Studying the Effect of Different RPD Design and Materials on Reduced Bone Support, a FEA study

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Aim of the study: To study the effect of reduced level of bone support on stress concentration and distribution. Also comparing the effect of different metals (gold, cobalt-chromium, and titanium) on alveolar supporting bone.
Material and methods: A FEA method is used on a reduced bone support class I Kennedy classification, with three different rest positions (mesial, distal, mesial and distal) Co-Cr partial denture; Then changing the modulus of elasticity of the chrome-cobalt, to study the effect of gold and titanium alloy on the supporting bone surrounding the abutment in terms of stress distribution.
Results: results revealed that best design type is by placing mesial and distal rest on abutment, also when comparing the three types of metals (Co-Cr, titanium, gold), there was no significant difference among the three metals.

دراسة تاثير استخدام الطقم الجزئي المتحرك على العظم المنحسر مع تغيير نوع المواد و التصميم. طريقة العناصر المحددة لتحليل الاجهاد

لقد استخدمت طريقة العناصر المحددة ذات البعدين لتحليل الاجهادات المسلطة على العظم الساند (المنحسر) للسن, اخذين بنظر الاعتبار تغيير تصميم الطقم الجزئي المتحرك و ذلك بتغيير مواضع المهماز الطاحن كما تم ايضا دراسة تاثير تغيير نوع المعدن على العظم, و قد اظهرت النتائج ان افضل نوع هو المهماز الانسي-الوحشي, كما بينت النتائج ان تغيير نوع المعدن لم يكن له تاثير يذكر .

INTRODUCTION

The phenomenon of mandibular residual ridge resorption in edentulous patients is currently considered a serious clinical issue;

It is a chronic, progressive, irreversible, and cumulative process characterized by sequential stages that first affect buccal and lingual surfaces and, eventually, the alveolar bone crest [1].

Progressive bone loss without proper prosthetic treatment and rehabilitation of the masticatory organ can contribute to numerous unfavorable results. Tooth loss cause masticatory impairment as well as loss of periodontal tissue receptors, which play a significant regulatory role in the function of the masticatory organ. The efficiency of mastication is thus markedly decreased. Apart from this, it can alter the nutrition habits of the elderly in favor of a high-fat diet, avoidance of fiber, raw vegetables and fruit. As a result, a deterioration in general condition and an increased risk of cardiovascular and neoplastic disease can occur[2]. The continual resorption of the residual ridge negatively impacts the stability, retention and support of RPDs, thus placing patients in a loop of continual change towards inferior stability and discomfort[3,4,5] Furthermore occlusal forces must be considered to be the major cause of RRR because these forces are able to cause rapid and thorough resorption without systemic bone loss [6]This why this study was conducted to find out the best possible denture design with least harmful effect on underlying bone

MATERIALS AND METHODS

A stone cast model was fabricated (30mg powder, 100mg water), trimming fist and second molars, then a Co-Cr framework was constructed to simulate a free end class I partial denture with lower second premolar as the primary abutment. Each component of the model was transferred exactely to the ANSYS programme; the 2-D model was formed as in figure (1)

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.

for reduced bone support, crown/root ratio is (1/0.7)7The table below show the three different rest seat positions,

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

RE-D	reduced bone support, distal rest.
RE-M	reduced bone, mesial rest.
RE-MD	reduced bone support, mesial-distal rest.

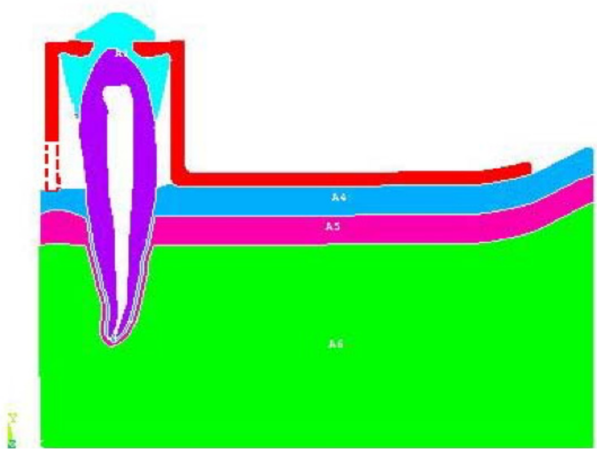


Fig (1): Schematic drawing of the 2-D model in reduced bone support

Material properties:

for measuring the effect of different types of metal is by changinging the Young's Modulous and Poisson's ratio as the table below.

