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Finite Element Stress Analysis of Circumferential Clasp Using Acetal Resin and Chrome Cobalt As Clasp Material

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ABSTRACT

Statement of problem: Restoration of esthetics is an important factor to consider in the fabrication of removable partial denture. RPD clasps made from metal cause esthetic problems. Acetal resins have been used as clasp material to improve esthetics. However, there are few FEA studies on acetal resin.

Purpose: The purpose of this FEA analysis was to compare stresses induced by acetal resin and cobalt chrome clasp.

Material and methods: Stress distribution induced in cast circumferential clasp was evaluated using three dimensional finite element experimental models for acetal and cobalt chromium clasps. Average load of 25 N were applied and stress distribution was evaluated

Result: FEA analysis showed the stresses induced by acetal resin clasp and Co-Cr clasp were similar on abutment teeth and bone, however within the clasp acetal resin generated less stress than Co-Cr clasp when downward forces and upward force of displacement were applied.

Conclusion: Within the limitations of the study, FEA analysis of cast circumferential clasp with acetal resin and cobalt chrome had induced similar stresses.

KEYWORDS : FEA Analysis, Circumferential clasp, acetal resin clasp, Chrome cobalt clasp, removable partial denture, Stress distribution

Introduction

Patient demands a removable partial denture (RPD) for health, anatomic, psychological, or financial reasons. Clasp-retained removable partial dentures (RPDs), for reasons of cost and time of fabrication, continue to be widely used for patients needing partial tooth replacement[1]. Restoration of esthetics is an important factor to consider in the fabrication of a removable partial denture (RPD).[2] several types of polymers and metal alloys have been used in RPD construction. Frequently, RPD clasps are made from the same alloy as the metal framework. The most common alloys used for clasps are cobalt-chromium (Co-Cr) alloy gold and titanium alloys, although these may be unesthetic.[3]

Methods to overcome this esthetic dilemma include the painting of clasps with tooth colored resin[4] use of lingually positioned clasps [5, 6] engagement of mesial rather than distal undercuts,[7] and use of gingival approaching clasps[8]. Unless clasps can be avoided by using precision attachments, While RPDs with precision attachments may be esthetically satisfying, however, they are expensive and more difficult to fabricate [9, 10].

Polyoxymethylene (POM) also known as acetal resin has been used as an alternative tooth-colored denture base and denture clasps material since 1986 and was promoted primarily for superior esthetic. Because of its compatibility, it is consider as RPD framework for patient with allergic reaction to co-chromium alloy.[9] It is reported that acetal resin have a sufficiently high resilience and modulus of elasticity to allow its use in the retentive clasps, connectors, and support elements for RPDs[11]. A clasp arm design producing less stress is important for predictable long-term use of an RPD. Three factors which are clasp material, clasp form, and the amount of undercut affect the design of a clasp arm[12]. Metals and metal alloys undergo permanent deformation and fatigue when exposed to repeated stress[13]. Although extensive work has been performed to determine the properties of a variety of materials used for RPD clasps[14], little is known about how acetal resin functions in this application. Hence, the present study aim to investigate FEA analysis and compare stress induced by circumferential clasp with two different materials.

Materials and Methods

Finite element analysis were conducted to evaluate the stress generated in experimental circumferential clasp. A graphic preprocesser of a finite element analysis program **(ANCYS software12.1)** was used to construct three dimensional finite element models of circumferential clasps With acetal resin and cobalt chrome for mandibular RPD.

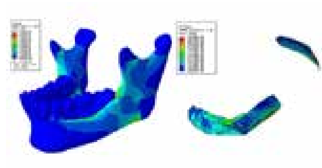

Fig 1: Geometric model of mandibular partial denture with circumferential clasp

For comparative analysis circumferential clasps were placed on 1st pre-molar, Geometrical models of these direct retainers were created using manual 3-D measurements. The geometric models (surface and line data) were then imported into **Hypermesh software 9.0** for meshing. Assembled finite element model of the cast partial framework, and mandible is then imported into for analysis. The material properties (young's modulus and Poisson's ratio) of the following were entered in the pre – processing stage (Table 1). A load of 222 Newton of downward force was applied to the removable partial denture with acetal resin 2mm and cobalt chromium circumferential clasp 1.2 mm and 3.318 N upward force for displacement for acetal resin and 14.504N for cobalt chromium was applied and stresses were evaluated.

Results

The generated Von-Mises equivalent stresses were calculated numerically. Results were displayed as colored stress to identify the regions of different stress concentration.

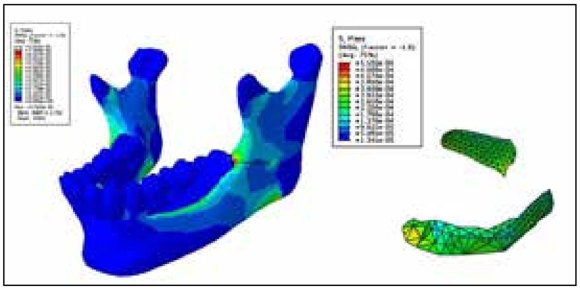

Fig 2: The stress distribution on 2 mm acetal resin clasp when downward force was applied.

