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Prosthodontics

EFFECT OF SPLINTING IN FIXED PARTIAL DENTURE- A 3D FINITE ELEMENT ANALYSIS

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ABSTRACT Fixed Partial dentures often require splinting of multiple abutments to overcome mechanical problems of long edentulous span or loss of bone support of abutments.
The study analysed stress levels in teeth and supporting structures in fixed prosthesis by Finite element method to assess how multiple abutments in fixed prosthesis modifies the stresses and deflections.
The stress and deflection was reduced in the supporting structures when a fixed prosthesis was fabricated and teeth were splinted together as 4, 5 or 6 unit FPD however by increasing the abutments the reduction of stress on the periodontium was not proportional. Stress concentrations were observed in the connector area and cervical tooth area adjacent the edentulous ridge. It was concluded that the mechanical problems of a long span FPD can not be completely managed by increasing the number of abutments.

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

Introduction

Fixed partial dentures are restorations 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.[1]

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.[2] Excessive flexing of long span bridges varies with the cube of the length of the span. Various modern research tools that have been used for analysing stresses in biological systems include Photoelastic studies and Finite element analysis. 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.[3,4] 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 normal abutment 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 model consisted of abutment teeth from lower canine to third molar with second premolar and first molar as pontics. A 3D geometric model of the FPD and its supporting structures was formed as per wheeler's textbook of tooth morphology. The 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.

The following 4 models were made.
NN:- normal bone support without restoration
N4:-Four unit FPD with normal bone support (no splinting)
N5:- Five unit FPD with normal bone support (splinted canine)
N6:- Six unit FPD with normal 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.

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	2.16×10^6	0.33
Dentin	2.14×10^6	0.31
PDL	7.03 x 10	0.45
Compact Bone	1.45×10^5	0.30
Cancellous Bone	2.15×10^3	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] 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

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	N4	N5	N6
III MOLAR	MESIODISTAL	30	16	11	8
	APICAL	37	38	37	33
II MOLAR	MESIODISTAL	26	14	9	7
	APICAL	30	38	37	35
I MOLAR PONTIC	MESIODISTAL	-	12	7	3
	APICAL	-	41	39	38
II PREMOLAR PONTIC	MESIODISTAL	-	10	5.5	1.5
	APICAL	-	42	38	35
I PREMOLAR	MESIODISTAL	11	10	3	1.2
	APICAL	19	41	34	34
CANINE	MESIODISTAL	11	11	3	1
	APICAL	18	40	29	30
DEFLECTION MAXIMUM		37.3	42.2	39.1	38.1

Displacement of third molar in NN was 30 microns and when included in N6 deflection was reduced by 73%.

Second molar deflections in N4, N5 and N6 compared to NN showed a reduction of 46%,65% & 73% respectively and in N4 compared to N5 and N6 reduction was 35% & 50%. In N6 22% lesser deflection then N5 was seen.

First premolar deflections in N4, N5 and N6 compared to NN showed a reduction of 9%,72% & 89% respectively and in N4 compared to N5 and N6 reduction was 70% & 88%. In N6 60% lesser deflection then N5 was seen.

Canine deflections in N5 and N6 compared to NN showed a reduction of 55% & 90% respectively and comparing N5 and N6 reduction was 66% .

Stresses

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

TABLE 3 MAXIMUM STRESSES

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	-
N4	Von mises	0.862E7	0.340E6	0.610E7	0.124E8
	Compressive	0.966E7	0.390E6	0.630E7	0.130E8
	Tensile	0.600E7	0.180E6	0.325E7	0.173E8
N5	Von mises	0.840E7	0.316E6	0.575E7	0.132E8
	Compressive	0.940E7	0.367E6	0.604E7	0.136E8
	Tensile	0.591E7	0.152E6	0.370E7	0.143E8
N6	Von mises	0.817E7	0.333E6	0.564E7	0.178E8
	Compressive	0.915E7	0.384E6	0.580E7	0.190E8
	Tensile	0.555E7	0.164E6	0.390E7	0.210E8

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, N4, N5 & N6 models were 0.34MPa, 0.34MPa, 0.31MPa, and 0.33 MPa. There was no change in the Von mises stresses in NN compared to N4. N5 and N6 showed decrease in stress of 8% & 3% compared to that of NN. N5 showed 7% less stress compared to N4 however N6 had 6% more stress than N5. 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 NN, N4, N5 & N6 was 6.83, 8.62, 8.4, & 8.17 MPa respectively.

