the students which had to be completed at the try-in and delivery stages of the construction of the MBRPD recording any modifications that were necessary to the cast occlusal rests of the MBRPD and/or the opposing tooth prior to the patient receiving the prosthesis. (Appendix II)

A pilot study was used to evaluate the methodology. This was presented at the International Association of Dental Research South Africa (IADR-SA) Conference in September 2006 in Pretoria. (Appendix III)

Chapter 5 – Results

5.1- Occlusal Rest Seat Preparations and Cast Metal Rests

The results are summarised in table 5.1 below. The raw data sheets are attached as appendix V

Table 5.1 Summary of the results

Descriptive Statistics	Mean	Range	Significance P value
B-L Rest Seat Prep	2.55 sd~0.53	1.53 – 4.00	p<0.05
1/3 B-L Tooth Width	3.09 sd~0.47	2.30 – 4.19	
M-D Rest Seat Prep	2.86 sd~0.64	1.85–4.16	p<0.05
1/3 M-D Tooth Length	2.44 sd~0.64	1.47 – 5.20	
Rest Seat Depth	0.85 sd~0.33	0.25 – 1.63	p<0.05
Recommended Depth	1.00	1.00	
Rest Seat Depth	0.85 sd~0.33	0.25 – 1.63	p<0.05
Cast Metal Rest thickness	1.10 sd~0.31	0.54 – 1.89	
Cast Metal Rest thickness	1.10 sd~0.31	0.54 – 1.89	p<0.05
Recommended Thickness	1.00	1.00	

- The mean bucco-lingual width of the occlusal rest seat preparations was less than the recommended mean one third bucco-lingual width of the teeth.
- The mean mesio-distal length of the rest seat preparations was more than the recommended mean one third mesio-distal lengths of the teeth.
- .The mean depth of the occlusal rest seat preparations was less than the minimum recommended depth of 1mm.
- The mean thickness of the cast metal rest was thicker than the mean depth of the rest seats that were prepared to receive them.
- The thickness of the cast metal rests ranged from 0.54mm to 1.89mm.

All these differences were statistically significant at a p value of less than 0.05.

5.1.1- Bucco-lingual Width of the rest seat preparations

When comparing the bucco-lingual width of the rest seat preparations with the recommended one third bucco-lingual width of the tooth a large discrepancy is evident and can be seen in figure 5.1.

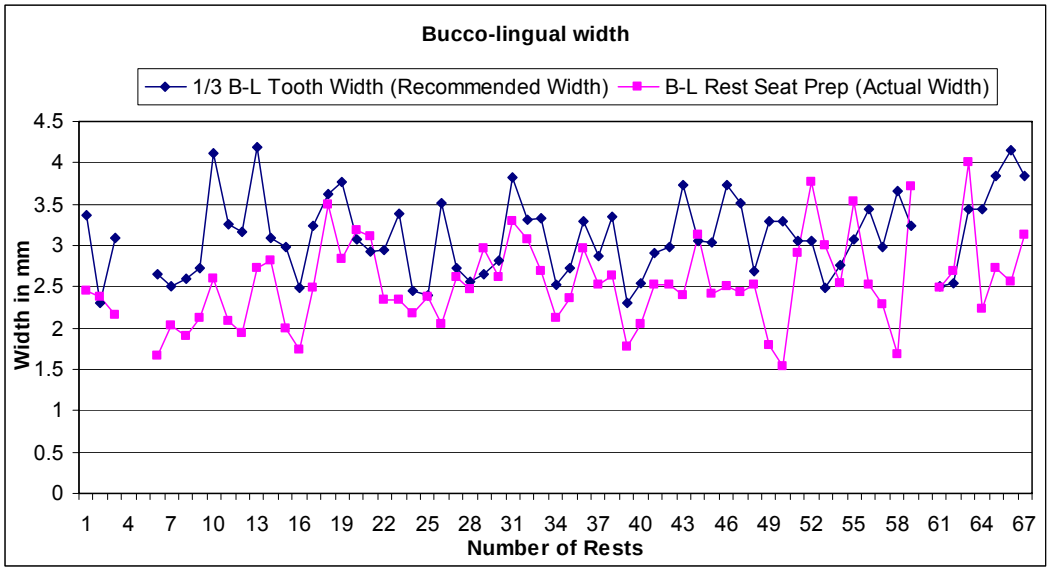


Figure 5.1: Plot of the bucco-lingual width of the rest seat preparation (actual) and one third the bucco-lingual width of the tooth (recommended).

In eighty one percent or fifty four out of the 67 cases, the width of the rest seat preparation was less than the recommended one third bucco-lingual width of the tooth (Fig. 5.2). Fifteen percent or ten of the rest seat preparations were equal to or greater than the recommended one third bucco-lingual width of the teeth There were no rest seat preparations for three of the cast metal rests.

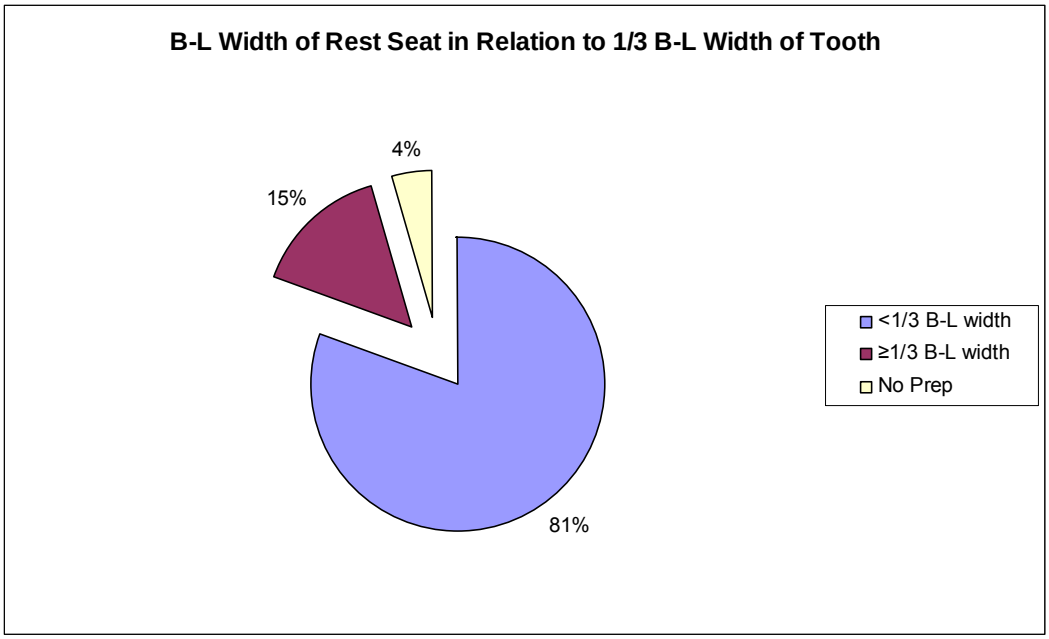


Figure 5.2: Pie chart of rest seat preparations in relation to the recommended one third bucco-lingual width of the tooth

If these results are plotted on a scatter graph (Fig. 5.3), the extent of the discrepancy between the bucco-lingual width of the rest seat preparation and the minimum recommended, one third the bucco-lingual width of the tooth, can be seen by the large number (81%) of plottings below the diagonal line.

The diagonal line in the graph is the ideal relationship between width of the tooth in a bucco-lingual direction (horizontal axis) and the width of the rest in a bucco-lingual direction (vertical axis).

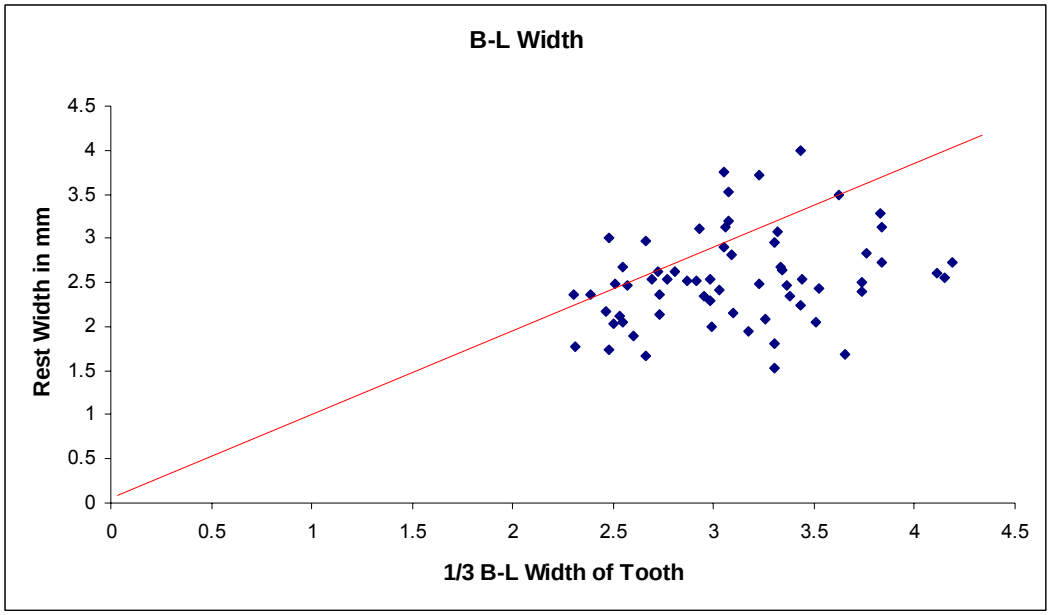


Figure 5.3: Scatter graph illustrating the relationship of bucco-lingual width of the rest seat preparation and one third bucco-lingual width of the tooth.