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

Materials	*Young's modulus (Mpa)*	*Poisson's ratio*
Co-Cr.Alloy	218000	0.33 (8)
Enamel	84000	0.33 (8)
Dentine	18600	0.31 (8)
PDL	3.45	0.45 (8)
Cortical bone	13000	0.3 (9)
Cancellous bone	1000	0.3 (9)
Gold	99300	0.33 (10)
Titanium	110000	0.33 (10)

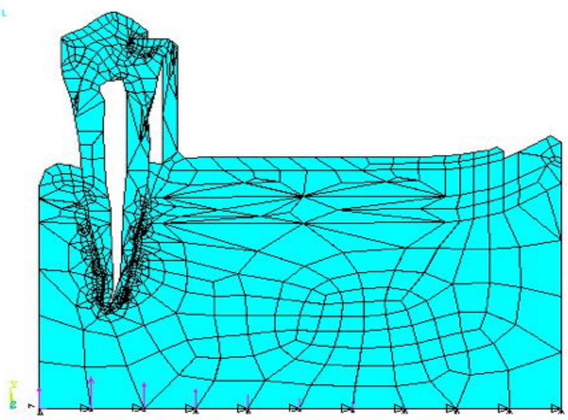


Fig (2): Shows 2-D plaine strain mesh in reduced bone support

A fine mesh of the Finite Element model was generated using the quadrilateral 8-node, as shown in Figures (2), 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.

The 8-node elements have compatible displacement shapes and are well suited to model Curved boundaries .

8 nodes elements having two degree of freedom at each node define the 8-node element Translations in the nodal X and Y directions.

The main goal of a FEA is to examine how a structure or component responds to certain loading conditions. Specifying the proper loading condition is therefore, a key step in the analysis,

After load application, the post processing procedure begins, It means reviewing the results of an analysis, it is probably the most important step in the analysis, because, it is trying to understand how applied loads affect the design, how good the finite element mesh is, and so on… The results of this study is represented by the equivalent Von Mises stress at selected nodes.

The mean of Three different nodes were selected on root surface except the apex were four nodes are choosen like the following:

A mesial cervical area

B mesial middle root surface area

C apical area

D distal middle root surface area

E distal cervical root surface area

RESULTS

Table (3): The comparison among the three metals (Cobalt-Chromium, Gold, and Titanium).

Groups	load	Mean Stress MPa	SD	95 C.I. Lower bound	95 C.I. Upper bound	Minimum	Maximum
(Area a)	C	5.60233	2.03501	0.54709	10.65757	3.47	7.53
	G	5.57267	2.62051	-0.93704	12.08237	2.72	7.87
	T	5.36667	1.64418	1.28229	9.45104	3.50	6.60
(Area b)	C	21.38767	2.59990	14.92915	27.84619	18.5	23.6
	G	22.92100	2.46894	16.78782	29.05418	20.2	24.9
	T	22.66667	2.48261	16.9953	28.83380	19.9	24.7
(Area c)	C	32.03725	23.09773	-4.71639	68.79089	15.7	65.3
	G	31.32825	22.06511	-3.78227	66.43877	14.5	63.5
	T	33.57500	20.36064	1.17667	65.97333	19.5	63.7
(Area d)	C	40.55667	2.56436	34.18644	46.92689	38.1	43.2
	G	41.86400	2.22102	36.34668	47.38132	39.8	44.2
	T	41.60000	2.26495	35.97355	47.22645	39.5	44.0
(Area e)	C	3.98467	1.70936	-0.26161	8.23094	2.01	4.99
	G	4.00000	1.83229	-0.55167	8.55167	1.89	5.19
	T	3.96667	1.79258	-0.48634	8.41968	1.90	5.10

