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A 3D FINITE ELEMENT ANALYSIS OF THE EFFECT OF SPLINTING IN FIXED PARTIAL DENTURES WITH ABUTMENTS HAVING COMPROMISED PERIODONTIUM

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ABSTRACT Fixed Partial dentures are an excepted form of management for missing teeth where the retainers are placed on abutment teeth. Splinting of multiple abutments to overcome mechanical problems of long edentulous span or loss of bone support of abutments is often required.
Finite element method was used to assess if multiple abutments in fixed prosthesis modifies the stresses and deflections in cases where splinting is required due to compromised periodontium.
There was reduction in stress and deflection of supporting structures when a fixed prosthesis was fabricated and teeth were splinted together as 4, 5 or 6 unit FPD in reduced bone support models. This was not proportional with any increase in number of units. It was concluded that increasing the number of abutments does not proportionately decrease the stress on the periodontium..

KEYWORDS : fixed partial dentures, finite element analysis, splinted abutments

Introduction

Photoelastic studies and Finite element analysis are amongst various modern research tools that have been used for analysing stresses in biological systems. In situations involving asymmetries it is appropriate to use a three dimensional FEM model that provides an actual representation of stress behaviour in the structure analysed.[1,2]

In patients with partial edentulism, Fixed partial dentures are amongst the treatment of choice when abutment teeth are present. These restorations are luted or otherwise securely retained to natural teeth, and or implant abutments that furnish support for the prosthesis. The basis of abutment selection for fixed partial dentures has been Ante's law which suggests that the root surface area of the abutment teeth should be equal to or greater than that of the teeth being replaced.[3]

Factors that influence the longevity of a fixed partial denture include occlusion, span length and the quantity and quality of periodontium around the abutment teeth.[4] Excessive flexing of long span bridges varies with the cube of the length of the span. This engineering tool was used in the present study to analyse the stress and deflection behaviour in different fixed partial dentures and aimed to analyse the stress levels in the teeth and supporting structures of an FPD and also to analyse and predict the effect of addition of multiple abutments in an FPD with reduced abutment bone support compared to normal bone support.

Materials and methodology

The structure considered for the finite element analysis was of a fixed partial denture replacing mandibular second premolar and adjacent first molar. The FEM model created wasfor an FPD to replace missing mandibular second molar and adjacent second premolar. Abutment teeth considered were from lower canine to third molar. A 3D geometric model of the FPD and its supporting structures was formed as per wheeler's textbook of tooth morphology (Fig 1). The normal crown root ratio was taken as 1:2.[5] A four unit FPD was designed to represent the standard model. Variation for the model was brought about by increasing the number of units (splinting) to 5 and 6 unit bridges and reducing the bone support to a crown root ratio of 1:0.7.[5]

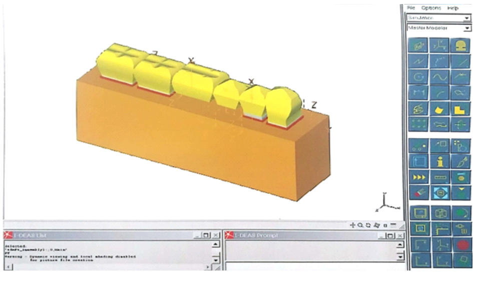

FIGURE 1

The following 5 models were considered.
NN:- Normal bone support without restoration
RN:- Reduced bone support without restoration
R4 :- Four unit FPD with reduced bone support (no splinting)
R5 :- Five unit FPD with reduced bone support (splinted canine)
R6 :- Six unit FPD with reduced bone support (splinted canine and third molar)

The 3D FEM corresponding to the geometric model was generated using the meshing tool of the Ideas 8 software. The structure was idealized using isoparametric 4 noded solid elements having 3 degrees of freedom in X Y and Z direction. The finite element model included cast Ni- Cr crown, tooth periodontal ligament and bone. The meshed model was then exported to ANSYS software format to apply the boundary conditions, loads and thereby conduct the analysis.(Figure 2)

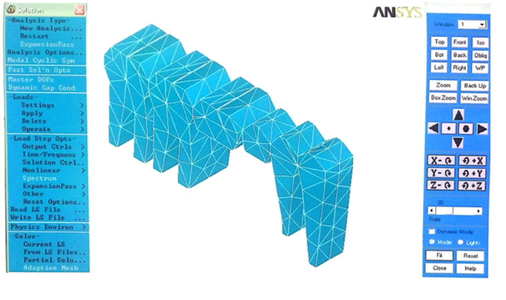

FIGURE 2

Boundary conditions : in all the models the lower border of the mandible is constrained against displacement, the mesial and distal borders are free to move in the mesiodistal direction, displacement in the facial direction was also constrained.[6]

Material properties : values are assigned to the different materials included in the model based on published data.[3,7,8] (table 1) all materials are assumed to be homogenous isotropic and linearly elastic.