However, if the 2.0 to 2.5mm rest width recommendation of Dykema, Cunningham and Johnston (1969); McGiveney and Carr (1999); and Zarb, Bergman, Clayton and MacKay (1978) is considered, then the majority (84%) of the rest seats are within an acceptable range as regards the width of the rest seat preparation (Fig. 5.4). However, this recommendation does not take into account the size differences between different teeth such as premolars and molars nor does it consider the differences in tooth size of different individuals.

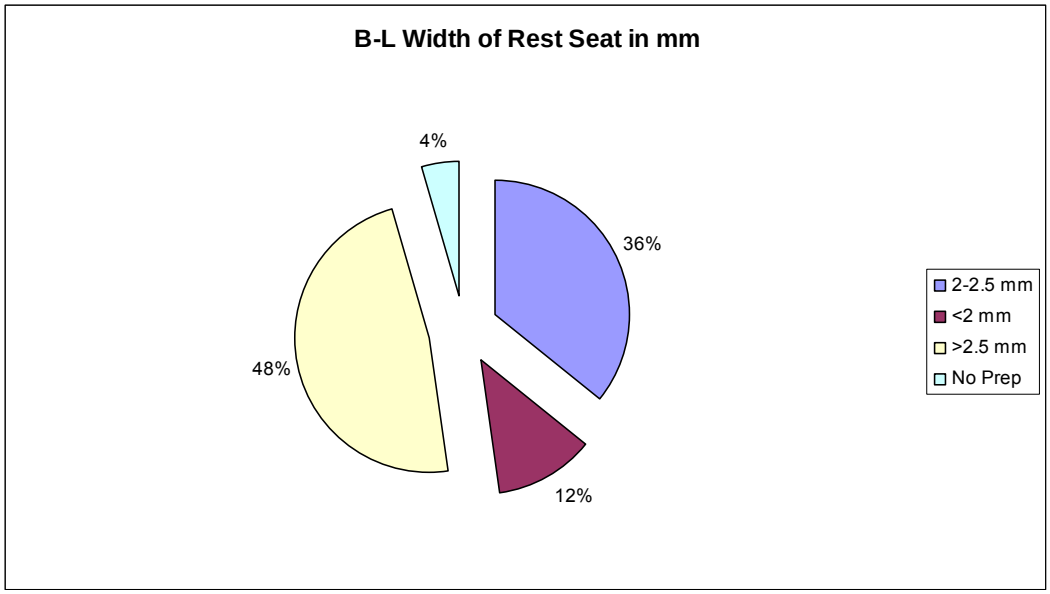


Figure 5.4: Bucco-lingual width of the rest seat preparations in millimetres

5.1.2- Mesio-distal length of rest seat preparations

Although the mean mesio-distal length of the rest seat preparations was more than the recommended mean one third mesio-distal lengths of the teeth as summarised in table 5.1; seventy two percent of the mesio-distal rest seat preparations were much less than the recommended one third mesio-distal length of the tooth (Fig. 5.5). The mean was influenced by the excessively long mesio-distal rest preparations in three of the cases (encircled in Fig. 5.6). Only twenty four percent or sixteen of the rest seat preparations were one third or more than the recommended one third mesio-distal length of the tooth, with forty eight deviating from the recommended length (Fig. 5.6). There were no rest seat preparations for three of the cast metal rests.

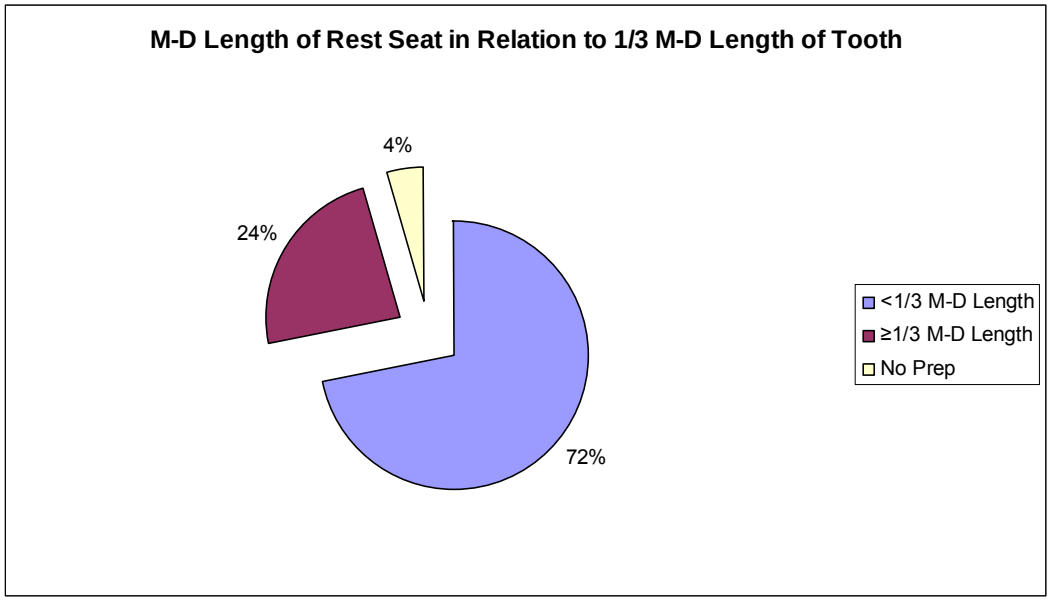


Figure 5.5: The mesio-distal length of rest seat preparations in relation to one third the mesio-distal length of the tooth

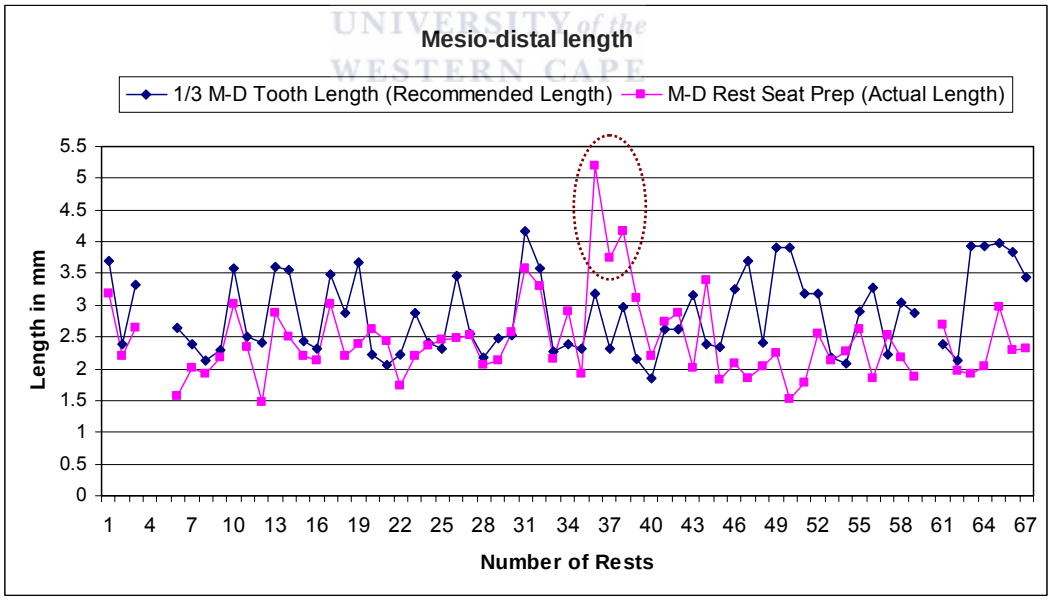


Figure 5.6: Plot of the mesio-distal length of the rest seat preparation (actual) and one third mesio-distal length of the tooth (recommended).

The scatter plotting reveals the extent of the under preparation of the mesio-distal dimension of the rest seat as regards length in terms of the recommended minimum one third mesio-distal length of the tooth (Fig. 5.7). However, in shorter teeth (mesio-distally) the preparations came closer to the ideal and this is evident by the clumping together of the readings towards the left of the chart. The shorter teeth would be the premolars.

The diagonal line in the scatter plot represents the ideal length of the rest seat preparation relative to the length of the tooth based on the recommendation in the literature.

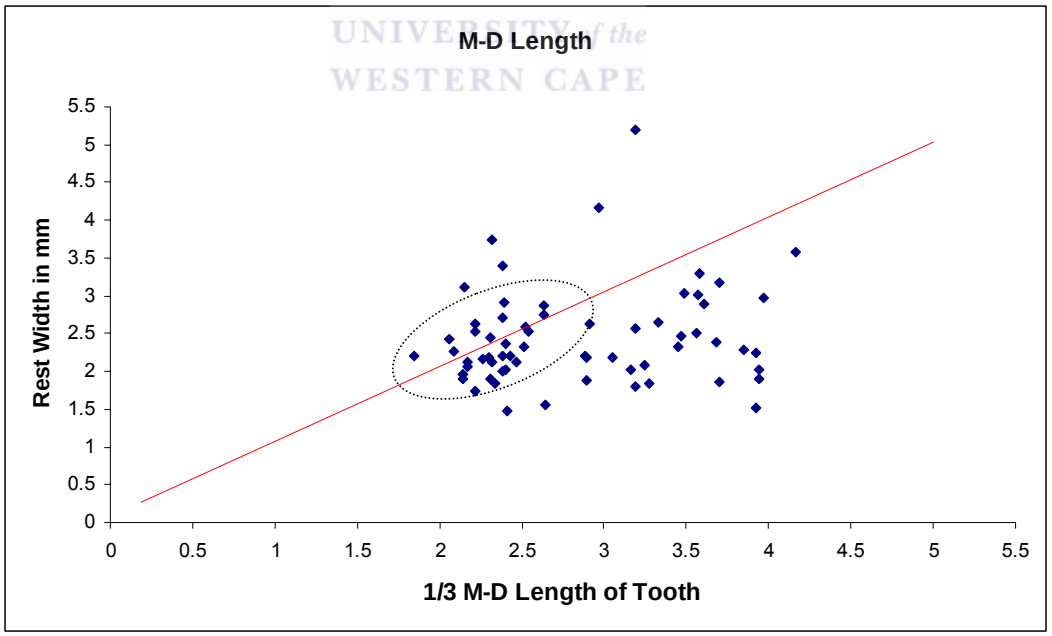


Figure 5.7: Scatter graph illustrating relationship of mesio-distal length of the rest seat preparation to one third mesio-distal length of the tooth.