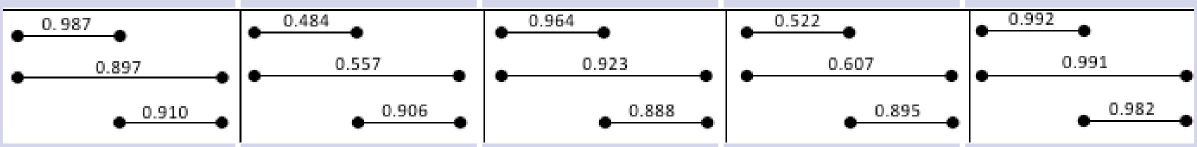
C=Cobalt-Chromium , G=Gold , T=Titanium

		Sum of squares	df	Mean square	F	Significant
(Area a)	Between groups	0.09885	2	0.04943 4.571	0.001	0.989
	Within group	27.423	6			
	Total	27.522	8			
(Area b)	Between groups	4.052	2	2.026 6.339	0.320	0.738
	Within group	38.037	6			
	Total	42.089	8			
(Area c)	Between groups	10.554	2	5.277 478.310	0.011	0.989
	Within group	4304.790	6			
	Total	4315.344	8			
(Area d)	Between groups	2.867	2	1.434 5.56	0.258	0.780
	Within group	33.278	6			
	Total	36.145	8			
(Area e)	Between groups	0.00167	2	0.000835 3.164	0.000	1.000
	Within group	18.985	6			
	Total	18.987	8			

ANOVA

LSD

Area a			Area b			Area c			Area d			Area e		
C	G	T	C	G	T	C	G	T	C	G	T	C	G	T



The maximum equivalent stress value were very close to each other, although gold and titanium showed a slight increase in mean stress values for the apical and middle third areas. But statistically there was no significant difference among the three metals in all, cervical, middle third or apical areas of root surface as shown in Table (3).

Table (4): The comparison among the three designs (RE-D, RE-M, and RE-MD) when pressure is applied on the saddle area in reduced bone support.

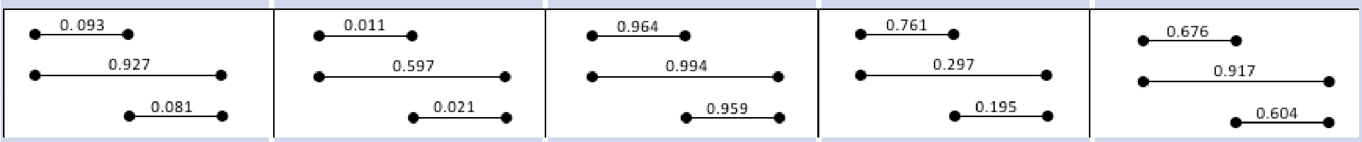
Groups	*load*	*Mean Stress MPa*	*SD*	*95 C.I.*		*Minimum*	*Maximum*
				Lower bound	*Upper bound*		
(Area a)	RE-D2	6.165	0.737	4.333	7.997	5.33	6.71
	RE-M2	13.657	7.880	-5.618	33.532	8.56	23.0
	RE-MD2	5.790	2.431	-0.250	11.831	3.31	8.16
(Area b)	RE-D2	15.566	0.888	13.360	17.772	14.954	16.588
	RE-M2	17.962	0.915	15.687	20.237	17.301	19.008
	RE-MD2	15.132	0.552	14.559	17.304	15.488	16.551
(Area c)	RE-D2	18.840	8.173	5.835	31.845	12.484	30.719
	RE-M2	19.153	8.051	6.341	31.964	10.301	29.831
	RE-MD2	18.788	12.158	-0.557	38.135	10.159	36.126
(Area d)	RE-D2	25.2000	1.860	20.578	29.821	23.707	27.284
	RE-M2	24.570	1.923	19.793	29.347	22.375	25.957
	RE-MD2	27.461	3.237	19.417	35.504	23.752	29.723
(Area e)	RE-D2	5.820	4.585	-5.570	17.210	2.664	11.080
	RE-M2	7.601	6.773	-9.223	24.427	2.251	15.217
	RE-MD2	5.379	2.700	-1.328	12.087	3.049	8.339