TABLE 1 MECHANICAL PROPERTIES OF MATERIALS

MATERIAL	YOUNGS MODULOUS Kg/cm^2	POISSON RATIO
Ni-Cr crown	2.16 x 10^6	0.33
Dentin	2.14 x 10^6	0.31
PDL	7.03 x 10	0.45
Compact Bone	1.45 x 10^5	0.30
Cancellous Bone	2.15 x 10^3	0.30

A 2 kg biting force was applied on all the cusps of the occlusal surface of each tooth and prosthesis based on previous studies.[9,10] ANSYS software was used to analyse the deformation pattern and stress distribution in the structure.

The maximum compressive, tensile and Von mises stresses in each model were calculated. The mesiodistal and apical deflections were also noted.

Results

The study evaluated the stress distribution and deformation of 4 FE models.

DEFLECTIONS (Figure 3)

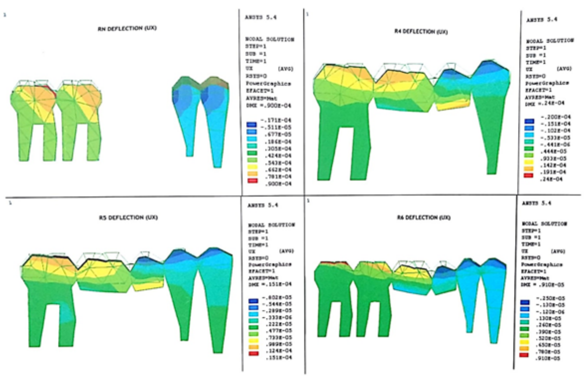

FIGURE 3

The Mesiodistal and apical displacement in microns of the pontic and abutments subjected to the vertical loading are shown in table 2

TABLE 2. –DEFLECTION IN MICRONS

LOCATION	DIRECTION	NN	RN	R4	R5	R6
III MOLAR	MESIODISTAL	30	90	24	15	9
	APICAL	37	52	45	43	38
II MOLAR	MESIODISTAL	26	70	19	10	7.5
	APICAL	30	41	42	41	43
I MOLAR PONTIC	MESIODISTAL	-	-	18.5	9	5
	APICAL	-	-	52	42	44
II PREMOLAR PONTIC	MESIODISTAL	-	-	19	8	3
	APICAL	-	-	54	43	43
I PREMOLAR	MESIODISTAL	11	17	20	8	2
	APICAL	19	23	58	40	41
CANINE	MESIODISTAL	11	18	21	8	2.5
	APICAL	18	21	27	37	36.5
DEFLECTION MAXIMUM		37.3	90	58.4	43.7	44.7

Displacement of third molar in NN & RN was 30 & 90 microns respectively and when included in R6 deflection was reduced by 90 %.

Second molar deflections in R4, R5 and R6 compared to RN showed a reduction of 73%,85% & 89% respectively and in R4 compared to R5 and R 6 reduction was 47% & 61%. In R6 26% lesser deflection then R5 was seen.

First premolar deflections in R4 increased by15% compared to RN. Additional spinting as in R5 and R6 compared to RN showed a reduction of 53% & 88% respectively and in R4 compared to R5 and R6 reduction was 60% & 90%. In R6 75% lesser deflection then R5 was seen.

Canine deflections in R5 and R6 compared to RN showed a reduction of 55% & 86% respectively and comparing R5 and R6 reduction was 68%.

Stresses

The Von mises, compressive and tensile stresses were noted in the different regions of the model assembly and are presented in table 3

MAXIMUM STRESSES (Figure 4)

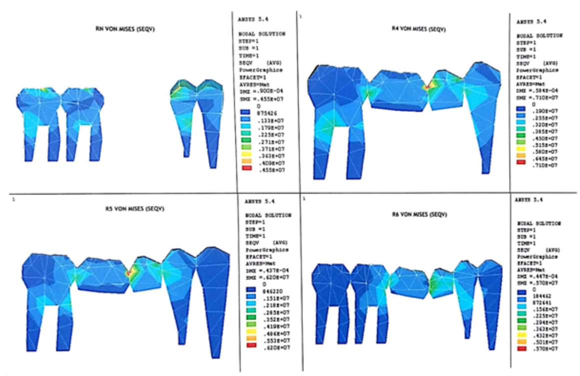

FIGURE 4

TABLE 3

DESIGN	STRESS	BONE	PDL	TOOTH	PROSTHESIS
NN	Von mises	0.683E7	0.340E6	0.460E7	-
	Compressive	0.768E7	0.367E6	0.485E7	-
	Tensile	0.464E7	0.141E6	0.179E7	-
RN	Von mises	0.954E7	0.580E6	0.455E7	-
	Compressive	0.107E8	0.604E6	0.480E7	-
	Tensile	0.606E7	0.254E6	0.285E7	-
R4	Von mises	0.927E7	0.540E6	0.710E7	0.132E8
	Compressive	0.104E8	0.627E6	0.745E7	0.175E8
	Tensile	0.658E7	0.254E6	0.355E7	0.170E8
R5	Von mises	0.889E7	0.435E6	0.620E7	0.175E8
	Compressive	0.999E7	0.480E6	0.630E7	0.213E8
	Tensile	0.649E7	0.197E6	0.390E7	0.221E8
R6	Von mises	0.887E7	0.446E6	0.570E7	0.174E8
	Compressive	0.995E7	0.514E6	0.605E7	0.209E8
	Tensile	0.623E7	0.214E6	0.360E7	0.230E8