If the guidelines of 2.5mm or more for the mesio-distal length of the rest seat preparation are used (Dykema, Cunningham and Johnston, 1969; McGiveney and Carr, 1999; and Zarb, Bergman, Clayton and MacKay, 1978), then the lengths of 36% of the rest seat preparations were acceptable (Fig. 5.8). This is in contrast to the one third mesiodistal length of the tooth guideline, where only 24% of the rest seat preparations were acceptable.

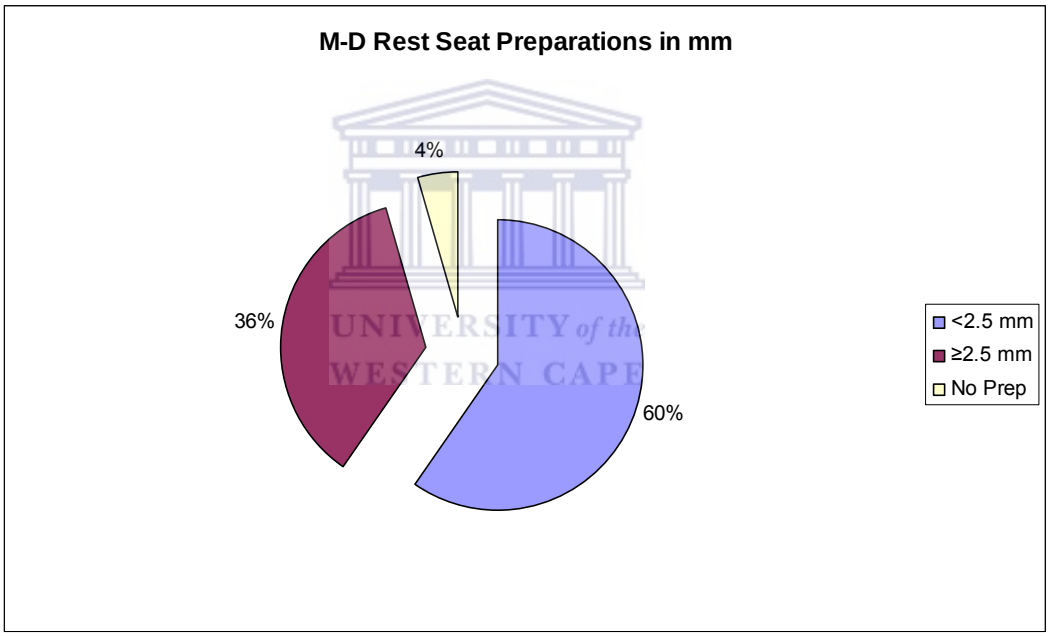


Figure 5.8: The mesio-distal length of rest seat preparations in millimetres

5.1.3- Rest Seat Depth and Metal Rest Thickness

Sixty six percent or forty four out of sixty seven of the rest seat preparations had less than the recommended 1mm depth (Fig. 5.9).

However, only thirty percent (20) rest seat preparations had a depth of equal to or greater than 1mm. Three cast metal rests had no corresponding rest seat preparation.

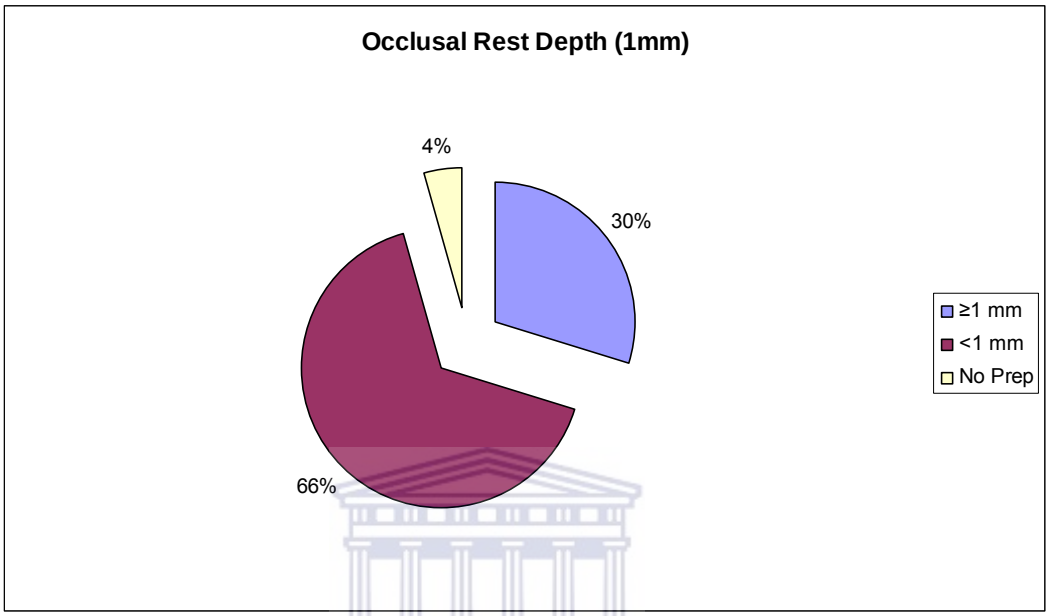


Figure 5.9: Occlusal rest depth

Although forty four (66%) rest seat preparations out of sixty seven were less than the recommended 1mm, only twenty six (39%) corresponding cast metal rests were less than 1mm thick (Fig. 5.10).

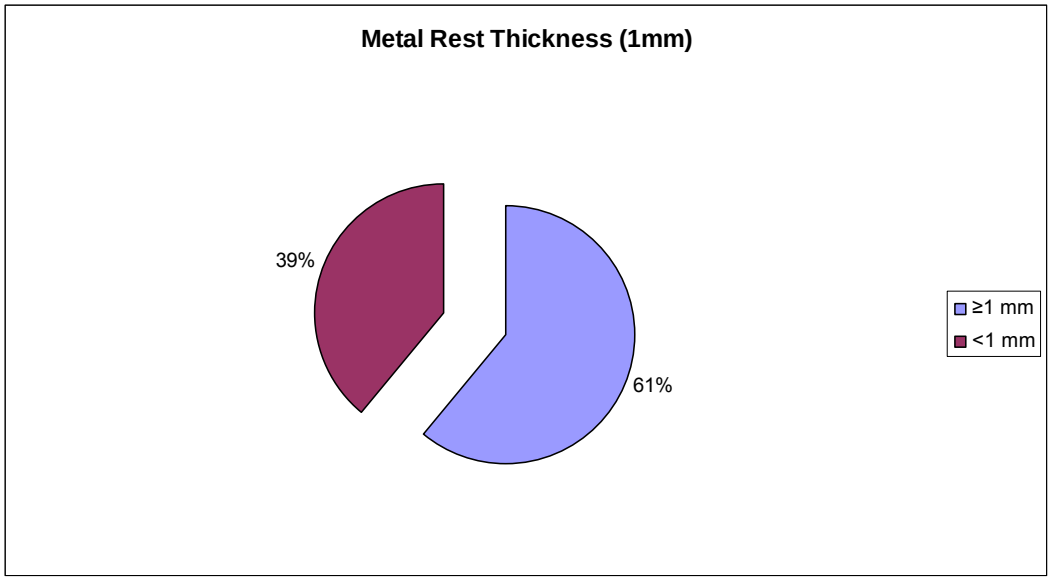


Figure 5.10: Metal rest thickness

Figure 5.11 shows the depth of each rest seat preparation with its corresponding cast metal rest thickness. It can be seen from this graph that the metal thickness of each rest was more than the corresponding depth of the rest seat preparation in 79% of the cases.