ANOVA

		Sum of squares	df	Mean square	F	Significant
(Area a)	Between groups	127.50	2	63.770 22.851	2.791	0.139
	Within group	137.106	6			
	Total	264.646	8			
(Area b)	Between groups	10.000	2	5.000 0.644	7.759	0.22
	Within group	3.866	6			
	Total	13.866	8			
(Area c)	Between groups	0.311	2	0.155 93.147	0.002	0.998
	Within group	838.323	6			
	Total	838.634	8			
(Area d)	Between groups	13.865	2	6.932 5.881	1.179	0.370
	Within group	35.285	6			
	Total	49.149	8			
(Area e)	Between groups	8.305	2	4.152 24.731	0.168	0.849
	Within group	148.387	6			
	Total	156.692	8			

LSD

Area a			Area b			Area c			Area d			Area e		
RE-D2	RE-M2	RE-MD2	RE-D2	RE-M2	RE-MD2	RE-D2	RE-M2	RE-MD2	RE-D2	RE-M2	RE-MD2	RE-D2	RE-M2	RE-MD2



Results of table (4) shows a decrease of mean stress values in the mesial-distal design compared to the mesial rest design and distal rest design in all areas cervical both mesial and distal side, middle area also mesial and distal side, except the apical area where there is a slight increase in mean stress values

DISCUSSION

It is possible to use an FEA to ascertain the stress distributions of a subject's interior, which are difficult to measure in an experimental analysis, to extract various physical data such as stress, strain, and displacement, conditions can be set more easily than in other biomechanical investigations. This is the reason why FEAs have been studied in typical biomechanical investigations in recent years [11]

A 2-D FEA method was performed in this study, since we are concerned with a very thin layer of bone (cortical bone), so the demand raised for using 2-D because in term of element number it provides a very fine mesh in critical areas which can provide very precise values results.

When comparing the Cobalt-Chromium, Gold, and Titanium metals:

The three metals show no significant difference in stress distribution although the modulus of elasticity of Co-Cr. is about twice that of gold and titanium[10]. But it did not seems to affect the transmission of force, this result will not allow for one material to be superior to other in terms of stress distribution and stress concentration.

The ideal design of an RPD focuses on protecting the abutments and minimizing damage to the residual ridge in an attempt to favorably distribute the occlusal forces on them [12]This is why this study focused on the design of frame work with reduced bone support to prevent further bone loss, results yield that the mesio-distal rest had the least stress values, in other words is superior to the other two designs as in Figure (3). This agrees with Sulik and White 1981 [13] that "when the masticator system is altered by the loss of teeth and supporting bone, the distribution of stresses is altered". This can be explained that, due to the external load there are direct and bending stresses. The direct stress is a compression stress while the stress due to the bending moment is a linear distributed cross the investigated area as shown in Figure (4). So for the mesio-distal rest design there are two external forces applied at opposite side of the tooth. The bending moment due to one of the two forces will eliminate the bending moment of the other force, so the effected force will only be the remainder compressive force [14,15] .

