IOSR Journal of Dental and Medical Sciences (IOSR-JDMS)
e-ISSN: 2279-0853, p-ISSN: 2279-0861.Volume 16, Issue 7 Ver. VII (July. 2017), PP 10-17
www.iosrjournals.org

The Role of Cuspal Flexure And the Weakening Effect of occlusal Amalgam Restoration in the Development of Abfraction Lesions – A Finite Element Study

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Abstract: *The pathogenesis of 'abfraction' has been considered to be multifactorial with contributions from occlusal loading becoming increasingly prominent in recent years. The objective of this study was to find out whether the presence of an extensive occlusal amalgam restoration and eccentric parafunctional loads would cause increased cuspal movement and therefore, increase in cervical stress exceeding the failure stress of enamel, capable of initiating tooth substance loss. Materials and Method: Two-dimensional finite element models (FEM) of maxillary premolar having variations in the size of an occlusal amalgam restoration were generated and the cervical stress profile under eccentric occlusal loads ranging from 10-100N were analysed using the ANSYS finite element stress analysis software package. Results: The mean cervical shear stress value for an intact premolar did not exceed the failure stress of enamel under the normal functional occlusal load of 10-70 N, but, with deep and wide occlusal amalgam restorations,the values exceeded the failure shear stress of enamel even at the normal functional occlusal load. Conclusion: The present investigation shows that in patients having excessive occlusal loads like bruxism and malocclusion and with increased dimensions of the occlusal cavity for amalgam restorations, the chances of developing abfraction lesions are more.*

Keywords: *abfraction, occlusal restoration, cuspal flexure, bruxism finite element study.*

I. Introduction

Non- carious cervical lesions (NCCL), which is characterized by the loss of dental hard tissue at the cemento-enamel junction (CEJ), is a condition commonly encountered in clinical practice, with prevalence reports ranging from 5-85%[1]. Historically, the loss of cervical enamel and dentin has often been attributed to the effects of abrasion, particularly the effect of toothpaste particles. More recently, its pathogenesis has been considered to be multifactorial with contributions from occlusal loading, erosion and abrasion[2], with occlusal loading becoming increasingly prominent in recent years. It has been proposed that occlusal loads cause the cusp to flex and this generates stresses in the cervical region of the tooth. These stresses may cause disruption of the bonds between the hydroxyapatite crystals leading to enamel loss[3]. This type of hard tissue loss at the cemento-enamel junction has been termed "ABFRACTION" by Grippo [4] to distinguish it from lesions caused by erosion and abrasion.There is some clinical evidence for the association of abfraction lesions with heavy occlusal loads. Xhonga (1977)[5] found the prevalence of these lesions to be significantly higher in patients who were bruxists. Lambrechts et al (1987)[6] found that bruxism and malocclusion were associated with abfraction lesions.These defects were also seen more commonly on anterior teeth and premolars, possibly because these smaller teeth were less able to withstand the applied occlusal loads. A recent clinical study also found that abfraction lesions are found six times more commonly in patients who have a group function type of occlusion compared to a canine-guided occlusion[7].Various invitro biomechanical studies have demonstrated the weakening effect of cavity preparations on teeth (Hood 1991[8], Burke 1992[9]). These studies showed that the progressive removal of tooth substance during cavity preparation led to increased cuspal flexure under occlusal loads. Many studies have shown that the general effect of cavity preparation was to reduce the resistance of teeth to fracture. It is therefore possible that teeth with occlusal restorations may be at a greater risk of developing abfraction lesions.So this study was conducted to investigate the shear stress profile in the buccal cervical region of an intact maxillary second premolar and with variations in the size of an occlusal amalgam restoration, under functional and para functional eccentric occlusal loads, using two-dimensional plane strain finite element modeling & stress analysis.The objective of this study is to find out whether the presence of an extensive occlusal amalgam restoration and eccentric parafunctional loads would cause increased cuspal movement and therefore, increase in cervical stress exceeding the failure stress of enamel, capable of initiating tooth substance loss.

II. Materials And Methods

An upper left second permanent premolar tooth, which was extracted for orthodontic purpose, was taken for this study. The tooth was sectioned longitudinally along the central bucco-lingual plane using a diamond disk.

Finite Element Modeling Procedure-

1.Design modeling :- Generation of a geometric model (tooth profile) represented by co-ordinate numbers.