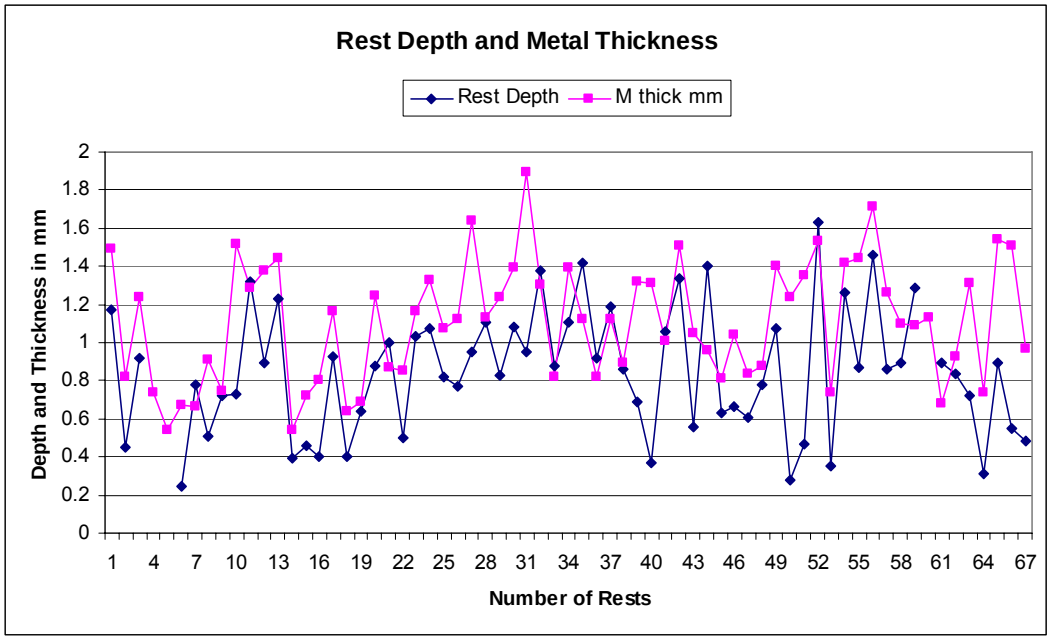


Figure 5.11: Rest seat depths with corresponding metal rest thickness

The scatter graph (Fig. 5.12) is a relationship between the thickness of the cast metal rests and the depth of the rest seats prepared to receive them. The diagonal line represents the ideal situation where the depth of the rest seat preparation corresponds perfectly with the thickness of the cast metal rest. However, as is evident in figure 5.11, 53 out of 67 or 79% of the cast rests are above the diagonal line implying a greater thickness of the cast metal rests as compared to the depth of the corresponding rest seat preparations. In three of the cases, where no rest seats were prepared, cast metal rests were present on the metal framework of the MBRPD.

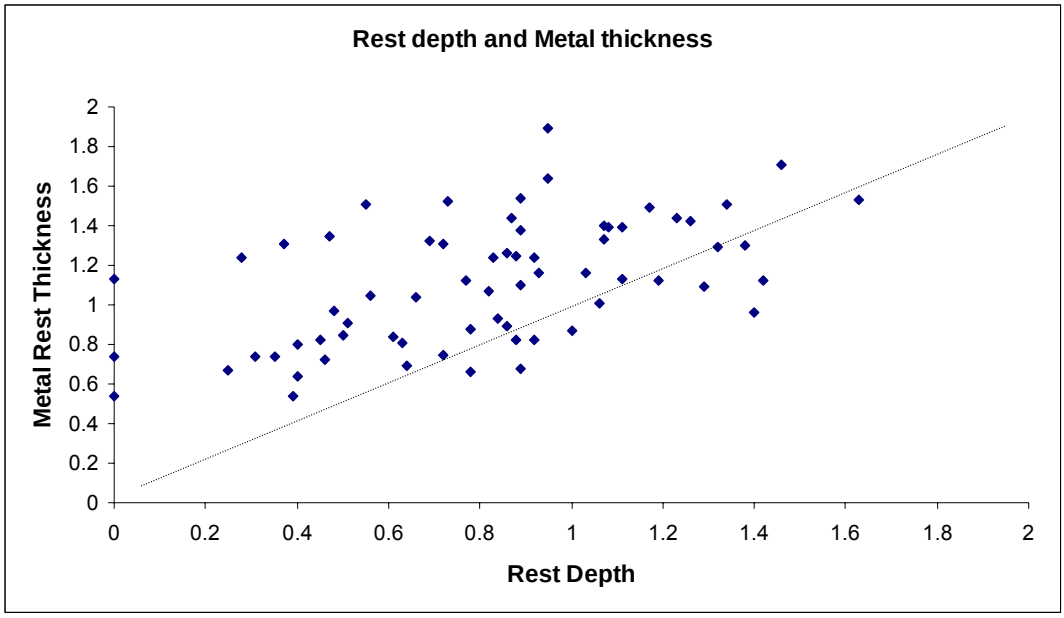


Figure 5.12: Rest seat depth and metal rest thickness

5.2- Shape of the Rest

Only 23.9% of the rest seat preparations had an ideal triangular shape. The remainder were irregularly shaped (Table 5.2).

Table 5.2: Rest shape

Rest shape	Number	Percentage
Triangular	16	23.9
Irregular	48	71.7
No Rest	3	4.5

Fifteen of the rest seat preparations were supervised by specialists and the remainder were supervised by full-time and part-time general dentists employed by the faculty (Table 5.3) (Fig. 5.13).

Table 5.3: Supervisor

Supervisor	Number	Percentage
Specialist FT	15	22.4
Generalist PT	25+2*	40.3
Generalist FT	24+1*	37.3

* 3 cast metal rests had no corresponding rest seats preparations.

When the rest shape and supervisor were cross tabulated (Table 5.4), it was found that of the triangularly shaped rest seat preparations,10 out of the 16 rest seat preparations were supervised by full-time specialists (Fig. 5.13).

Table 5.4: Supervisor * Rest shape Crosstabulation

Supervisor	Rest shape	
	Triangular	Irregular
Specialist FT	10	5
Generalist PT	2	23
Generalist FT	4	20

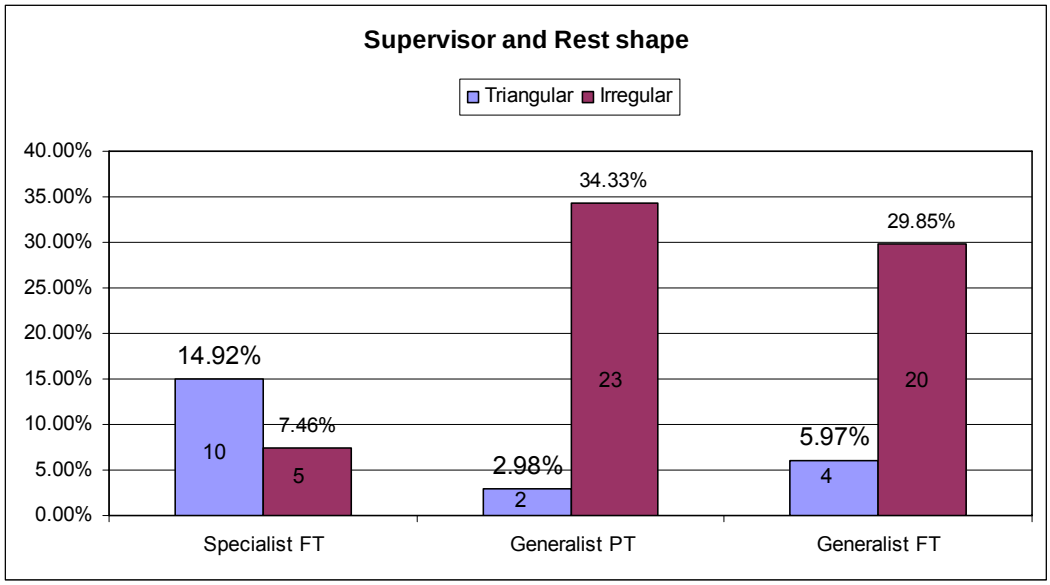


Figure 5.13: Supervisor and rest shape

5.3- Management of Over-bulked Metal Rests

From the results (Table 5.1) and the plottings above the diagonal line in figure 5.12, it is evident that seventy nine percent (53) cast metal rests were over bulked in the laboratory and did not exactly replace the topography of the abutment tooth. The students were requested to complete a form to record how they managed this discrepancy. The results are tabulated in tables 5.5 and 5.6.

Table 5.5: Situation opposing the abutment teeth with over-bulked cast metal rests

Opposing surfaces to over-bulked cast metal rests	Number of cast metal rests	Percent
Denture tooth	27+3*	56.6
Natural tooth	21	39.6
Edentulous space	2	3.8

* 3 cast metal rests had no corresponding rest seats preparations.

Of the fifty three abutment teeth with over-bulked cast metal rests; twenty one had opposing natural teeth, thirty had an opposing denture while two had opposing edentulous areas (Table 5.5).

Table 5.6: Over-bulked cast metal rests opposing natural teeth

Adjustment	Number	Percent
Metal Rest Adjusted	15	71.4
Natural Tooth Adjusted	4	19.1
Both Adjusted	2	9.5

Of the twenty one over-bulked cast metal rests that were opposing natural teeth; fifteen cast metal rests were adjusted, four opposing teeth were adjusted and in two cases both the opposing teeth and cast metal rests were adjusted (Table 5.6). Of the fifteen cast metal rests that were

adjusted, two were completely removed. These are depicted on figure 5.14 as two plots circled on the x axis. None of the cast metal rests opposing dentures or edentulous spaces were ground.

The resultant action of the students can clearly be seen in the scatter graph of the depth of rest seat preparations against thickness of the cast metal rests in figure 5.14. The plottings are closer to the diagonal line representing the ideal relationship between the depth of the rest seats and the metal thickness of the cast metal rests as compared to the plottings in figure 5.12.