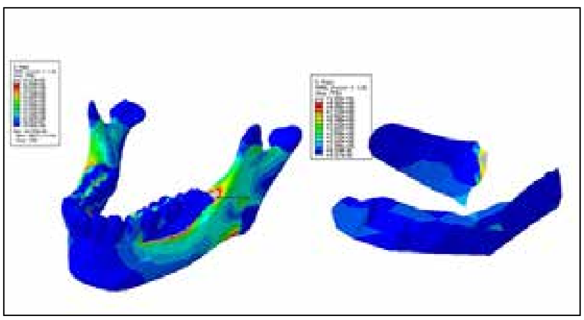

Fig 3: The stress distribution on 1.2 mm cobalt chrome clasp when downward force was applied.

Fig2 and Fig3 display the Von-Mises equivalent stresses for acetal and cobalt chromium circumferential clasps when downward force was applied. Different shades of colour (red, yellow, and green, blue) indicate stress, with dark red showing the maximum stress and dark blue showing an absence of stress and in between shades are the variation of stresses from minimum to maximum. The stress concentration was reported in MPa. The stresses concentration within the acetal resin clasp was 5.243 and with cobalt chrome clasp was 16.02 when the downward force was applied. This shows that the stress within the clasp with cobalt chrome was more as compared to acetal resin. Fig4 and Fig5 display the Von-Mises equivalent stresses for acetal and cobalt chromium circumferential clasps when upward force for displacement was applied.

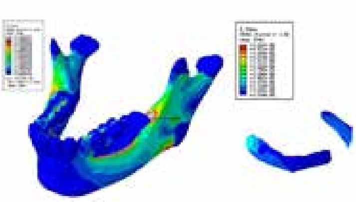

Fig 4: The stress distribution on 2 mm acetal resin clasp when upward force was applied.

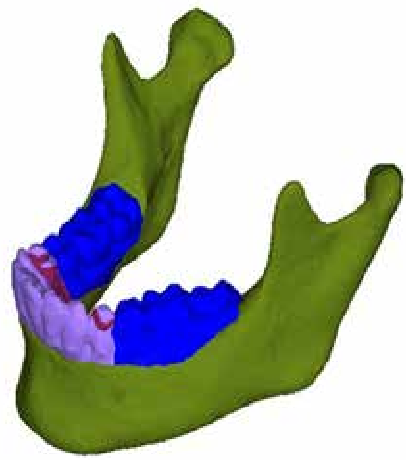

Fig 5: The stress distribution on 1.2 mm cobalt chrome clasp when upward force was applied.

The stresses concentration within the acetal resin clasp was 5.102 and with cobalt chrome clasp was 9.958 when the upward force for displacement was applied. This shows that the stress within the clasp with cobalt chrome was more as compared to acetal resin. The stress concentration on teeth and bone for both upward and downward forces were almost similar with acetal resin 2mm and cobalt chromium 1.2 mm. circumferential clasp

Discussion:

Occlusal loads exerted on a removable partial denture (RPD) are transmitted to abutment teeth and oral mucosa through occlusal rests, retainers, connectors and the denture base. RPDs are not rigidly fixed, they are subject to movements in response to functional loads.[15,16] These functional movements induce stresses and displacements in the metal framework of the denture. Direct retainers are designed and used to control these possible movements.[17] The choice of retention elements and their individual design require biomechanical considerations.[18-20].

Retentive clasp arms must be capable of flexing and returning to their original form and should retain an RPD satisfactorily. The tooth should not be unduly stressed or permanently distorted during service and should provide esthetic results.[21]

It is reported that acetal resin have a sufficiently high resilience and modulus of elasticity to allow its use in the manufacture of retentive clasps, connectors, and support elements for RPDs. Retention clasps can be excellent with retainer that lock the remaining dentition, however they may subject abutment teeth to excessive stresses & premature tooth loss .Some clinicians aimed to reduce the weight of the prosthesis to minimize the damage to the abutment teeth, splinting some or all the abutment teeth to dissipate the forces.[8,9] Arda and Arikan, simulated a 36-month clinical use of RPD clasps made of acetal resin and assessed their retentive force and deformation by comparison with similar clasps cast of Co-Cr. The result showed no deformation for the acetal resin clasp, unlike the Co-Cr clasp which presented an increase in the distance between the tips. However, the acetal resin clasps require less force for insertion and removal than Co-Cr clasps even after the simulated period[22].

Acetal resin has a relatively high proportional limit with little viscous flow, enabling it to behave elastically over a large enough range to be used as a material for clasp fabrication[23]. The advantages of using FEA analysis in removable prosthodontics are the exact and reliable manipulation process and relatively short analysis time[24]. In our study FEA analysis showed the stresses induced by acetal resin clasp and Co-Cr clasp were similar on abutment teeth and bone, however within the clasp acetal resin generated less stress than Co-Cr clasp when downward forces and upward force of displacement were applied. Hence, acetal resin offers the strength of metal, flexibility and comfort of plastic, they make a ideal material for the fabrication of dental prosthesis particularly clasp.

Conclusion:

Within the limitations of the study the FEA stress analysis showed that, stresses induce by acetal resin and cobalt chromium clasp material were similar. Further research on the clinical efficacy of acetal resin clasp is needed to determine whether these materials are suitable alternative for RPD clasps.

Sl. No	Component	Material	Young's modulus	Poisson's Ratio
1	Partial denture	Acrylic	2.4 GPa	0.3
2	Metal strip	Co-Cr	224 GPa	0.3
3	Clasp	Acetal	2.7 GPa	0.2
		Co-Cr	224 GPa	0.3
4	Cortical Bone	Cortical bone	1.0E4 MPa	0.3
5	Teeth	Dentin	1.86E4 MPa	0.31

Figure legends:

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