The co-ordinates of the tooth profile were obtained by mounting the sectioned tooth on the Universal Measuring Microscope (UMM, Carlzeiss, GDR, Germany) (Fig-1). The outline of each layer of the tooth was viewed through the microscope and key point numbers were obtained by measuring the x and y co-ordinates of each point which was 0.2mm apart. Total numbers of co-ordinates in the tooth profile was 802.

The finite element tooth modeling & stress analysis were done using the ANSYS finite element software in a windows 2000 based personal computer (IBM Pentium IV) in the Department of Biomechanics, NIT, Calicut, Kerala, India.

The profile of the tooth (fig.2) with the key point numbers was generated in the ANSYS finite element analysis software package by entering the corresponding co-ordinates.

Next, the tooth profile was divided into various areas (Fig.3) and each area was given the respective material properties (as given in Table -1). The area for each material was selected by entering the co-ordinate numbers of each layer (A1-enamel, A2-dentin, A3-pulp, A4-periodontal ligament and A5-alveolar bone) in the computer. Because pulp was modeled as a void, the area of both dentin & pulp was taken together and then the area of the pulp was subtracted.

2.Simulation :- The conversion of the tooth profile into a Finite Element Model (FEM). This procedure involves two steps –

- Meshing
- Giving Boundary Conditions.

The process of generating the FEM from the geometric model is called MESHING. In this study, meshing was done for each area using elements and nodes. The outline of the tooth, dentino-enamel junction (DEJ) and pulp were represented in the finite element model(obtained from the tooth profile). The thickness of the periodontal ligament and surrounding cortical bone were derived from standard textbooks[13] to be of 0.3 mm each. The pulp was modeled as a void [14]. Thus, a two-dimensional plane strain finite element mesh of the maxillary second premolar (Fig.4) was developed from the geometry of the tooth using the ANSYS finite element package. The mesh contained 3867 eight-noded isoparametric quadrilateral elements and 12,165 nodes (Fig.5).

After meshing, the BOUNDARY CONDITIONS were linked to the finite element model to complete the modeling procedure. In this study, the boundaries were rigidly fixed beyond the cortical bone in the X and Y directions, to restrict the freedom of movement beyond that area. For this, each node along the border is selected one by one and fixed in both directions by selecting a degree of freedom of zero. The total number of nodes restricted was 552.

The finite element modeling and meshing was done for all the six designs used in this study, which was previously mentioned. The tooth profile was modified by drawing the various design used in this study. The methods of standardization of the various designs are described below. Finite Element Modeling Of The Various Designs Used In This Study(Fig-6).

Design 1 :- Intact premolar. The procedure was as described above.

Design 2:- Tooth with narrow width and shallow depth occlusal class 1 amalgam restoration. For standardizing the depth of the cavity, the nodal point below the central groove of the tooth, which was 0.2mm below the dentinoenamel junction (DEJ) was taken. The total depth measured from buccal wall was 1.7mm. For standardizing the width of the cavity, the key point (co-ordinate) numbers and nodal numbers at the buccal and lingual cusp tips were taken and distance between these two nodes was measured. It was found to be 5.4mm. The width of the ideal cavity was one-fourth the intercuspal distance i.e., 1.4mm. To simulate the occlusal convergence of the cavity for amalgam restoration, two nodes 0.2mm on each side of the floor of the cavity was taken i.e., width at the base of the cavity was 2.2mm. All the selected nodal points were joined by lines and the line angles at the base of the cavity was rounded off to prevent stress concentration.

Design 3:- Tooth with medium width and shallow depth occlusal class 1 amalgam restoration. Here the depth was kept as same as that of design 2. For medium width, one-third intercuspal distance was taken i.e., 1.8mm. The width of the base of the cavity was also increased by selecting two nodal points 0.2mm lateral on both sides.

Design 4:- Tooth with very wide and shallow depth occlusal class 1 amalgam restoration.

The depth was kept same as design 2&3. The width was increased to half of the intercuspal distance i.e., 2.7mm.