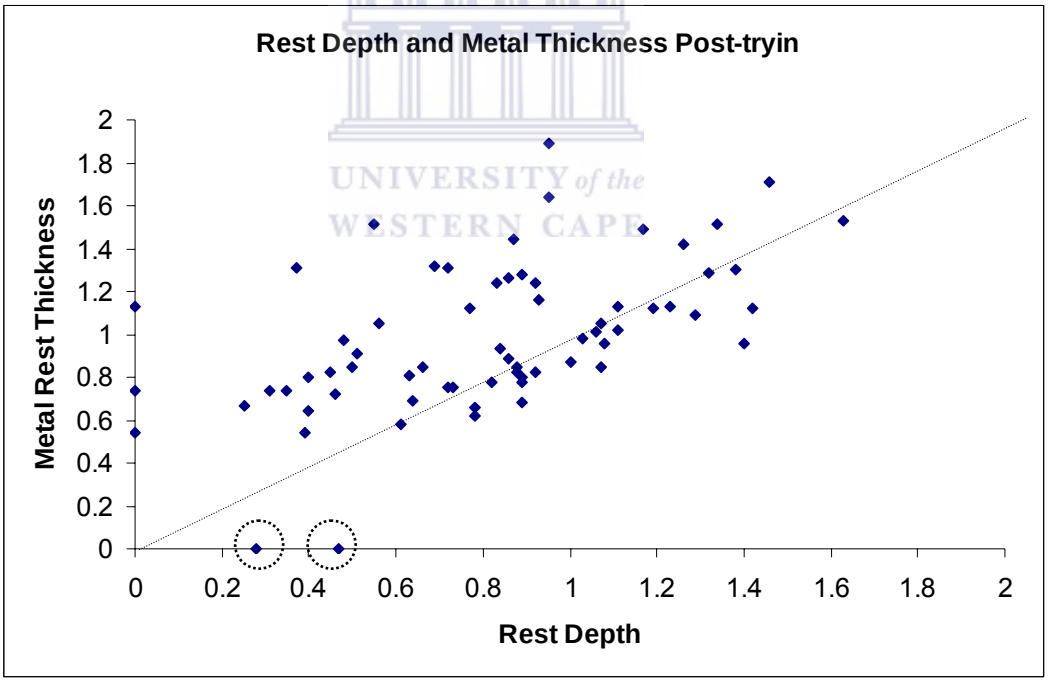


Figure 5.14: Rest seat depth and metal rest thickness recorded after try-in

Chapter 6 – Discussion

6.1- Introduction

A large number of patients attending the Oral health Centres at the Mitchells Plain and Tygerberg campuses of the University of the Western Cape are partially edentulous. These patients are attended to by the students, under supervision, for all their basic oral health care needs and eventually restorations with either a fixed or removable partial prosthesis.

Undergraduate dental students attend a preclinical Removable Partial Denture Block Course in their fourth year studying. Within this aforementioned course, the students acquire skills in design, preparing the mouth for and manufacturing of partial dentures prior to consulting patients requiring a removable partial denture.

The recommended guidelines at the Dental Faculty of the University of the Western Cape are that the width of the occlusal rest seat preparation should be one third the bucco-lingual width of the tooth; the mesio-distal length of the rest seat preparation should be at least one third to one half the mesio-distal length of the tooth; and the depth should be at least one to one and a half millimetres deep. Most of the rest seat preparations that were evaluated in this study were under prepared in terms of width, length and depth. The majority of the metal rests that were cast to be seated in

these rest seat preparations were thicker than the available space that was created for them.

6.2- Bucco-lingual Width of the Rest Seat Preparations

Eighty one percent of the rest seat preparations were narrower than the expected one third bucco-lingual width of the teeth (Fig. 5.2) as recommended by Stratton and Wiebelt (1988), and Phoenix Cagna and DeFreest (2003). However, when considering the recommendation of Dykema, Cunningham and Johnston (1969), that the occlusal rest seat preparation should be 2.0mm wide; the width was acceptable as it ranged from 1.53mm to 4.0mm with 84% being equal to or greater than the minimum 2.0mm width recommended by Dykema, Cunningham and Johnston (1969) (Fig. 5.4).

6.3- Mesio-distal Length of the Rest Seat Preparations

The mesio-distal length of the rest seat preparations was shorter than the minimum one third mesio-distal width of the tooth in seventy two percent (forty eight) of the cases (Fig. 5.5). However, when the minimum 2.5mm length recommended by McGiveney and Carr (1999); and Zarb, Bergman, Clayton and MacKay (1978) is applied, then 36% (twenty four) of the rest seats prepared were equal to or more than 2.5mm recommended (Fig.

5.8). This is an improvement on the one third mesio-distal length of the tooth criteria, but the majority (60% or forty) were still short of the recommended 2.5 mm mesio-distal length (Fig. 5.8).

This was unlike the bucco-lingual width of the rest preparation where the majority of the rest seat preparation (fifty four or eighty one percent - Fig. 5.2) had a width that was unacceptable in terms of the proportion criteria namely, one third bucco-lingual tooth width; but had a width that was acceptable when the minimum 2.0mm criteria was applied.

In teeth with a shorter mesio-distal length, the mesio-distal length of the rest seat preparation was closer to the recommended minimum one third mesio-distal length of the tooth compared to teeth with a longer mesio-distal length (encircled in Fig. 5.7).The short rest seat preparations in the mesiodistal dimension that the students prepared would result in the production of a short cast metal rest. This would be adequate for teeth with a smaller mesio-distal dimension, such as the premolars. The second maxillary premolars and mandibular premolars with their single roots are more likely to be cone-shaped, and according to Osborne and Lammie's (1974) concept of comparing the tooth to a cone, these teeth will be least subjected to torquing forces when the tooth, with a short cast metal rest, is loaded.

However, in teeth with a longer mesio-distal length, as in molars, the

discrepancy between the minimum recommended length and the actual length was greater than in the teeth with the shorter mesio-distal lengths. This may have been due to being over-conservative or a lack of confidence to prepare adequately long rests that are needed, for molar teeth. The Osborne and Lammie's (1974) cone analogy implies that a short metal rest on a relatively longer tooth (mesio-distally) would produce more torquing forces when loaded. However, as molar teeth are not cone shaped with their double and triple root systems, the effect of the force transmitted to them via a relatively short cast metal occlusal rest is unknown.

6.4- Rest Seat Depth and Cast Metal Rest Thickness

The majority (66%) or forty four of the rest seat preparations were shallower than the minimum 1mm recommended depth (Fig. 5.9). While the majority (61%) or forty one of metal rests for these rest seat preparations were 1mm or thicker (Fig. 5.10 and Fig. 5.11). This suggests that the technicians over bulked the cast metal rests.

On analysis of the scatter graph in detail in figure 6.1, it is evident that 75% or 50 out of 67 of the cast metal rests were thicker than the rest seat preparations available. This suggests that the technicians over bulked the cast metal rests. In addition, three cast metal rests had no corresponding rest seats prepared (encircled in red along the y axis). The over-bulking of the cast metal rest is represented by all the points above the diagonal line

in the scatter graph. These cast metal rests would sit proud on the surface of the tooth and could interfere with the occlusion in the presence of an opposing dentition. The 19% or 13 out of 67 cast metal rests that are under the diagonal line are those metal rests that were not as thick as the space provided for them. These would not have optimally restored the topography of the tooth. Here the technicians most likely cast thinner rests, or adjusted it to fit into occlusion against the opposing dentition. A possible explanation maybe that the technicians are taught to cast rests to a minimum of 1mm thickness, irrespective of the depth of rest seat preparation and this may explain the broad band of rests (39% or 26 out of 67) that lie between the thickness of 0.8 and 1.2 mm. If all the cast metal rests were made to fit the rest seat preparations, then all the points would be scattered around the diagonal line on the scatter graph.

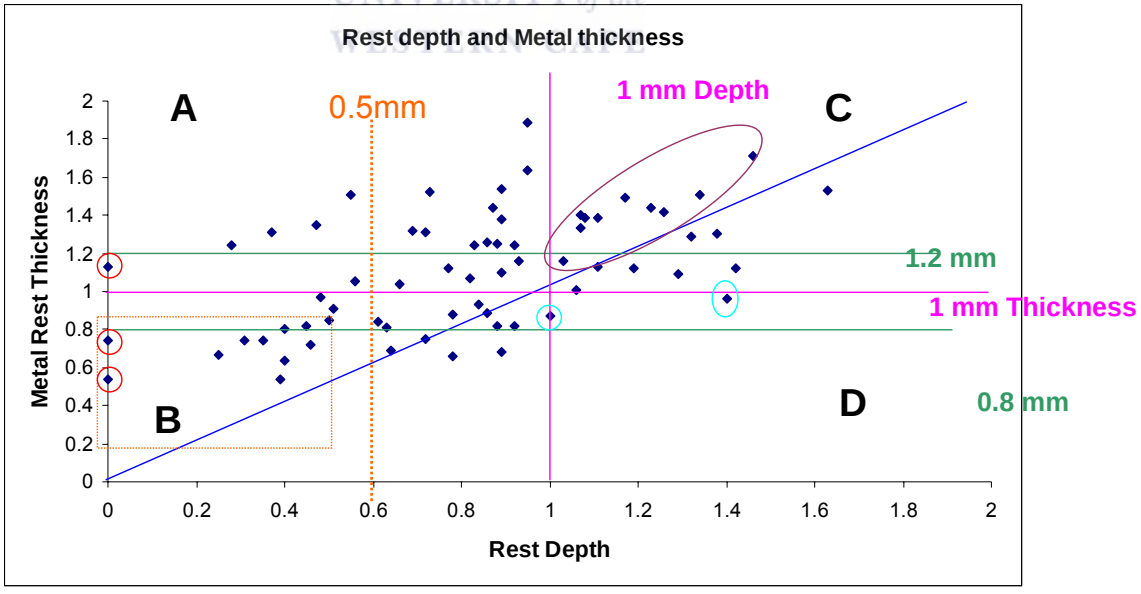


Figure 6.1: Scatter graph of Rest depth and metal thickness with lines drawn on the 1mm rest seat depth and 1mm metal thickness

This graph (Fig. 6.1) can be analysed further, if lines are placed at the minimum depth of 1mm of rest seat preparations and at the minimum metal thickness of 1mm, the graph is divided into four quadrants, that are labelled A, B, C and D.

