Exerted Stresses from Loading Distal -Extension Removable Partial Denture with Different Occlusal Rest Position A Finite Element Stress Analysis Study

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ABSTRACT

The treatment of distal extension base removable partial denture has long been the dilemma of many Prosthodontists, since the support for this type of restoration is based on two functionally different systems, the teeth and associated periodontal membrane and the edentulous ridges. So one of their most elusive goals were to finish the prosthesis by utilizing both systems of support without exposing the tissues to undue stresses which might lead otherwise to bone resorption.

Material and method: A two-dimensional finite element analysis method was used to assess the stress distribution on supporting structure where different rest position, including mesial-occlusal rest, distal-occlusal rest, and mesio-distal occlusal rest.

The X, and Y coordinate for each node of the model was transferred to the ANSYS program, a load of 10MP was used in this study, where each of the models was subjected to load distributed on the saddle area.

Results: Von Mises stress values revealed that, mesial rest produces less stress concentration,

الاجهادات الناتجة من تحميل الطقم الجزئي المتحرك في حالة السرج الطليق لعدة مواضع للمهماز الطاحن ، طريقة العناصر المحددة لتحليل الاجهادات

المستخلص

ان علاج حالات السرج الطليق بواسطة الطقم الجزئى المعدني ظل يمثل معضلة يواجه المختصين في طب الاسنان ذلك لأن أسناد الطقم في مثل هذا النوع من العلاج مزود بنوعين مختلفين من الانسجة. الاسنان و الانسجة المحيطة و العظم المتبقي , لذا فقد أصبح هدف هؤلاء المختصين هو انتاج طقم جزئى مستعملا كلا النوعين من الاسناد بدون تسليط ضغط مضاعف على هذه الانسجة الذى قد يؤدى بالتالي الى سوفان العظم

لقد استخدمت طريقة العناصر المحددة ذات البعدين لتحليل الاجهادات المسلطة على العظم الساند للسن, باستخدام كل من المهماز الطاحن الانسي, المهماز الطاحن الوحشي, و المهماز الطاحن الانسي/ الوحشي.اظهرت نتيجه الدراسه ان استخدام المهماز الانسي كان من افضل الانواع و ذلك لان كميه الضغط المسلط على العظم كان الاقل مقارنه بالانواع الاخرى

INTRODUCTION

The treatment of distal extension base removable partial denture has long been the dilemma of many Prosthodontists, since the support for this type of restoration is based on two functionally different systems, the teeth and associated periodontal membrane and the edentulous ridges. So one of their most important goals were to finish the prosthesis by utilizing both systems of support without exposing the tissues to unnecessary stresses which might lead otherwise to bone resorption [(1)].

One of the dentist's most interesting and thought-provoking situations occurs when treatment requires a rigid prosthetic replacement, which must be compatible with two different kind of support, this situation exists in treatment with distal extension partial dentures, When the functional occlusal load is induced on this kind of partial denture, a rotary movement usually occurs around the fulcrum of the terminal abutment teeth dentures [(2)].

The ideal situation is most closely approached when the restoration allows the concentrated force of the occlusal load to be collinear with the long axes of the teeth, since the teeth and periodontium are best suited to resist axially directed forces [(3)].

This is why various components of the removable partial dentures are specifically designed to withstand these forces and the success of prosthesis depends on whether it does this effectively. By success is meant that both comfort and function of the denture are satisfied, as well as "preservation of what remains" Devan 1952''[(4)]. Kratochvil 1963[(5)] was one of the first researchers to hold the concept of mesial rest position; he found numerous advantages over distal rest placement. The mesial rest will direct forces more perpendicular to the long axes of the tooth, also gingiva adjacent to most posterior tooth is less likely to be pinched with mesial rest.

Thompson *et al*[(6)] used photoelastic model to observe and evaluate the effect of different direct retainer design and occlusal rest position on abutment movement, but it is a quantative and inaccurate method, but the finite element method has superseded other techniques, when was first introduced to the dentistry field in the early seventies, because, stress magnitude can be easily obtained and all types of stress output can be calculated. The computer gives a discription of each piece of the model, where to be placed when loaded and how much of a load each component will carry, it is used in vitro investigation method for the examination of the complex mechanical behaviors of prostheses and surrounding structures; It is therefore ideally suited for the present study[7,8,9].

MATERIALS AND METHOD

A two dimensional strain mesh of the mandibular second permanent premolar with its supporting structures, distal extension RPD, and bone forming part of the mandible.

Three models were prepared for this study; the models were with normal bony support, crown /root ratio (1/2)

Table (1) represents the symbols and designs of the FEM.

Table (1)

Symbols	*Design*
D	normal bone support, distal rest.
M	normal bone support, mesial rest.
MD	normal bone support, mesial-distal rest.