Design 5:- Tooth with narrow width and medium depth occlusal class 1 amalgam restoration.
In this, the width was same and as that of the design 2. The depth was increased by 0.5mm from design 2, i.e., 0.7mm from the DEJ. Total depth measured from the buccal wall was 2.2mm.
Design 6:- Tooth with narrow width and very deep occlusal class 1 amalgam restoration. In this model also, the width was the same as design 2&5. The depth was increased by 0.5mm from design 5 i.e., 1.0mm from the DEJ. Total depth was 2.7mm when measured from the buccal wall.
All the steps which were mentioned before, like drawing the tooth profile, assigning areas, giving material properties, selecting element size, meshing and giving boundary conditions were done for each of the FEM designs.

Finite element stress analysis
Next step was the solution of the finite element model after the application of various load conditions. The software generates the required set of equations (normally partial differential equations) describing the problem. The software performs a series of quality checks on the model to establish its validity and correctness. Subsequent to this verification stage, the software proceeds to solve the set of equations based on the boundary conditions.In this study, the model was loaded with loads starting from 10 Newton and increasing by 10 N increments up to a load of 100 N. The load was applied at 45^o angle to a point 0.4mm inside the buccal cusp tip to simulate the effect of tooth contact in a lateral excursive movement (Fig-7).The shear stresses in the buccal cervical region were sampled along two horizontal planes. The first plane A-A was 1.6mm occlusal to the cementoenamel junction and the second plane B-B was 0.3 mm occlusal to the cementoenamel junction (Fig.8). These sampling planes were chosen because it is still not clear if abfraction lesions begin above or below the cemento-enamel junction. Shear stresses were sampled at two nodal points for each plane (one point in enamel and one point at the dentino-enamel junction), and the mean shear stress calculated in that enamel plane.

III. Results

The cervical shear stress profiles generated for the various FEM designs under an eccentric load of 100N are shown in the Figures-9, 10,11,12,13 & 14. The displacement of the tooth (tooth flexure) can also be seen in the picture – the meshed tooth being the position before cuspal loading.
The results of the shear stress values obtained along the planes A-A and B-B under eccentric occlusal loads of 10N, 20N, 30N, 40N, 50N, 60N, 70N, 80N, 90N and 100N for the FEM designs 1, 2, 3, 4, 5 & 6 are tabulated in Tables 2& 3. The mean peak shear stresses found in the B-B plane of the cervical region of an intact premolar (Design -1) under a normal occlusal load of 10 and 20N were low ie, 20.411 MPa and 40.822 MPa respectively, which was below the reported failure shear stress value of enamel (60 -93 MPa) [15]. The peak stress exceeded the failure stress at a higher load (parafunctional load) i.e., 80N, the stress being 103.366MPa. For the plane A-A, the peak shear stress never exceeded the failure stress of enamel for any of the FEM designs. The maximum value obtained was 49.659 MPa i.e., for the design 6 (narrow width and very deep restoration) under an eccentric occlusal load of 100N.
Figure-15 is the graph showing the mean peak shear stresses in the enamel plane B-B for the designs 1 to 6, under eccentric occlusal loads ranging from 30N to 80N.The failure load at which the mean shear stress exceeded the reported maximum failure shear stress of enamel, for each design, is shown in the graph - 72N for Design 1 intact tooth), 52N for Design 2 (narrow & shallow), 44N for Design 3 (medium wide and shallow), 40N for Design 4 (very wide and shallow), 46N for Design 5 (narrow and medium depth) and 38N for Design 6 (narrow & very deep). The variation in the shear stress along the planes A-A and B-B for a load of 40N is shown in Fig.16. The value of stress for design 6 (narrow & very deep) has exceeded the failure stress (93MPa) in plane B-B. In plane A-A, all the values remained well below the failure shear stress of enamel. It was found that the shear stress increased as the width and depth increased. The mean shear stress value of 17.819MPa found for the narrowest cavity (design 2) for a load of 10 N was higher than that of the intact tooth (design 1) ie,12.921MPa. However, the peak stresses increased to a maximum shear stress of 23.5755 MPa for the widest amalgam cavity (design 4). For variations in cavity depth the increases in peak cervical shear stress were even more marked (25.086 MPa for design 6 with deep cavity) than the increase found with cavity width.