Quadrant A represents the 22 rest seat preparations out of 67 that were less than 1mm in depth and the corresponding cast metal rests were thicker than 1mm. The technicians overcompensated by making the cast metal rests at least 1mm, or more, in thickness, as they would have been trained to do so in a technical manner to make cast metal rests at least 1 mm thick in the same group, there is a metal rest, circled in red on figure 6.1 (and two in category B) where a metal rest was cast even though no rest seat was prepared, but a rest seat was included in the design. It must be stressed that placing metal rests on unprepared teeth is not the teaching policy at the dental faculty. However, there are some part-time supervisors that could have accepted the final impression based on the opinion that if there is no opposing tooth, a rest seat preparation in the abutment tooth is not necessary (Patterson, 2002).

Quadrant B represents the 22 occlusal rest seat preparations out of 44 that were under prepared. The thickness of the cast metal rests fabricated by the technicians for these rest seat preparations was less than the recommended minimum of 1mm. The four cast metal rests below the diagonal line in this category would not restore the topography of the

tooth, while the 15 above the diagonal line would sit proud of the occlusal rest seat preparation and yet be less than the minimum thickness of 1 mm. The three on the diagonal line would have restored the topography of the tooth optimally. The reluctance of the students to prepare abutment teeth to the full extent of the recommendation could be partly explained by the sensitivity the patient may have experienced during preparation or to the fear of exposing dentine in the abutment tooth (Jones, Goodacre, Brown, Munoz, *et al,* 1992). None of the cast metal rests were less than 0.5 mm in thickness, although, twelve of the rest seat preparations in this quadrant and in quadrant A were 0.5mm or less in depth This is understandable, as technicians would find it difficult, technically to cast an occlusal rest that would be less than 0.5mm in thickness. It is these rest seat preparations and cast metal rests that lie within this orange rectangle that would pose a major problem in the clinic, particularly in the presence of opposing teeth.

The options for a cast metal rest that interferes with the occlusion include grinding the rest, grinding the opposing tooth or both. In this study; fifteen metal rests were ground, four opposing teeth were ground and in two cases both the teeth and cast metal rest were ground (Table 5.6). Grinding an already thin cast metal rest poses a danger of fracturing the rest, thereby compromising the support of the denture. Grinding the opposing tooth would result in unnecessary tooth destruction and may also suggest to the patient that the practitioner is trying to fit the denture to the mouth.

Quadrant C represents the 18 out of 20 rest seat preparations and their corresponding cast metal rests that have an adequate depth of rest seat preparation and thickness of cast metal rest, respectively. All those cast metal rests above the diagonal line, can be adjusted into occlusion to restore the topography of the tooth without compromising the prognosis of the cast metal rest because there is sufficient bulk of metal available for adjustment. This is a favourable situation and is represented by the purple oval in the scatter plot (Fig. 6.1). However; all cast metal rests below the diagonal line will fall short of restoring the topography of the occlusal surface of the tooth as the thickness of the cast metal rest is less than the depth of the prepared occlusal rest seat.

Quadrant D represents those rests that had rest seat preparations that were greater than the recommended minimum depth of 1mm. In this group there are two cast metal rests (encircled in blue in Fig. 6.1) that are too thin for the corresponding rest seat preparation. The cast metal rest on the right is 0.5mm thinner than the available rest seat preparation. This poses a problem in that it could become an area for food impaction and plaque formation with resultant caries in the abutment tooth. The other cast metal rest on the left in this quadrant has a thickness of 0.9 mm that may be compatible with the 1mm depth of the rest seat preparation.

It is evident from this study and supported in the literature that occlusal rest seats are not being prepared as recommended especially as regards depth of rest seat preparation (Jones, Goodacre, Brown, Munoz, *et al,* 1992; Culwick, Howell and Faigenblum, 2000; Dunham, Brudvik, Morris, Plummer, *et al,* 2006). This begs the question as to what thickness of metal rest is needed for optimal results. Gapido, Kobayashi, Miyakawa and Kohno (2003) found that thicknesses of 0.8mm for chrome cobalt alloys was adequate in terms of fatigue resistance based on the earlier findings by Culwick, Howell and Faigenblum (2000) that found that general dental practitioners clinically prepared rest seats to an average depth of 0.78mm.

If 0.8mm is used as the minimum depth to which rest seats should be prepared, then the depth of 56% of the rest seats was acceptable (Fig. 6.2) and 82% of the metal rests were equal to or more than the 0.8mm thickness required for a rest to resist deformation (Fig. 6.3).

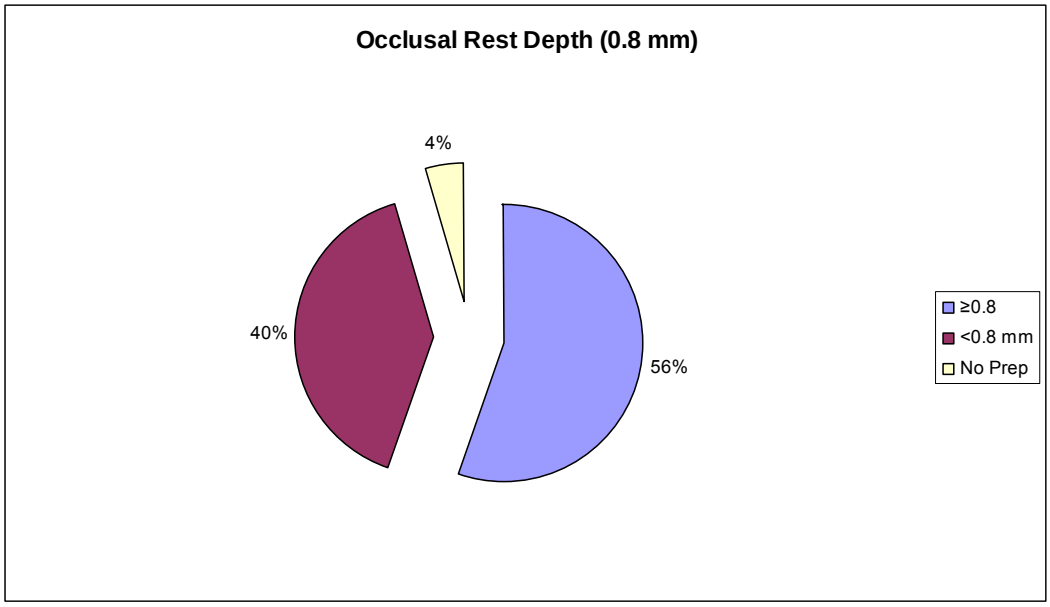


Figure 6.2: Occlusal rest depth at 0.8mm

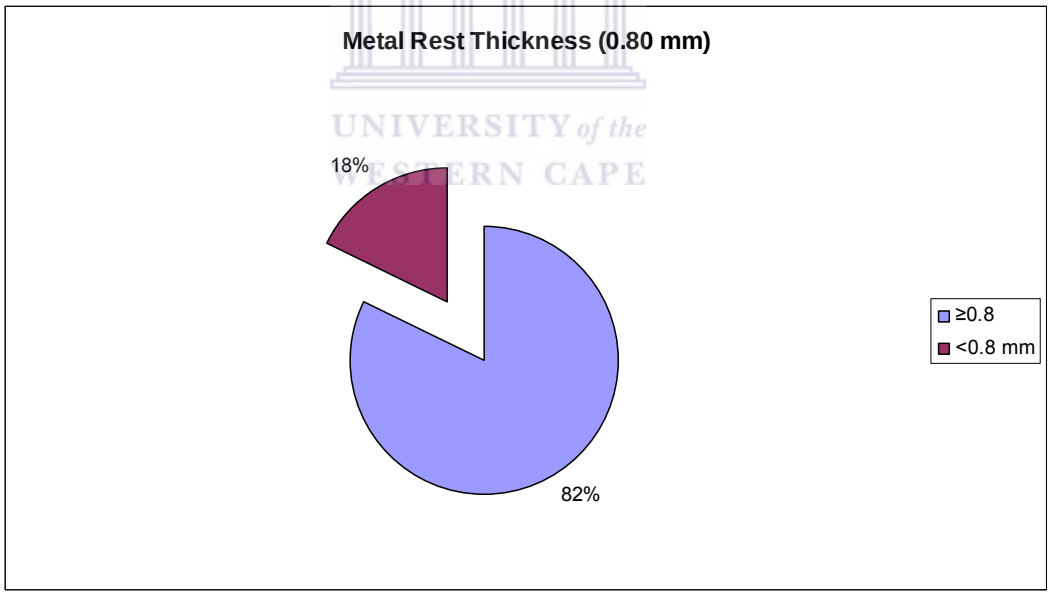


Figure 6.3: Metal rest thickness at 0.8mm

What needs to be investigated further is at what absolute minimum thickness a cast metal rest will function adequately without the risk of fracture? The thinnest cast metal rest that was recorded in this study measured 0.54mm. These MBRPD with the thin cast metal rests have been identified and will be followed-up clinically so as to determine if they can withstand the occlusal forces that they will be subjected to.

The recent findings by Dunham, Brudvik, Morris, Plummer, *et al,* (2006) suggest that in the case of a circumferential clasp assembly support for the partial denture is derived from the clasps resting on the suprabulge surface of the tooth, as well as the cast occlusal rest within the rest seat preparation. This report is bound to stimulate new ideas as regards support for metal-based removable partial dentures.

6.5- The Shape of the Occlusal Rest Seat

Seventy two percent (48) of the occlusal rest seat preparations were irregularly shaped (Table 5.2), with the majority (10) of those that were shaped as per recommendations having been supervised by specialists (Fig. 5.13). This finding is supported by the findings of Culwick, Howell and Faigenblum (2000), where academic teachers and postgraduate students prepared rest seats that were triangular in shape with a smooth contour blending into the surrounding tooth as opposed to general dental practitioners who created “round depressions indicative of a single application of a round bur placed on the marginal ridge”.

