Three dimensional finite element analysis of the stress distribution pattern in the design modifications of the u-shaped palatal major connector

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CONTENTS

TITLE

C E R T I F I C A T E

This is to Certify that this Dissertation titled **"THREE-DIMENSIONAL FINITE ELEMENT ANALYSIS OF STRESS DISTRIBUTION PATTERN IN THE DESIGN MODIFICATIONS OF THE U-SHAPED PALATAL MAJOR CONNECTOR"** is a bonafide work done by **Dr.R.HARIHARAN** in partial fulfillment for the award of Degree of **MASTER OF DENTAL SURGERY – PROSTHETIC DENTISTRY** of the Tamil Nadu **Dr.M.G.R. Medical University, February 2005.** This work was done under our guidance and supervision in the Department of Prosthodontics, Saveetha Dental College & Hospitals, Chennai 600 077.

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INTRODUCTION

3 DIMENSIONAL FINITE ELEMENT ANALYSIS OF THE STRESS DISTRIBUTION PATTERN IN THE DESIGN MODIFICATION OF U–SHAPED PALATAL MAJOR CONNECTOR

"MAJOR CONNECTOR" – as the word implies plays a major role in removable partial denture service since it functions to unite the various components of the prosthesis into a single unit. The major connector distributes the forces placed on the RPD to all the supporting structures.

Major connectors must be rigid, provide vertical support and protect the soft issues, provide a means of obtaining indirect retention where indicated, provide an opportunity of positioning denture bases where needed, maintain patient comfort.

Factors that influence the rigidity of a major connector include, the Composition of the Alloy used in the framework, Extension of the major connector, Arc length of the span being covered, Curvature of the palate.

Depending on the clinical situation the following six types of maxillary major connectors are used.

1) **Single posterior palatal bar**

It is used for interim partial denture until more definitive treatment can be rendered.

2) **Palatal Strap**

It is the most versatile maxillary major connector, consists of wide, thin band of metal that crosses the palate is an unobtrusive manner , 8 mm wide.

3) **Double Palatal Bar**

Main advantage of the double palatal bar is its rigidity. In comparison to amount of soft tissue coverage, it is by for the most rigid maxillary major connector.

4) **Anteroposterior Palatal Strap**

It is a structurally strong and rigid major connector that derives good support from palate.

5) **Complete Palate**

Provides the ultimate in rigidity and

6) The **U – Shaped** maxillary major connector consists of thin band of metal running along the lingual surface of the posterior teeth and extending anteriorly to cover the cingulum of the present anterior teeth and extends on to the palate to cover the entire rugae area. The lateral borders should be at the junction of the horizontal and vertical slopes of the palate. The rigidity can be increased by extending the borders slightly on to the horizontal palatal surface. All borders or angles of the connector should be gently curved & smooth.

Advantages of this major connector is that the central portion of the hard palate is uncovered by the metal so that interferences with the dorsum of the tongue are minimized. It can derive some vertical support and indirect retention from the palate. In patients with considerable vertical overlap of Anterior teeth, the horse shoe is thin yet strong enough to support the replacement teeth.

This U – shaped connector is indicated for use in patients for replacement of several anterior teeth, Inoperable palatal torus that may interfere with a framework of another design, The patients with an exaggerated gag reflex unable to tolerate a strap crossing their posterior palate, presence of hard median suture line.

U – shape connectors lacks the rigidity of other maxillary major connector designs. When vertical force is applied to either or both ends of the horseshoe major connector there is a tendency for the connector to spread or straighten. Therefore it is a poor choice for a distal extension partial denture. For the same reason this is not a good connector when cross-arch stabilisation is required. It has less resistance to flexing, and movement can occur at the open ends. To avoid the tendency to flex the metal crossing the rugae area must be thicker than that used in most other major connectors. But this will cause interferences with phonetics and patient comfort. Modifications of the design in extending the major connector would overcome these problems. It can be done by adding a strap posteriorly curved to the contour of palate. Other possible and logical design include medial extension of the medial borders of the major connector, palatal extension from the centre of major connector and doubling the thickness of connector. So the aim of this study is to

- ❖ Determine the stress distribution and deflections following load applications in the design modifications of the U – shaped connector.
- ❖ Identify which design modification is able to function more efficiently.

The concept of **"FINITE ELEMENT ANALYSIS"** is used to obtain the above said objective. This is basically an engineering design analysis in which the problem under study is solved by way of three dimensional modeling, meshing, applying certain physical properties and finally thorough analysis is done.