IV. Discussion

The prevalence of non-carious cervical lesions, which are characterized by the loss of dental hard tissue at the cemento-enamel junction, has been variously estimated as between 5% and 85%[1]. This large variation in the prevalence estimates is not too surprising since it is often very difficult to decide upon the precise etiology of the lesion and in many instances, it is likely that the etiology is multifactorial. Through the years, the dental profession has held a variety of theories about the causes of non-carious cervical lesions, including chemical wasting of the teeth, the effects of tooth brushing and lateral forces. More recently, its pathogenesis has been considered to be multifactorial with contributions from occlusal loading, erosion and abrasion (Spranger

1995)[16]; with occlusal loading becoming increasingly prominent in recent years. Grippo (1991)[4] has coined the term 'ABFRACTION' for this type of hard tissue loss at the cemento-enamel junction, produced by eccentric occlusal loading forces. Hagberg (1987)[17] found that teeth are subjected to cyclic occlusal loads of the frequency of about one Hertz during chewing and swallowing every day, with a contact time of 0.2seconds. The occlusal load applied during chewing and swallowing averages around 10-20N ranging upto 70N, but varies according to age, sex and muscular build. However, during parafunction, occlusal loads can exceed these figures. It is also interesting to note that during a 24-hour period, the total time that the teeth are in contact is around 10 minutes. However, for a bruxist this can range from 30 minutes to 3 hours.

Moreover, one current hypothesis by Grippo (1991)[18] is that compressive or tensile strains gradually produce microfractures called ABFRACTIONS in the thinnest region of enamel at the cemento enamel junction (CEJ). Such fractures predispose enamel to loss when subjected to tooth brush abrasion and / or chemical erosion. This process may be key in the formation of some class V defects. Spranger (1995)[16] suggested that occlusal loads contribute to the development of non-carious cervical or abfraction lesions via the effects of cuspal flexure. The loads applied to the teeth in centric occlusion initially cause depression of the tooth into the socket in or near the long axis of the tooth. As the periodontal membrane is only around 0.3mm wide[13], the tooth almost immediately 'bottoms out' in the socket causing the walls of the tooth socket to dilate that begins with loads of less than 10N. Once the root has 'bottomed out' the cusps of the teeth also deform laterally.

In 1983, Mc Coy[19] proposed that bruxing produced most of the destructive forces on tooth structure, and discussed occlusal equilibration as a way to reduce lateral forces.

The lateral movement of the cusps caused by both axial and non-axial loads will generate large stresses in the enamel compared to the dentin. This is because in any loaded system, much of the applied load is' conducted' by the stiffest material with the highest elastic modulus (Jeremy .S. Rees ,2000)[7]. Enamel has a much higher elastic modulus (around 80 Gpa compared to 15 Gpa)[10] and will therefore attract much more of the applied load. However, this may cause problems in the cervical region of the tooth that are thought to initiate crack propagation within the brittle cervical enamel, so that eventually small portions of the enamel break away exposing the underlying dentin (Spranger H, 1995)[16].

The presence of an existing coronal cavity is known to weaken a tooth extensively, particularly when the occlusal isthmus width exceeds one quarter of the intercuspal distance. Hood (1991)[8] has measured the effect that a coronal cavity preparation had on the lateral deformation of the cusps under occlusal load using strain gauges. He applied a vertical load of 30kg (294N) to extracted premolar teeth and reported that the outward horizontal movement of each premolar cusp was in the order of 5 microns for an intact tooth. This lateral deformation was so extensive that cuspal fracture was initiated

Rees JS (2001)[20] investigated the importance of the periodontal ligament and alveolar bone as supporting structures in finite element studies. Therefore in this study the tooth was modeled with the surrounding periodontal ligament and cortical bone.

De Vree JH, Peters MC, Plasschaert AJ (1983)[21] compared the two methods i.e., photo elastic and finite element stress analysis, for determining internal stresses in tooth structure under a specific load condition and found that the sensitivity of the finite element method towards variation of a number of relevant parameters was found to be superior.The results of this study showed that, for an intact premolar (FEM Design 1) the mean shear stress found in the cervical region (B-B plane) were low. When the occlusal load was increased from 10N to 70N shear stress also increased proportionately, but it was below the failure shear stress of enamel.

The data on the failure shear stress of enamel are rather sparse and somewhat diverse, due to the difficulties in obtaining flaw free samples large enough to test. The available values reported by Cooper & Smith (1968)[15] ranges from 64-93 MPa.