Crown stresses

The highest value of stresses was noted in the connector areas of the prosthesis. High compressive stresses were noted in the occlusal surface of rigid connectors and peak tensile stresses were noted towards the gingival surface of connectors. A gradual increase in stresses was observed in the prosthesis as the number of abutments increased. The maximum stress was seen in the connector region between the pontics.

Periodontal ligament stresses

The maximum Von mises stress in the NN,RN, R4, R5 & R6 models were 0.34MPa, 0.58MPa, 0.54MPa, 0.43 Mpa and 0.44MPa. The maximum von mises stress reduced by 7% in case of R4 compared to RN. R5 and R6 showed decrease in stress of 25% & 24% compared to that of RN. R5 showed 21% less stress compared to R4 however R6 had 2% more stress than R5. The periodontal ligament stresses show an initial decrease as the unrestored condition is restored by 4 and 5 unit FPD however there is a slight increase in stress of the 6 unit FPD when compared to the 5 unit prosthesis.

Tooth stresses

In the teeth the maximum stresses are seen in the cervical dentin area near the edentulous ridge. The distal region of the teeth showed greater stress then the mesial surface of the teeth. Increasing the number of abutments gradually decreased the maximum stresses generated in the dentin of the abutments.

Bone stresses

Relatively high stresses were generated along the cortical bone. The highest stresses in the bone were found around the root Apex. The Von mises stresses in RN, R4, R5 & R6 was 9.54,9.27, 8.89, 8.87 MPa respectively.

Discussion

Finite element method of stress analysis was used to analyze stresses and deflections bought about by restoring dentition with fixed partial dentures of spans ranging from 4 to 6 units with reduced crown root ratio of 1:0.7. If abutments are healthy, the edentulous span is short, and prosthesis is well designed an FPD provides long term management to the patients. Splinting of abutment teeth is believed to act by distributing and redirecting functional and para functional forces to bring them within the tolerance of the supporting tissues and to eliminate mobility.[11] A long span FPD places increased loads on the periodontium when compared to the short span FPD. Excessive flexing of the long span under these loads can cause failure. It is common clinical occurrence for teeth adjacent to edentulous spaces to drift or tilt toward the space. The mesiodistal deflection is more significant than the apical deflection in cases of FPD.[6] Splinting strengthens teeth that have weakened owing to loss of alveolar bone[12] ;it spreads the, workload over more area of root surface and alveolar bone surface,reduces deflections[5] and inhibits mobility of teeth.[13] Periodontal diseases compromises alveolar bone support. Clinical crown root ratios become altered, resulting in longer clinical crowns and shorter root component in the alveolus. The occlusal work load gets magnified as the centre of rotation of the tooth becomes high in comparision to the decresed alveolar bone support. This uneven stress often exceeds the tolerence of the supporting periodontal and alveolar tissues, and the teeth may become mobile.This study shows a reduction in the deflections and overall stress in the Periodontal ligament of the abutments used in the FPD when compared to the freestanding unrestored cases similar to previous photoelastic studies.[14] However there is no proportionate reduction in the stress on the Periodontal ligament by increasing the number of abutments. The stress concentration was seen in connector areas which should be managed by making them as bulky as possible to ensure optimum strength.[15]

Limitations of the study.

Inconsistencies in the 3D model are possible as biological tissue do show variation between individuals. The physical property of the biomaterial may limit the accuracy of the results.

Individual variables of tooth preparation[16], occlusion, intercuspal position[17] which are required for a successful FPD have not been considered in the study.

Though a minimum crown root ratio recomended is 1:1 studies indicate that long term maintenance of teeth treated with periodontal therapy can serve as successful abutments in an FPD inspite of severe bone loss.[18,19]. Further studies with variables of crown root ratio and alveolar bone loss correlated with clinical trials would be ideal to guide the dentist in selecting abutment teeth and the amount of splinting required.

Conclusion

Within the limits of the study it can be concluded that though loss of bone support increases stress and deflections, rehabilitation with FPD reduces the stresses and deflection in supporting tissue in cases with reduced bone support. Increasing the number of splinted abutments does reduce the stresses on the periodontium however not proportional to the increase in number of abutments by splinting

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