Chapter 7 – Conclusions and Recommendations

7.1- Conclusions

This study indicates that students tend to under-prepare rest seats to accommodate cast metal rests in terms of width, length and depth. However, when the minimum width and length guidelines of 2mm (Dykema, Cunningham and Johnston, 1969) and 2.5mm (McGiveney and Carr; 1999; Zarb, Bergman, Clayton and MacKay, 1978), respectively are considered, the preparations approached acceptable levels. The depth of the rest seat preparations was inadequate; however, the technicians produced MBRPD with over-bulked cast metal rests to compensate for the deficiency in the depth of the preparation.

The study of the literature revealed that there were two schools of thought regarding the bucco-lingual width and the mesiodistal length of the rest seat preparation. One favoured the proportional method while the other preferred specifying actual dimensions for the rest seat preparation. There is a need for some sort of consensus regarding the preparation guidelines for the width and length of the rest seat preparations.

Although there is a general consensus that there should be at least a 1mm reduction of the occlusal surface where the rest seat is to be located, this is rarely achieved clinically. This study supports the findings of others in that dental students do not necessarily prepare occlusal rest seats

according to the recommended guidelines especially as regards depth of preparation

Further work is required to determine the absolute minimum thickness an occlusal rest should be and this needs to be followed up by a clinical study on the effect of thin occlusal rests.

7.2- Recommendations

The conclusions of this study and the work done by Jones, Goodacre, Brown, Munoz, *et al,* 1992 and Culwick, Howell and Faigenblum (2000) confirm the findings that rest seat preparations are rarely prepared to the minimum recommended depth of 1mm. Secondly, the work done by Dunham, Brudvik, Morris, Plummer, *et al,* (2006) showed that support for a MBRPD is obtained from the position of the clasp arms lying against the supra bulge area of the tooth, rather than from the metal rest within the rest seat preparation. These factors imply that a re-think is needed on the design of metal-based removable partial dentures, especially as regards depth preparation for rest seats on abutment teeth.

There needs to be a paradigm shift in the way partial dentures are designed and this calls for experimentation with new designs that use the supra bulge surface of the abutment tooth for support of the MBRPD, rather than from the occlusal rests. Where occlusal rests need to be used, clinical studies are necessary to evaluate the efficacy of rest seat preparations that are less than 1mm in depth.

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Appendix I

Data Collection Sheet

Patient's Name/No. Student Technician

Supervisor

Specialist Generalist Full Time Part Time

Denture

F/P P/F P/P /P P/ Other

Kennedy Classification

Class	Mod	Other

Major Connector

Clasps

Tooth	Assembly Type	Comments

Rests

Occlusal	Cingulam	Embrasure	Other

Occlusal Rests

Tooth	*Opp. Dent N/E/D	**Bounded Saddle Y/N/Tooth	Shape of Rest	Depth of Rest	Thickness of Metel Rest	Thickness of Metel Rest Post Try-in	Adjustment of opposing tooth

Bucco-Lingual Dimensions

Tooth	B-L Tooth Width	B-L Rest Prep	B-L Rest %Tooth

Mesio-Distal Dimensions

Tooth	M-D Rest Prep	M-D Tooth	M-D Rest % M-D Tooth

* Opposing Dentition Natural, Edentulous, Denture

** Bounded Saddle Yes, No or Tooth

Appendix II

Questionnaire to be completed by students at the metal try-in and delivery stage of the MBRPD.

Student Patients name/no. Supervisor

Is the metal framework fitting? Yes/No

If not, what part is not fitting?

Is it fitting after adjustment? Yes/No

What adjustments were made?

Does the framework have to be re-made?

Was the Occlusal rest interfering with the occlusion? Yes/No

Which rest/s was/were high (corresponding tooth numbers)

For each rest adjusted please answer following

	Rest 1 (tooth no.)	Rest 2 (tooth no.)	Rest 3 (tooth no.)	Rest 4 (tooth no.)
Did you grind the: rest away				
Did you grind the: some of the rest				
Did you grind the: opposing tooth				
Did you grind: both rest and opposing tooth				

Appendix III

Abstract of study presented at the IADR-SA September 2006

Evaluation of Occlusal Rests of Metal-Based Removable Partial Dentures.

S. CASSIM, Y.I. OSMAN and V. WILSON, University of Western Cape, Cape Town, South Africa.

Occlusal rests provide vertical support for removable partial dentures (RPDs). RPDs without occlusal rests are "gum strippers" that adversely affect the gingival margins of teeth. **Objective:** To evaluate occlusal rest seats for metal-based removable partial dentures (MBRPD) prepared by dental students at the UWC Oral Health Centres. **Materials and methods:** Twenty stone models and the corresponding metal frameworks of MBRPD were examined for the depth, width and length of occlusal rest preparations and the metal thickness of the rests. Models were surveyed for the maximum bucco-lingual (B-L) width of the tooth. The mesio-distal (M-D) length was obtained from the marginal ridges of the tooth. Measurements were made with a modified Digital Caliper, under magnification of 1.5X, by a pre-calibrated observer. The B-L width and M-D length of the rest preparation was compared to the recommended one third B-L width and one third M-D length of the tooth, respectively. The depth of the rest preparation was compared to the minimum recommended depth (1mm) and the thickness of the metal rest. Data was analysed using a pair-wise comparison (Wilcoxon signed-rank test) at $p<0.05$. **Results:** The occlusal rest preparations (B-L width, M-D length and depth) were significantly different ($p<0.05$) from the recommended preparation dimensions. However, there was no significant difference between the minimum recommended thickness (1mm) and the actual metal rest thickness. **Conclusions:** Within the limitations of this study,

dental students tend to be conservative when preparing occlusal rests for MBRPD. However, the fabricated metal rests were thicker than the depth of the preparations, suggesting overcompensation by the technicians. Rests less than 1mm in thickness may fracture, resulting in a lack of support for the MBRPD.

Appendix IV- Statistical Analysis

Descriptives

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	Cases Used	All non-missing data are used.
Syntax		DESCRIPTIVES VARIABLES=RestDepth Mthickmm MThickPosttryin @13BLWidth BLRestPrep @13MDtooth MDRestprep /STATISTICS=MEAN STDDEV MIN MAX .
Resources	**Elapsed Time**	0:00:00.00

Descriptive Statistics

	N	Minimum	Maximum	Mean	Std. Deviation
Rest Depth	64	.25	1.63	.8461	.32995
M thick mm	67	.54	1.89	1.1078	.31289
M Thick Post-tryin	67	.00	1.89	.9878	.35074
1/3 B-L Width	64	2.30	4.19	3.1008	.47826
B-L Rest Prep	64	1.53	4.00	2.5423	.52730
1/3M-D length	64	1.47	5.20	2.4422	.64243
M-D Rest prep	64	1.85	4.16	2.8556	.63589
Valid N (listwise)	64				

Frequencies

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Resources	**Elapsed Time**	0:00:00.00
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Statistics

		Supervisor	Opposing	Rest shape	Opposing Tooth Ground	Metal Rest Ground
N	**Valid**	67	67	64	65	67
	Missing	0	0	3	2	0

Frequency Table

Supervisor

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	**Specialist FT**	15	22.4	22.4	22.4
	Generalist PT	27	40.3	40.3	62.7
	Generalist FT	25	37.3	37.3	100.0
	Total	67	100.0	100.0	

Opposing

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	**Denture**	38	56.7	56.7	56.7
	Tooth	27	40.3	40.3	97.0
	Edentulous	2	3.0	3.0	100.0
	Total	67	100.0	100.0	

Rest shape

		Frequency	Percent	Valid Percent	Cumulative Percent

Valid	**Triangular**	16	23.9	25.0	25.0
	Spherical	44	65.7	68.8	93.8
	Rectangular	4	6.0	6.3	100.0
	Total	64	95.5	100.0	
Missing	**System**	3	4.5		
Total		67	100.0		

Opposing Tooth Ground

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	**Yes**	6	9.0	9.2	9.2
	No	22	32.8	33.8	43.1
	Opposing Denture	37	55.2	56.9	100.0
	Total	65	97.0	100.0	
Missing	**System**	2	3.0		
Total		67	100.0		

Metal Rest Ground

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	**Yes**	17	25.4	25.4	25.4
	No	50	74.6	74.6	100.0
	Total	67	100.0	100.0	

Crosstabs

Notes

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	Cases Used	Statistics for each table are based on all the cases with valid data in the specified range(s) for all variables in each table.

Syntax		CROSSTABS /TABLES=Supervisor BY Restshape /FORMAT= AVALUE TABLES /CELLS= COUNT /COUNT ROUND CELL .
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	Cells Available	116508

Case Processing Summary

	Cases					
	Valid		Missing		Total	
	N	Percent	N	Percent	N	Percent
Supervisor * Rest shape	64	95.5%	3	4.5%	67	100.0%

Supervisor * Rest shape Crosstabulation
Count

		Rest shape			Total
		Triangular	Spherical	Rectangular	
Supervisor	**Specialist FT**	10	4	1	15
	Generalist PT	2	22	1	25
	Generalist FT	4	18	2	24
Total		16	44	4	64

NPar Tests

Notes

Output Created		03-JUL-2007 16:58:05
Comments		
Input	**Data**	E:\Dr Cassim Stats\Dr Cassim Stats\working dataDr cassim.sav
	Filter	<none>
	Weight	<none>
	Split File	<none>
	N of Rows in Working Data File	67
Missing Value Handling	**Definition of Missing**	User-defined missing values are treated as missing.
	Cases Used	Statistics for each test are based on all cases with valid data for the variable(s) used in that test.