REVIEW OF LITERATURE

KAIRES A.K. (1956)[33] said that major connectors require rigidity if they are to provide cross arch stabilisation and distribute forces among the supporting structures. He demonstrated that modifying a mandibular major connector to reduce its rigidity increased the horizontal stress on the abutment teeth. Flexible major connectors were unable to distribute stresses and therefore placed more stress on the individual abutments.

KRATOCHVIL FJ (1963)[35] in a study of influence of rest position and clasp design on movement of abutment, teeth applied the concept of stress releasing clasp designs used on distal abutment of distal extension RPD's based on the fact that major connector of an RPD is flexible when vertical functional forces are applied and is best able to transfer and distribute horizontal forces to dental arch.

POTTER RB etal (1967)[49] : said that a connector must be rigid it is to be successful in transmitting lateral stresses between the components of the RPD. Failure to supply adequate rigidity can result in patient discomfort and possible damage to oral structures. They demonstrated that connectors that use 2 bars or those that cover a greater portion of the palate provide greater support and rigidity.

HINDELS G.W. (1970)[29] discussed the stress analysis in distal extension partial dentures, stated that a flexible major connector causes unequal distribution of forces with changes in their intensity that could possible cause damage to the supporting structures.

KRATOCHVIL FJ (1971)[34] In his study on maintaining supporting structures with a removable partial prosthesis said that the connector must be rigid if it is to be successful in transmitting lateral stresses between the components of cast partial prosthesis. His views were similar to Potter and his associates.

BARBENEL J.C. (1971)[6] In his study on design of partial denture components, noted that an increase in arch length led to an increase in framework flexibility. He also listed down the factors that influence the rigidity of a major connector which include composition of the alloy used in the framework, width and thickness of the connector, arc length of the span being covered, and curvature of the palate.

CECCONI BT (1973)[13] Stated that the rigidity of a lingual bar increased by a square factor when its height (Occlusogingivally) was increased, and by a cube factor when its thickness (labiolongually) was increased. He also found that the stress on a mandibular bilateral distal extension RPD, were concentrated in 3 locations: the center of the bar, junctions of the bar and acrylic resin denture bases bilaterally. He concluded that a framework should be of maximum thickness labiolingually to maximize rigidity, especially at the regions of greatest stress concentration.

LAVERE AM etal (1973)[38] in their study on the selection of major connector for the extension - base removable partial denture stated that antero posterior straps enhanced rigidity because they form a circle making the framework twice as rigid as each strap individually for adequate rigidity, they proposed wide. Rigidity was further enhanced when the straps lay in 2 different planes, creating an L – beam effect.

HENDERSON D (1973)[27] discussed views similar to Lavere, said that to compensate for the relatively flexible form of U – shaped design of the lingual bar, a half pear – shaped cross section is adopted using the L – beam effect to enhance rigidity in situations where torque and bending forces are present.

SCHWALM CA etal (1977)[54] found that there was no adverse effect on the mobility of the abutment teeth when RPD's were maintained with a comprehensive recall program (1-2 years) and included the following in their design and fabrication : rigid major connectors, altered cast impressions, prepared guide plane, rest seats in the long axis of tooth, chrome alloy framework and wrought wire or 1 – bar clasps.

CHANDLER JA etal (1982)[11] performed a clinical evaluation of patients eight to nine years after placement of the removable partial dentures and concluded that there was no adverse effect on the teeth and soft tissues. This was attributed to the splinting action of the metal framework, better dissipation of functional stresses by appropriate clasp design.

ELIASON C.M. (1983)[19] discussed RPA clasp on distal abutments of distal extension RPD's. RPA is mesial rest proximal plate Aker's Clasp system. This system and other like RPI, RPL system is based on the observation that both maxillary and mandibular connectors offer less resistance to torsional forces than compressive forces. So major connector is flexible when vertical functional forces are applied and is best able to transfer and distribute horizontal forces to dental arch. So RPA system is designed to release stresses on abutments by giving denture base some freedom of tissue ward movement without torquing the clasped abutments to compensate for the difference in quality of available supporting tissues.

DE FRANCO RL (1984)[17] said that rigidity is necessary in distal extension situations to evenly distribute occlusal loads, prevent torque and stress to the abutment teeth, and ensure the effectiveness of the RPD components. In class – III situations rigidity of the framework is of less concern, however as the framework is tooth supported and shorter than those used in distal extension situations.

REITZ PV etal (1985)[52] conducted a photoelastie study of a split palatal major connector that was flexible in the tissue ward direction only by splitting the major connector, results demonstrated that the split connector did reduce the stress

delivered to the distal extension abutment when the base was loaded on the experimental model.