If we consider the upper limit i.e., 93MPa as the failure shear stress of enamel, it was seen from the graphical representation (Fig.15) that, for the intact premolar the failure load was above 70 MPa along the enamel plane B-B and it never exceeded the failure stress in plane A-A. This finding correlates with the cervical location of abfraction lesions in clinical situations and the increased prevalence of these lesions in patients having parafunctional habits. Also for a normal functional occlusal load of 20N, the mean shear stress in plane B-B was only 25.842Mpa, which is much lower than the reported ultimate failure stress of enamel. This is not too surprising a finding, since not every premolar develops an abfraction lesion. The occlusal load in patients with parafunctional habits like bruxism, is even higher ranging from 100N to 500N (Hagberg 1987)[17].

In this study, it was seen that for the intact premolar with eccentric occlusal load of 100N the mean shear stress value in the plane B-B was 129.21, which is above the reported ultimate failure shear stress of enamel. This may explain the increased prevalence of abfraction lesions in bruxism patients (Xhonga 1977)[5].

Khan et.al (1999)[22] reported a strong association between cervical lesions and occlusal tooth wear or occlusal erosion, with 96% of teeth with a cervical lesion also having evidence of occlusal pathology.

In this study, occlusal loads ranging from 10 to 100N was used to simulate functional and parafunctional loads. The load was applied at an angle of 45^o to a point. 0.4mm inside the buccal cusps to simulate the effect of tooth contact in a lateral excursive movement.According to Brian Palmer(1997)[23], abfractions are not generally found on teeth of calm, non-stressed individuals with a natural and ideal class 1 occlusion, where the loading forces of the excursive movement will be directed onto the cuspid. Abfractions are frequently found, however, on cases where mal-aligned cuspids causes initial lateral guidance forces to be exerted on the lingual incline of the buccal cusp of the first maxillary bicuspid (or which ever tooth bears the initial lateral guiding force of excursion).

Rees JS (2002)[24] found that a 500N load applied to the inner aspect of the buccal or the lingual cuspal inclines produced maximum principal stress value of up to 358MPa that exceed the known failure stresses for enamel. Similar findings were obtained in this study also which showed that the mean cervical shear stress for an intact tooth at an eccentric load of 100N was 129.21Mpa, which exceeded the failure shear stress of enamel.

For an intact premolar the peak shear stress found in the cervical region were low. When an oclusal restoration was introduced into the model, the peak shear stress increased. Furthermore, the stresses along the plane B-B were higher than the stresses along the plane A-A. The reason for this is probably due to a lever effect; the distance from the occlusal loading point to the sampling plane was greater for plane B-B, resulting in greater stress concentration.For increases in the width of the occlusal amalgam restoration, the stresses increased as the cavity width increased (Fig.15). The peak stresses increased to a maximum shear stress of 165.029 MPa for design 4(wide cavity) which exceeded the failure stress of enamel when compared with 90.447 (design 1 intact tooth) for an eccentric load of 70N.

The reason for this is probably related to the strength of the remaining tooth. Vale (1956)[25] demonstrated that the strength of a prepared tooth was unaffected when the width of a coronal cavity was only one-quarter of the intercuspal distance, but decreased significantly when the width increased to one-third of the intercuspal distance. Vale was attributed with the ‘one-third rule’, which advocates cuspal coverage if the occlusal isthmus width is greater than one-third of the intercuspal distance.

The narrowest cavity in this study was one-quarter intercuspal distance, while the medium width cavity was one-third the intercuspal distance and wide cavity was greater than one–third of the intercuspal distance i.e. one-half of the intercuspal distance (Fig.2 design 2, 3&4). This explains the reason for the increased cervical stresses found in the widest cavity design.For variation in cavity depth, the increase in peak cervical stress was even more marked than obtained width increase in cavity width of the occlusal restoration. The reason for this may be explained by considering the coronal cavity to be acting as a simple cantilever beam. The deflection of this beam (or cusp) and therefore the localized stress that it will generate is directly related to the cube of the cavity depth. Therefore, as the cavity is deepened, the cervical stresses increased dramatically. It is possible that due to this effect, the prevalence of abfraction lesions may be higher in teeth that already have a pre-existing occlusal restoration.The peak shear stress in the B-B plane increased as the depth of the occlusal amalgam restoration increased (Fig.15). The peak shear stresses at load 70N increased to a maximum of 175.602 MPa for design 6(deepest cavity) when compared to 90.447 MPa for design 1 (intact tooth).