For all the above design

A distributed surface pressure on the saddle area, demonstrating (first and second molar), of 10 MPa.

After drawing three figures on a graded paper each coordinate both in X, Y were transmitted to the ANSYS program as an input data.

The key points were connected by lines, then connecting these lines created six areas,

Co-Cr .Alloy, Enamel, Dentine, Periodontal ligament, mucosa, cortical bone, and Cancellous bone.

The proper value of the Young's Modulus,"E" and, Poisson's ratio "V" are shown in Table (2)

Table (2)

Materials	*Young's modulus (Mpa)*	*Poisson's ratio*
Co-Cr.Alloy	218000	0.33 [10]
Enamel	84000	0.33 [11]
Dentine	18600	0.31 [11]
PDL	3.45	0.45 [11]
Cortical bone	13000	0.3 [12]
Cancellous bone	1000	0.3 [12]
Gold	99300	0.33 [13]
Titanium	110000	0.33 [13]

A fine mesh of the Finite Element model was generated using the quadrilateral 8-node, which is a higher order version of the 2D-4-node element; it provides more accurate results and can tolerate irregular shapes without as much loss of accuracy as shown in figure (1).

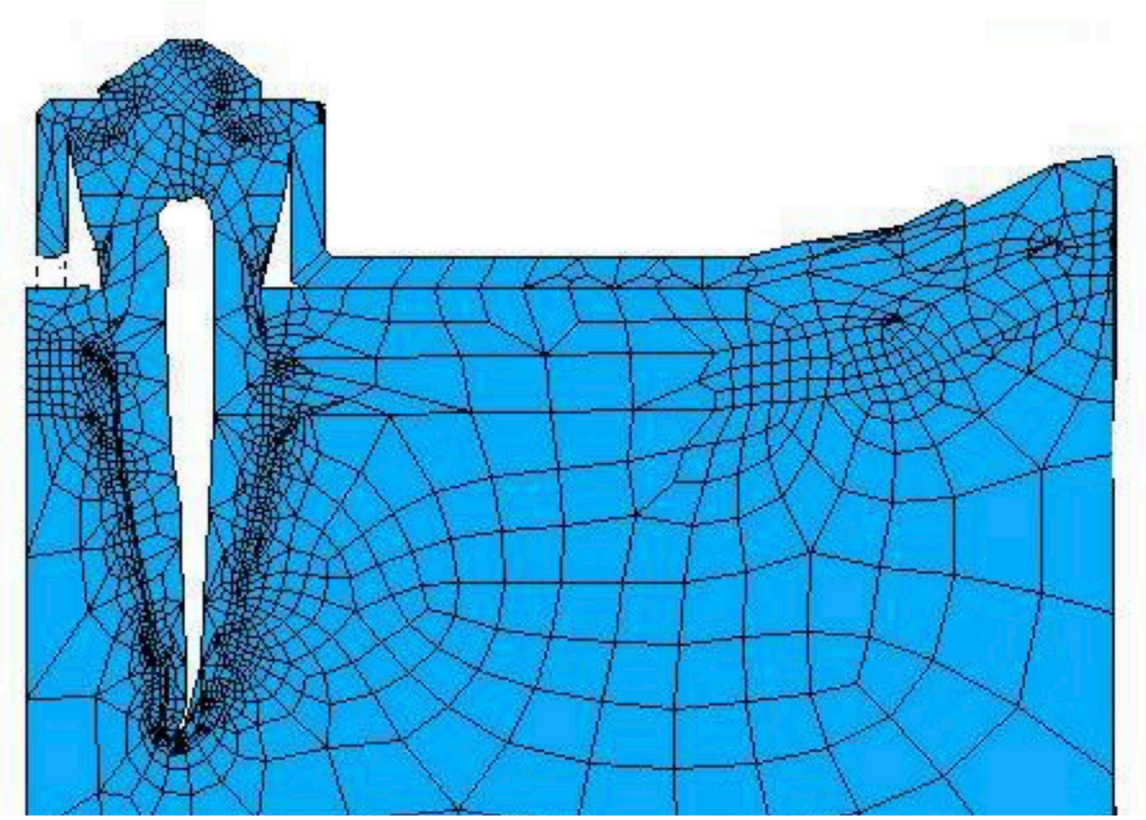


Fig (1) Shows 2-D plain strain mesh in normal bone support

After applying load as described previously, the ANSYS program will do the processing of the given data , Listing the results; The results of this study is represented by the equivalent Von Mises stress at selected nodes [10,11,14,15].