Discussion

An FPD is an established treatment modality and gives a long life of function especially if the abutments are healthy, the edentulous span is short, and the prosthesis is well designed. Splinting by increasing the number 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.[10] 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. This study used the finite element method of stress analysis to analyze stresses and deflections bought about by restoring dentition with fixed partial dentures of spans ranging from 4 to 6 units with normal crown root ratio of 1:2. 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[11] ;it spreads the, workload over more area of root surface and alveolar bone surface and inhibits mobility of teeth.[12] 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 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.[13]

Limitations of the study.

Construction of the 3D model may not be truly consistent 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[14], occlusion, intercuspal position[15] which are required for a successful FPD have not been considered in the study.

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 rehabilitation with FPD reduces the stresses and deflection in supporting tissue, increasing the number of splinted abutments does not proportionately reduce the stresses on the periodontium.

REFERENCES

1. Ante I H.The fundamental principles of abutments.Mich state Dent Soc Bull 1926;8:14-23
2. Sigvard Palanquist, Bjorn Soderfolldt. Multivariate analysis of factors influencing the longevity of Fixed partial denture, retainer and abutments. J Prosthet Dent 1994; 71:245-50.
3. Farah JW, Craig RG , Meroueh KA Finite element analysis of three – and four-unit

bridges . J Oral Rehabil . 1989 Nov ;16(6):603-11.

4. Huiskes R, Chao EY. A survey of finite element analysis in orthopedic biomechanics :the first decade.J Biomech.1983;1696):385-409.J Prosthet Dent. 2001 May;85(5):455-60.
5. Yang, Lang and Felton. Finite element analysis on the effect of splinting in fixed partial dentures. J Prosthet Dent 1999;81:721-8.
6. Augereau D,Pierrisnard L,Barquins M. Relevance of the finite element method to optimize fixed partial denture design. Part I. Influence of the size of the connector on the magnitude of strain. Clin Oral Investig. 1998 Mar; 2(1):36-9.
7. Rees JS. An investigation into the importance of the periodontal ligament and alveolar bone has supporting structures in finite element studies. J Oral Rehabil. 2001 May;28(5):425-32.
8. Grenoble DE, Katz JL,Dunn KL,Murty KL,Gilmore RS. The elastic properties of hard tissue and appetites. J Biomed Mater Res 1972;6:221-233
9. Lundgren D, Laurell L. Occlusal force pattern during chewing and biting in dentitions restored with fixed bridges of cross-arch extension. I. Bilateral end abutments. J Oral Rehabil. 1986 Jan;13(1):57-71.
10. Siegel SC, Driscoll CF, Feldman S. Tooth stabilization and splinting before and after periodontal therapy with fixed partial dentures:Dent Clin North Am. 1999 Jan; 43(1):45-76.
11. Yang HS, Thompson VP. A two-dimensional stress analysis comparing fixed prosthodontic approaches to the tilted molar abutment. Int J Prosthodont. 1991 Sep-Oct;4(5):416-24
12. Wylie RS, Caputo AA. Fixed cantilever splints on teeth with normal and reduced periodontal support. J prosthet Dent. 1991 Dec;66(6):737-42.
13. Yang HS, Chung HJ, Park YJ. Stress analysis of a cantilevered fixed partial denture with normal and reduced bone support : J Prosthet Dent. 1996 Oct;76(4):424-30.
14. Jacobi R, Shillingburg HT Jr, Duncanson MG Jr. Effect of abutment mobility, site ,and angle of impact on retention of fixed partial dentures. J Prosthet Dent . 1985Aug;54(2):178-83.
15. Nyman S, Lindhe J and Lundgren D. The role of occlusion for the stability of the fixed bridges in patients with reduced periodontal tissue support. J Clin Periodontol. 1975 Apr;2(2):53-66.