The failure load was reduced to a lower level with increase in cavity width and depth; the more marked reduction being for the increase in cavity depth i.e., 38N for design 6(deepest cavity). It is therefore possible that, due to this effect, the chance of developing abfraction lesions may be higher in the teeth that already have a pre-existing occlusal restoration.Similar findings were obtained by Rees (2000)[7]. He examined a lower premolar using a finite element model. He found that oblique loads applied near the cusp tip produced stresses of up to 70MPa that are near the known failure stress of enamel. Similar findings wee obtained in this study also which showed that, for the intact premolar with eccentric occlusal load of 100N the mean shear stress value in the plane B-B was 129.21 which is above the reported ultimate failure shear stress of enamel.Rees Js, Hammadeh M, Jagger DC (2003)[26] studied the biomechanics of abfraction lesion formation in maxillary incisor, canines and premolars using a two – dimensional plane strain, finite element study. They found that the maximum cervical principal stress along a horizontal plane 1.1mm above the amelo-cemental junction was 181.4MPa for the incisor, 25.2MPa for the premolar and 66.8MPa for the canine. In this study also, it was found that the shear stress along the horizontal plane 1.6mm above the amelo-cemental junction was 16.934MPa for the maxillary premolar, which is in agreement to the above finding.

Figures and Tables

Table-1:- Material Properties Used For The Finite Element Modeling.

Material	**Reference**	**Elastic modulus (MPa)**	**Poisson's ratio**
Enamel	Rees & Jacobsen (10)	80,000	0.30
Dentin	Rees & Jacobsen (10)	15, 000	0.31
Compact bone	Rees (11)	13,800	0.26
Periodontal ligament	Rees & Jacobsen (11)	50	0.49
Amalgam	Bryant & Mahler (12)	52,400	0.30

Table-2 :- Mean Shear Stress At The Enamel Planes B-B
For The FEM Design –1,2,3,4,5&6

	Mean Shear Stress (Mpa)					
Load (N)	**Design1**	**Design2**	**Design3**	**Design4**	**Design5**	**Design6**
10	12.921	17.819	20.763	23.5755	20.411	25.086
20	25.842	35.638	41.526	47.151	40.822	50.172
30	38.763	53.457	62.298	70.7265	61.233	75.258
40	51.684	71.276	83.052	94.302	81.644	98.844
50	64.603	89.095	103.815	117.878	102.055	125.43
60	77.527	106.914	124.578	141.453	122.466	150.516
70	90.447	124.733	145.341	165.029	142.877	175.602
80	103.366	142.552	166.104	188.604	163.288	200.688
90	116.291	160.371	186.867	212.18	183.699	225.774
100	129.21	178.19	207.63	235.755	204.11	250.86

Table-3 :- Mean Shear Stress At The Enamel In Planes A-A
For The Fem Design –1,2,3,4,5&6

Load (N)	**Mean Shear Stress (Mpa)**					
	Design1	**Design2**	**Design3**	**Design4**	**Design5**	**Design6**
20	3.3867	6.5906	7.935	9.592	7.9089	6.5261
30	5.0801	9.8859	11.9025	14.388	11.8634	14.8976
40	6.7734	13.1812	15.87	19.1834	15.8178	19.8634
50	8.4668	16.4765	19.8375	23.9793	19.7723	24.8293
60	10.1601	19.7718	23.805	28.7751	23.7267	29.7951
70	11.8535	23.0671	27.7725	33.571	27.6812	34.761
80	13.5468	26.3624	31.74	38.3668	31.6356	39.7268
90	15.2402	29.6577	35.7075	43.1627	35.5901	44.6927
100	16.934	32.953	39.675	47.959	39.545	49.659

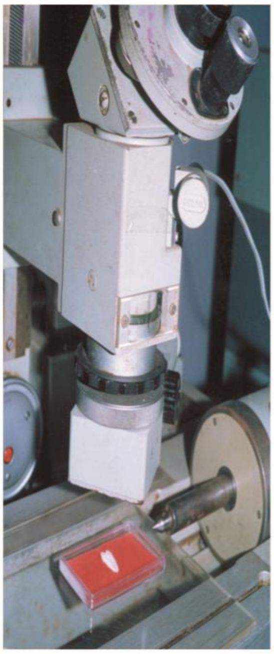


Fig. 1 - Buccolingual section of the upper second premolar tooth mounted on the Universal Measuring Microscope