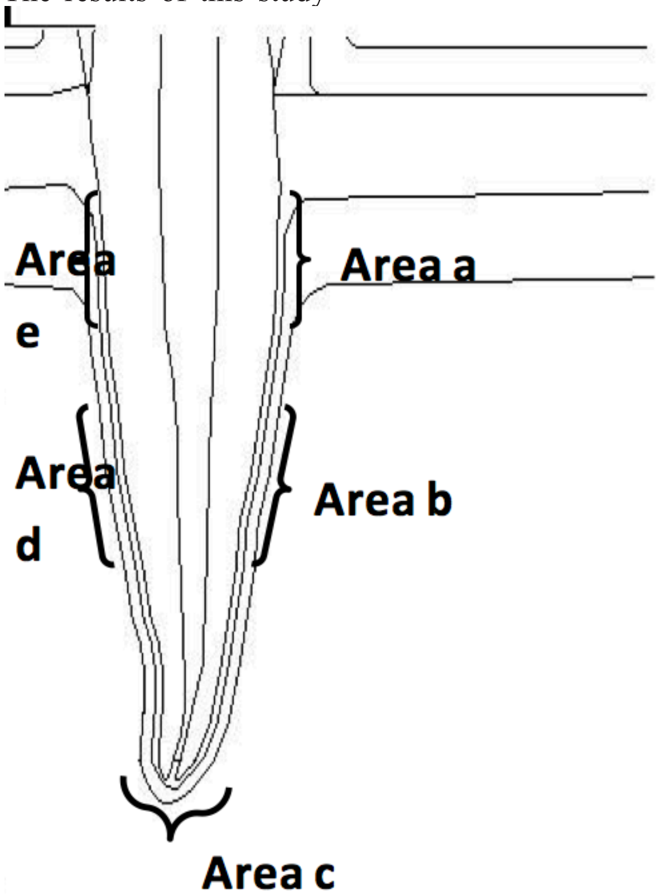
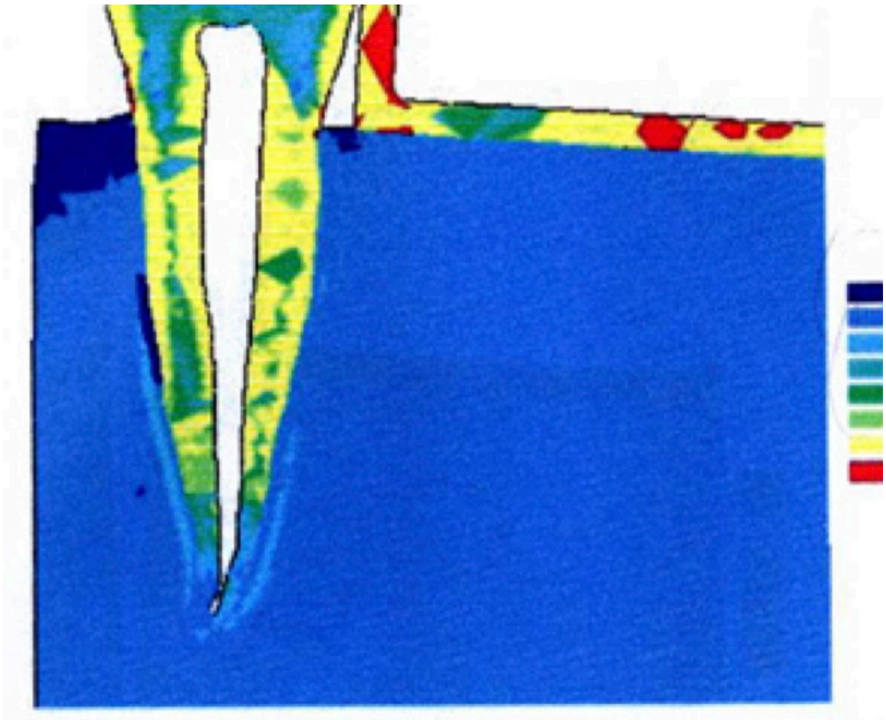


Fig (2): Shows the selected areas for measuring the mean stress values.

RESULTS

When external distributed pressure is applied on the saddle area for the three designs (D, M and MD), Table (3) shows no significant difference among the three designs except in (area d) where the mean stress value of MD is the highest followed by D as shown in figuer (3) and M, where the mesial rest is significantly lower than the distal rest and the mesio-distal rest at P>0.01 .