Syntax		NPAR TEST /WILCOXON=@13BLWidth @13MDtooth RestDepth RestDepth Mthickmm WITH BLRestPrep MDRestprep Mthickmm R_R_D R_M_Th (PAIRED) /MISSING ANALYSIS.
Resources	**Elapsed Time**	0:00:00.00
	Number of Cases Allowed(a)	40329
a Based on availability of workspace memory.		

Wilcoxon Signed Ranks Test

Ranks

		N	Mean Rank	Sum of Ranks
B-L Rest Prep - 1/3 B-L Width	**Negative Ranks**	53(a)	35.36	1874.00
	Positive Ranks	11(b)	18.73	206.00
	Ties	0(c)		
	Total	64		
M-D Rest prep - 1/3M-D length	**Negative Ranks**	16(d)	28.75	460.00
	Positive Ranks	48(e)	33.75	1620.00
	Ties	0(f)		
	Total	64		
M thick mm - Rest Depth	**Negative Ranks**	13(g)	16.38	213.00
	Positive Ranks	51(h)	36.61	1867.00
	Ties	0(i)		
	Total	64		
Recom Rest Depth - Rest Depth	**Negative Ranks**	19(j)	26.89	511.00
	Positive Ranks	44(k)	34.20	1505.00
	Ties	1(l)		
	Total	64		
Recom Metal Thick - M thick mm	**Negative Ranks**	40(m)	36.45	1458.00
	Positive Ranks	24(n)	25.92	622.00
	Ties	0(o)		
	Total	64		

a B-L Rest Prep < 1/3 B-L Width

b B-L Rest Prep > 1/3 B-L Width

c B-L Rest Prep = 1/3 B-L Width

d M-D Rest prep < 1/3M-D length

e M-D Rest prep > 1/3M-D length

f M-D Rest prep = 1/3M-D length
g M thick mm < Rest Depth
h M thick mm > Rest Depth
i M thick mm = Rest Depth
j Recom Rest Depth < Rest Depth
k Recom Rest Depth > Rest Depth
l Recom Rest Depth = Rest Depth
m Recom Metal Thick < M thick mm
n Recom Metal Thick > M thick mm
o Recom Metal Thick = M thick mm

Test Statistics(c)

	B-L Rest Prep - 1/3 B-L Width	M-D Rest prep - 1/3M-D length	M thick mm - Rest Depth	Recom Rest Depth - Rest Depth	Recom Metal Thick - M thick mm
Z	-5.578(a)	-3.879(b)	-5.531(b)	-3.403(b)	-2.796(a)
Asymp. Sig. (2-tailed)	.000	.000	.000	.001	.005

a Based on positive ranks.

b Based on negative ranks.

c Wilcoxon Signed Ranks Test

Appendix V- Raw Data

Supervisor	Opposing	Denture	Rest shape	Rest Depth	M thick mm	M Thick Post-tryin	M_R_G	O_T_G	1/3 B-L Tooth Width	B-L Rest Seat Prep	1/3 M-D Tooth Length	M-D Rest Seat Prep
1	1	1	1	1.17	1.49	1.49	2	3	3.36	2.46	3.7	3.18
1	1	1	1	0.45	0.82	0.82	2	3	2.3	2.37	2.38	2.2
1	1	1	2	0.92	1.24	1.24	2	3	3.1	2.15	3.33	2.64
2	1	2			0.74	0.74	2	3				
3	1	3			0.54	0.54	2	3				
3	1	3	2	0.25	0.67	0.67	2	3	2.66	1.66	2.64	1.56
2	1	4	2	0.78	0.66	0.66	2	3	2.5	2.03	2.38	2.01
2	1	4	1	0.51	0.91	0.91	2	3	2.6	1.9	2.14	1.91
2	1	4	2	0.72	0.75	0.75	2	3	2.73	2.13	2.3	2.18
3	2	5	2	0.73	1.52	0.75	1	2	4.11	2.6	3.57	3.02
3	2	5	2	1.32	1.29	1.29	2	2	3.26	2.08	2.51	2.33
3	2	5	2	0.89	1.38	0.8	1	2	3.17	1.94	2.41	1.47
3	2	5	1	1.23	1.44	1.13	1	2	4.19	2.73	3.61	2.89
3	1	6	1	0.39	0.54	0.54	2	3	3.09	2.82	3.56	2.51
3	1	6	2	0.46	0.72	0.72	2	3	2.99	2	2.43	2.21
3	1	6	2	0.4	0.8	0.8	2	3	2.48	1.74	2.32	2.13
3	1	6	2	0.93	1.16	1.16	2	3	3.23	2.48	3.49	3.03
1	2	7	1	0.4	0.64	0.64	2	1	3.62	3.49	2.89	2.19
1	2	7	1	0.64	0.69	0.69	2	2	3.76	2.83	3.68	2.39
1	2	7	2	0.88	1.25	0.85	1	2	3.07	3.19	2.22	2.63
2	2	8	2	1	0.87	0.87	2	2	2.93	3.11	2.06	2.43
2	2	8	2	0.5	0.85	0.85	2	1	2.95	2.34	2.22	1.74
2	2	8	2	1.03	1.16	0.98	1	2	3.38	2.35	2.88	2.2
3	2	9	3	1.07	1.33	1.05	1	2	2.46	2.17	2.4	2.37
3	2	9	2	0.82	1.07	0.78	1	2	2.39	2.37	2.31	2.45
2	1	10	2	0.77	1.12	1.12	2	3	3.51	2.05	3.47	2.47
2	1	10	1	0.95	1.64	1.64	2	3	2.72	2.62	2.54	2.52
3	1	11	2	1.11	1.13	1.13	2	3	2.57	2.47	2.17	2.06
1	1	12	2	0.83	1.24	1.24	2	3	2.66	2.97	2.47	2.13
1	2	12	1	1.08	1.39	0.96	1	2	2.81	2.62	2.52	2.58
1	1	12	2	0.95	1.89	1.89	2	3	3.83	3.29	4.16	3.58
3	1	13	2	1.38	1.3	1.3	2	3	3.32	3.08	3.58	3.3
1	2	14	1	0.88	0.82	0.82	2	2	3.33	2.68	2.26	2.16
2	2	15	2	1.11	1.39	1.02	1	2	2.53	2.12	2.39	2.91
3	1	16	2	1.42	1.12	1.12	2	3	2.73	2.36	2.31	1.91
1	1	17	1	0.92	0.82	0.82	2	3	3.3	2.96	3.19	5.2
1	1	17	1	1.19	1.12	1.12	2	3	2.87	2.52	2.32	3.75
1	1	17	1	0.86	0.89	0.89	2	3	3.34	2.64	2.97	4.16
3	1	18	3	0.69	1.32	1.32	2	3	2.31	1.77	2.15	3.12
3	1	18	2	0.37	1.31	1.31	2	3	2.55	2.05	1.85	2.2
2	1	19	2	1.06	1.01	1.01	2	3	2.91	2.52	2.63	2.75
2	1	19	2	1.34	1.51	1.51	2	3	2.98	2.53	2.63	2.88
3	3	20	1	0.56	1.05	1.05	2	.	3.74	2.4	3.16	2.02
3	2	20	2	1.4	0.96	0.96	2	2	3.06	3.12	2.38	3.4
3	2	20	2	0.63	0.81	0.81	2	1	3.03	2.42	2.34	1.83
3	2	20	1	0.66	1.04	0.85	1	1	3.74	2.5	3.25	2.08

3	2	21	2	0.61	0.84	0.58	1	2	3.52	2.43	3.7	1.86
3	2	21	2	0.78	0.88	0.62	1	2	2.69	2.53	2.4	2.03
3	2	21	2	1.07	1.4	0.85	1	2	3.3	1.8	3.92	2.25
3	2	21	2	0.28	1.24	0	1	2	3.3	1.53	3.92	1.51
2	2	22	2	0.47	1.35	0	1	2	3.05	2.91	3.19	1.79
2	2	22	2	1.63	1.53	1.53	2	2	3.05	3.76	3.19	2.56
2	2	22	2	0.35	0.74	0.74	2	1	2.48	3	2.17	2.13
2	1	23	2	1.26	1.42	1.42	2	3	2.77	2.54	2.09	2.27
2	1	23	2	0.87	1.44	1.44	2	3	3.07	3.53	2.91	2.62
2	1	24	2	1.46	1.71	1.71	2	3	3.44	2.53	3.27	1.84
2	1	24	2	0.86	1.26	1.26	2	3	2.98	2.29	2.22	2.52
2	2	24	2	0.89	1.1	0.78	1	2	3.65	1.69	3.05	2.18
2	1	25	2	1.29	1.09	1.09	2	3	3.23	3.72	2.89	1.88
2	1	26			1.13	1.13	2	3				
2	1	27	2	0.89	0.68	0.68	2	3	2.51	2.49	2.38	2.7
2	1	27	2	0.84	0.93	0.93	2	3	2.55	2.68	2.14	1.96
2	1	27	2	0.72	1.31	1.31	2	3	3.43	4	3.94	1.91
2	1	27	2	0.31	0.74	0.74	2	3	3.43	2.24	3.94	2.03
1	2	28	1	0.89	1.54	1.28	1	1	3.84	2.72	3.97	2.97
1	3	28	3	0.55	1.51	1.51	2		4.15	2.56	3.85	2.29
2	1	29	3	0.48	0.97	0.97	2	2	3.84	3.13	3.45	2.32