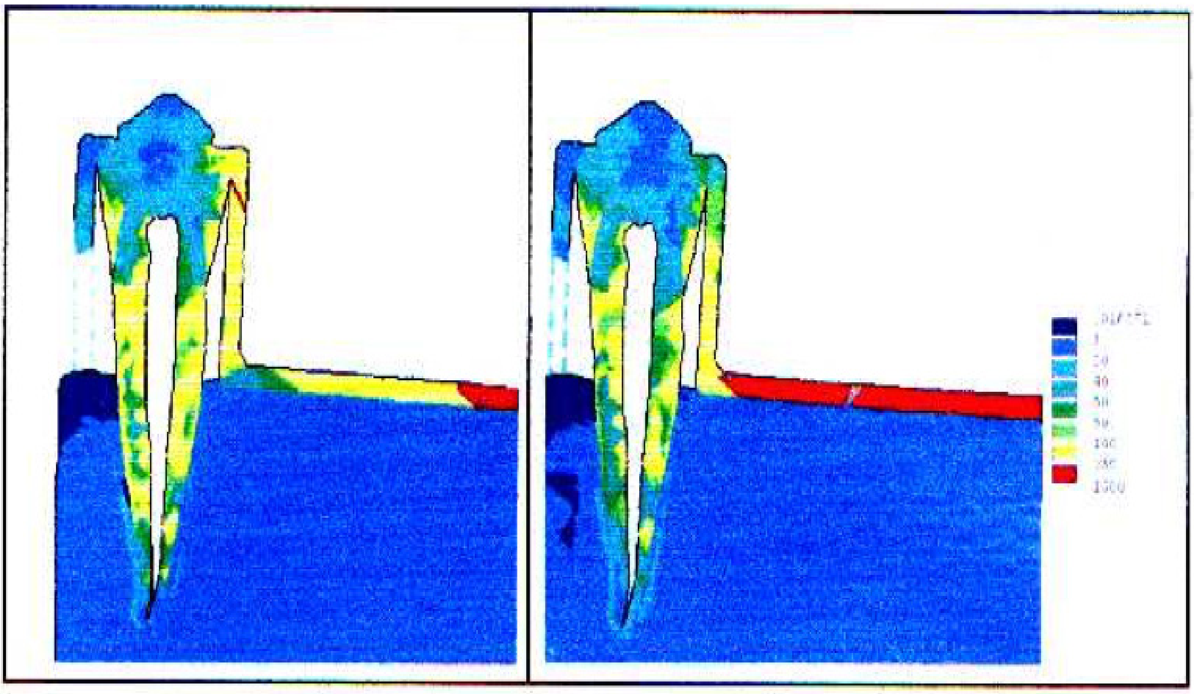
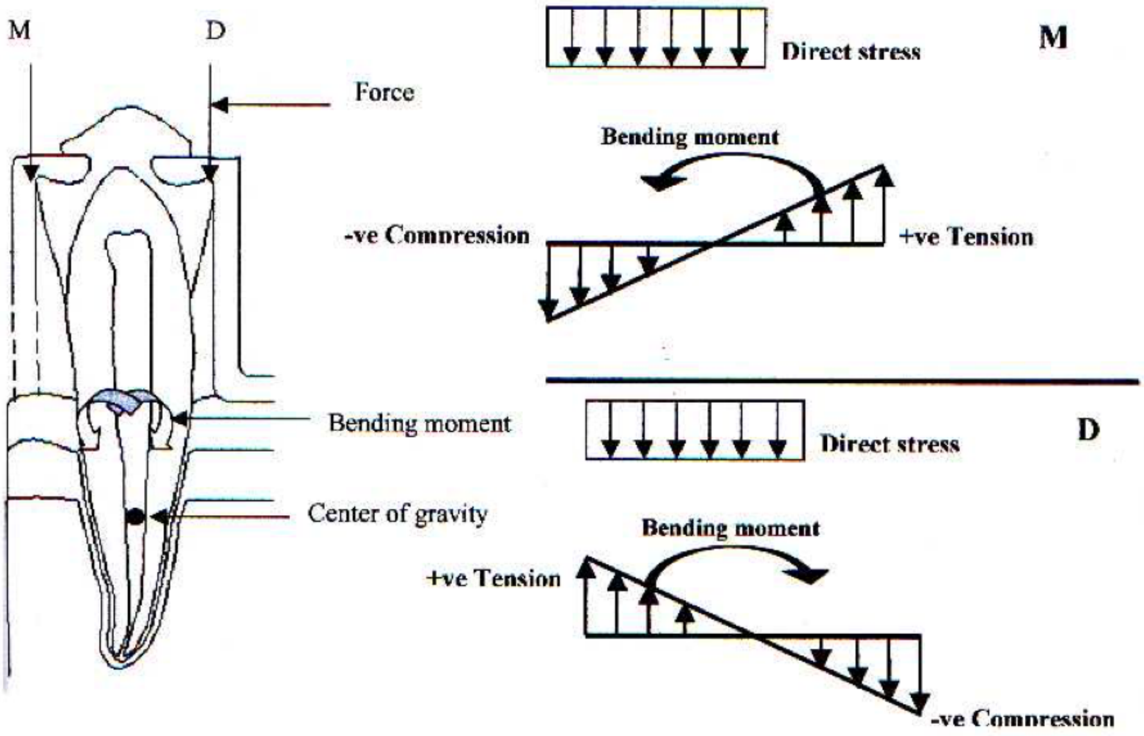


Figure (3) Distribution of the equivalent Von Mises stress contour for the mesio-distal rest design.



Figure(4) schematic drawing of type of stresses generated from loading the tooth.

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