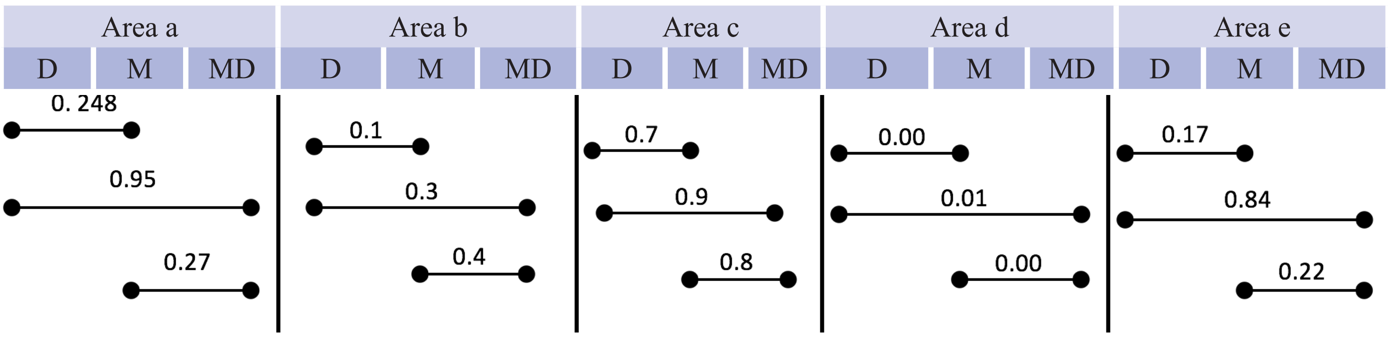
Figuer (3) distribution of the equivalent Von Mises stress contour for distal rest design

Table (3): The comparison among the three designs (D, M, and MD) when pressure is applied on the saddle area.

Groups	Design	Mean Stress MPa	SD	95 C.I.	Minimum	Maximum	
				Lower bound	Upper bound		
(Area a)	D	5.866	1.310	2.610	9.123	4.35	6.64
	M	4.610	1.302	1.373	7.846	3.29	5.90
	MD	5.803	0.958	3.421	8.184	4.82	6.74
(Area b)	D	14.336	0.975	11.912	16.759	13.3	15.2
	M	16.712	1.619	12.688	20.736	14.865	17.890
	MD	15.666	2.384	9.743	21.590	13.235	18.001
(Area c)	D	15.781	6.055	6.145	25.416	9.44	21.0
	M	14.139	7.144	2.771	25.507	7.47	24.3
	MD	15.114	8.989	0.810	29.419	7.66	27.8
(Area d)	D	30.611	1.451	27.005	34.217	29.7	32.3
	M	21.766	1.449	18.165	25.368	20.6	23.4
	MD	35.202	1.718	30.934	39.470	33.4	36.9
(Area e)	D	5.344	1.577	1.424	9.263	4.09	7.12
	M	2.743	1.993	-2.208	7.694	1.21	5.00
	MD	5.009	2.479	-1.149	11.167	2.32	7.20

ANOVA

		Sum of squares	*df*	*Mean square*	*F*	*Significant*
(Area a)	Between groups	3.007	2	1.503 1.445	1.040	0.409
	Within group	8.670	6			
	Total	11.676	8			
(Area b)	Between groups	8.509	2	4.254 3.087	1.378	0.322
	Within group	18.523	6			
	Total	27.032	8			
(Area c)	Between groups	5.452	2	2.726 56.172	0.049	0.953
	Within group	505.545	6			
	Total	510.997	8			
(Area d)	Between groups	279.837	2	139.919 2.387	58.618	0.000
	Within group	14.322	6			
	Total	294.159	8			
(Area e)	Between groups	12.012	2	6.006 4.203	1.429	0.311
	Within group	25.220	6			
	Total	37.232	8			



DISCUSSION

A two- dimensional finite element analysis method is carried out, although tooth is a three-dimensional structure, but the use of a 2-D model is also valuable, because of improved performance in terms of element number(16,17).

Where external pressure is applied on the saddle area, the stress is higher in (area d) mesial middle third of root surface than the apical area (area c), this approaches more the normal physiological occlusal force, that stress at the apex is less than on root side, which will subsequently prevent any traumatic load on the apical area which leads to blood vessels strangulation and bone resorption. because the normal physiological axial force applied on unrestored tooth, the internal stresses are distributed evenly around the root, with minimum pressure at the place of entry of the neurovascular supply to the tooth this explain how the blood vessels entering the tooth are not affected by physiological occlusal forces; This is the reason why the bone destruction is always seen on the walls of the socket and almost never around the apex .(18,19)

It can be explained that, in mesial rest when load is applied on the saddle, the effort arm will increase, so greater part of the load is carried by the ridge and proportionately less by the tooth, further, since the saddle is farther removed from the fulcrum point (Mesial rest), the stress over the ridge is increased and more evenly distributed in an antero-posterior direction. Also the direction of torquing movement will change in a favorable direction, that is mean in a forward direction which can be supported from the adjacent tooth(20,21).

CONCLUSION

The stress value of mesial rest design was significantly less than the the other designs in the mesial middle third of root surface when pressure is applied on the saddle area.

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