Fig. 3 - Personal Computer Pentium IV with ANSYS finite element stress analysis software package

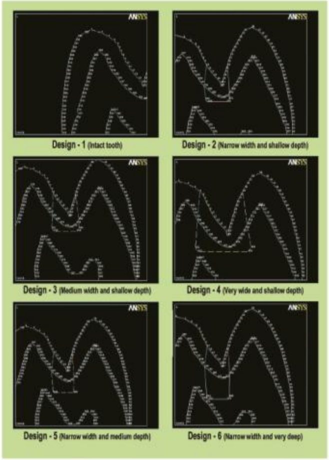


Fig. 4 - Finite Element Model (FEM) designs used in this study showing the Key Point Numbers

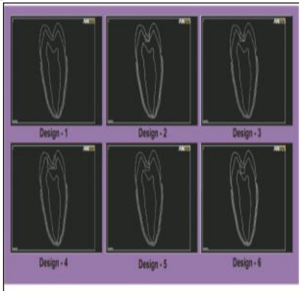


Fig. 5 - Tooth profiles generated in the ANSYS

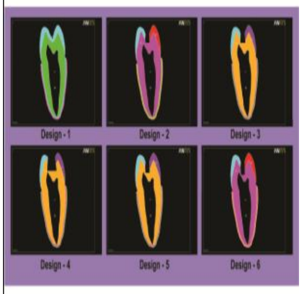


Fig. 6 - Designing Areas

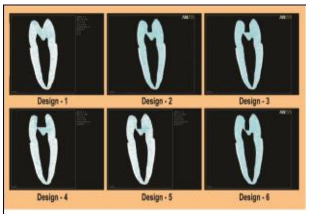
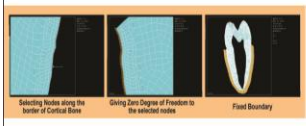


Fig. 7 - Finite element meshing (FEM) with elements and nodes

Fig. 8 - Close up of FEM at Cementoenamel Junction showing Elements and Nodes


Selecting Nodes along the border of Cortical Bone

Giving Zero Degree of Freedom to the selected nodes

Fixed Boundary

Fig. 9 - Giving boundary conditions

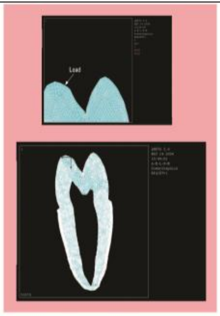


Fig. - 10 Application of Load 0.4mm inside the buccal cusp of the Finite Element Model

Fig. - 11 Position of Stress Analysis Planes A-A and B-B

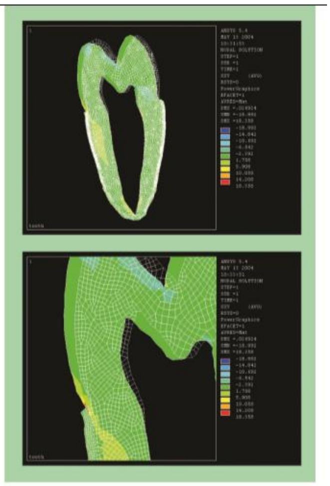


Fig. - 12 Shear stress pattern for FEM Design - 1 (Intact Tooth)
Under an eccentric load of 10 N
(Unmeshed outline - position after Cuspal flexure)

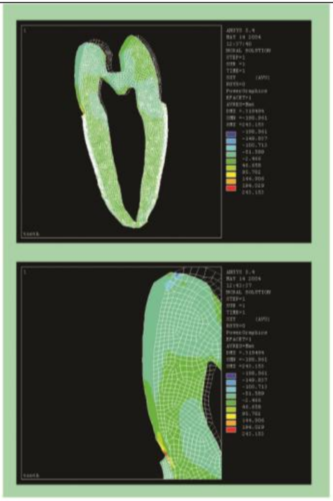


Fig. - 13 Shear stress pattern for FEM Design-2 (Narrow width and Shallow depth)
Under an eccentric load of 100 N