FEINGOLD G.M. etal (1988)[21] In their study on abutment tooth and base movement with attachment retained removable partial dentures stated that resilient attachments showed an increase in the amount of denture base movement when compared with rigid attachments.

BEN UR Z etal (1989)[5] Studied the rigidity of major connectors when subjected to torsional and bending forces. Rigidity tests were performed on maxillary major conectors of different designs : Palatal straps, posterior palatal straps, anterior palatal straps, anteroposterior palatal straps on different planes, and U – shaped major connectors. The major connector that exhibited the greatest degree of rigidity was the anteroposterior palatal bar type, set on different planes, and the most flexible major connector was the U – shaped palatal bar. The most common major connector design in a mandibular RPD is the lingual bar.

COWAN R.D. etal (1991)[10] In their study, by way of telephonic interviews of patients using of RPD, demonstrated that a high percentage of patients who wear RPD's had no complaints after 2 and 4 years. This investigation did not study the influence of the fit to the abutment itself or to the stability of the RPD's.

SYNDER H.A. etal (1992)[60] explained the effect of clasp form on permanent deformation, where in permanent deformation and wear of nearly all clasp forms (1 year usage) was demonstrated. This is attributed to the non-rigid designing of RPD's where stress on the abutment teeth is reduced. Consequently the forces exerted on the RPD are mainly borne by the remaining bone and soft tissues. Due to resorption of the of the supporting bone, permanent tissue ward displacement by rotation of the RPD may occur, resulting in deviation of the clasps.

KELTJENS H.M. A.M. etal (1997)[30] assessed the fit of direct retainers after 8 years of use. A total of 101 metal framework RPD were investigated including 54 extension base prosthesis without any tooth supported replacement, 47 tooth supported prosthesis that replaced only premolars and molars of the framework studied about 60% of claps showed a space between retainers and abutments. The relative risks and a backward regression analysis revealed that the variable non rigid extension RPD had the greatest

influence on clasp fit. It was concluded that in extension base RPD's a rigid design should be preferred.

GORFIL C, BROSH T etal (1999)[69] investigated which design and cross-sectional shape of major connectors most favourably influence rigidity and flexibility. In the maxillary arch, the most rigid major connector was the antero posterior palatal bar combination placed on different horizontal and vertical planes. The most flexible was the U – shaped design. In the mandibular arch, the most important factor in achieving rigidity was the cross – sectional shape of the major connector. The half – pear shaped cross-section proved to be the most rigid. This study tested only one framework of each design.

LAWRENCE K. GREEN etal (2003)[40] studied the effects of changing width, thickness and shape on rigidity of U – shaped maxillary major connector. Designs were a U – shaped strap with a posterior strap, wide strap, U – shaped strap that widened at the midline, U – shaped strap that was twice the thickness of other straps. A fifth group made by removing the posterior strap form A – P strap. It was concluded that doubling the thickness of the anterior strap of

U – shaped maxillary major connector improved the rigidity of framework to torsional loads. A posterior strap became more effective in maintaining framework rigidity to compressive forces as the length of the arch is increased.

CONCLUSION

Within the limitations of this 3-Dimensional Finite Element Analysis study the following inferences are made

(1) Different angulations and different magnitude of forces induced different stress patterns in the Major Connector Designs, Palatal Mucosa and Periodontal Ligaments.

(2) Increase in magnitude of forces at both the angulations increases the stress values for the Major Connector Designs, Palatal Mucosa and Ligaments

(3) Lateral forces generate greater stress than the vertical forces in the Palatal Mucosa.

(4) Lateral forces generate greater stress than the vertical forces in the Periodontal Ligaments.

(5) The Double Thickness group exhibits the least stress for the U-shape Major Connector.

(6) The Double Thickness group delivers greatest stress to the Palatal Mucosa and Periodontal ligaments.

(7) Design modification 1 delivers least stress to the Palatal Mucosa and Periodontal Ligament

S U M M A R Y

The 3 Dimensional models of the Normal Design and Design Modifications of U-shaped palatal major connector Hard Palate, Palatal Mucosa, Periodontal Ligament, Alveolar Bone, Teeth were simulated using I-DEAS and PRO-E finite element softwares. For the analysis the models were loaded on the functional cusps of premolars and molars at 60^{o} and 90^{o} angulations for 200N, 250N, and 300N for each tooth.

The results of the study showed that the Design Modification 1 delivers least stress to the Palatal Mucosa and the Periodontal Ligaments, while the Double Thickness group exhibits least stress in the major connector and greatest stress to Palatal Mucosa and Periodontal Ligaments.

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