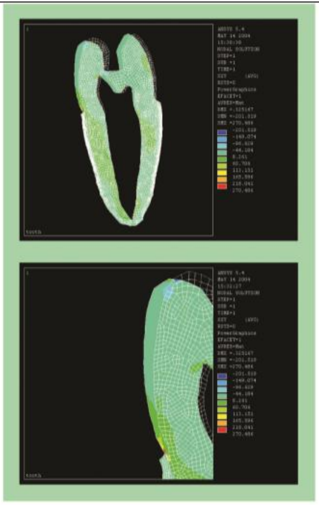


Fig. - 14 Shear stress pattern for FEM Design-3 (Medium width and Shallow depth)
Under an eccentric load of 100 N

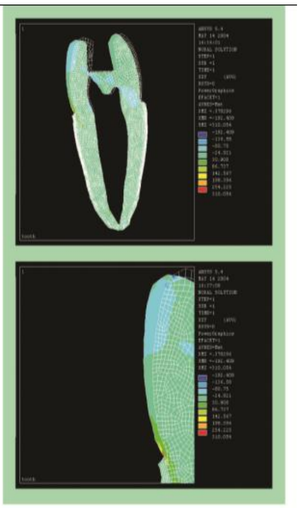


Fig. - 15 Shear stress pattern for FEM Design-4 (Very wide and Shallow depth)
Under an eccentric load of 100 N

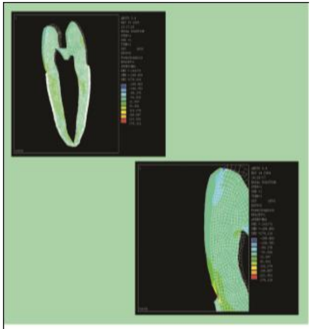


Fig. - 16 Shear stress pattern for FEM Design-5 (Narrow width and Medium depth)
Under an eccentric load of 100 N

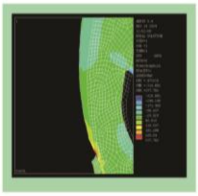
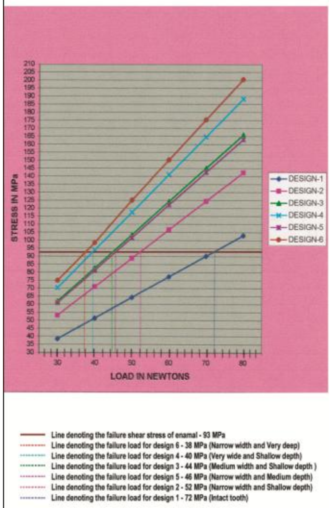


Fig. - 17 Shear stress pattern for FEM Design-6 (narrow width and very deep)
Under an eccentric load of 100 N

FIG. 18 - GRAPH SHOWING THE MEAN SHEAR STRESS VALUES FOR THE FEM DESIGNS 1 TO 6 UNDER ECCENTRIC LOADS RANGING FROM 30N TO 80N



V. Conclusion

The present investigation led to the conclusion that

- In a normal occlusion, the chances of developing abfractions are less.
- For individuals with bruxism (parafunction loads), the chances of developing abfractions are more.
- Teeth having deep and wide occlusal amalgam restorations have an increased chance of developing abfraction lesions.
- In patients having excessive occlusal loads like bruxism and malocclusion, the dimensions of the occlusal cavity for amalgam restorations should be restricted. Also the treatment should be combined with occlusal rehabilitation favoring canine-guided occlusion rather than group function type of occlusion in order to avoid excessive occlusal loads.

Although it is clearly evident from this finite element study that the teeth subjected to large eccentric occlusal loading and teeth with occlusal amalgam restoration have increased chances of developing abfraction lesions, there is a strong need for standardized in vivo tests for the identification of the multifactorial etiology of abfraction lesions under clinical situations. Then only we can arrive at a definite conclusion about the relationship between the presence of coronal amalgam restoration and abfraction lesions.

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*Dr. Jayasree.S. "The Role of Cuspal Flexure And the Weakening Effect of occlusal Amalgam Restoration in the Development of Abfraction Lesions – A Finite Element Study." IOSR Journal of Dental and Medical Sciences (IOSR-JDMS) 16.7 (2017): 10-17.