The influence of shifting the class I cavity position prepared in posterior teeth buccally and lingualy on stress distribution (Finite element analysis study)

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ABSTRACT

Background: Rehabilitation of the carious tooth to establish tooth structure integrity required cavity design that show a benign stress distribution. The aim of this study was to investigate the influence of the cavity position on the stress values in the reamining tooth structure restored with amalgam or resin composite.

Materials and methods: Seven 2-D models of maxillary first premolar include class I cavity design was prepared, one sound tooth (A) 3 composite (B1, B2, and B3) and 3 amalgam (C1, C2, and C3). In design (Bl and C1) the cavity position is in the mid distance between bacc-lingual cusp tip, design (B2 and C2) and (B3 and C3) shifted toward the buccal cusp and the lingual cusp for 0.5 mm respectively. One hundred N vertical load was applied and stress analysis was applied using Ansys v14 software.

Results: The maximum Von Mises stress 585.35 MPa in the sound tooth and (899,46, 690.46, and 941.47) in central, buccal, and lingual cavities position filled with a composite restoration respectively. Whereas, the highest stress (1540.37 MPa), (1233.09 MPa) and (1214.34 MPa) appears with a central, buccal and lingual cavities filled with amalgam respectively.

Conclusion: Reestablishment of the stress level of maxillary premolars subjected to class I cavity preparations are cavity bacc-lingual position and restorative-system-dependent.

Key words: Cavity position, class I, amalgam, composite, stress level. (J Bagh Coll Dentistry 2015; 27(1):11-17).

INTRODUCTION

Rehabilitation of the carious tooth structure is to establish tooth structure integrity, functionally and aesthetically. Tooth structure, cutting to remove the caries lesion and provide the amalgam restoration with adequate retention, resistance, and prevent recurrence caries, required to follow G.V. Black cavity preparation principle [(1)]. Outline of amalgam cavity designs according to G.V. Black principle needs to include all occlusal fissures, so that the bucc-lingual cavity postion should follwed the central fissure [(1)]. The cavity design, preparation such as depth, width, line angle and positions of cavity designs, has great impact on stress distribution and fracture resistance of a tooth under occlusal load [(2-3)].

Studying the loss of tooth substance after cavity preparation for direct and indirect restorations and its relationship with fracture strength, found that the higher tooth structure loss result in lower fracture strength [(4)] . However, introducing a colored restoration and bonding system that helps the retention and reinforcing the reaming tooth structure, permit the dentists no more obey the G. V black principle for cavity preparation [(5-8)]. Although, the probability of tooth cracking and/or fracture is due to the degradation in restoration quality, the major causes for tooth fracture is related to remain tooth structure and stress distribution [(9)].

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Tooth fracture has become an obstacle to maintaining lifelong oral health. In that regard, the fracture of restored teeth continues to be a problem of increasing clinical concern. In an attempt to understand the mechanisms responsible for tooth fracture, the stress distribution within restored teeth that results from masticatory loading has been studied extensively. Early investigations were conducted using photoelasticity to examine specific aspects of cavity design on the resulting stress distribution [(4,10)].

2D and 3D finite element stress analysis today considered one of the common investigation methods for stress analysis [(10)]. Although 2D FEA not represent the actual model but it gives basic knowledge about the stress difference between the designs that can be used for practical and clinical studies. However, reviewing the articles found that mostly investigate on the cavity design which, include the width, depth and line angle shape, no study were conducted on posterior amalgam or composite restored cavity position bucco-ligually.

The goal of this study was to investigate the influence cavity position on the stress values in reaming tooth structure restored with amalgam or resin composite.

MATERIALS AND METHODS

Seven 2-D models of maxillary first premolar include class I cavity design were prepared

according to filling materials, as shown in Figure (1) one sound tooth (A) 3 composite (B1, B2, and B3) and 3 amalgam (C1, C2, and C3). Design (A) control model, sound tooth structure without cavity preparation. Design (BI and C1) the cavity position in the mid distance between back-lingual cusp tip, design (B2 and C2) the cavity position shifted toward the buccal cusp 0.5 mm, design (B3 and C3) the cavity position shifted toward the lingual cusp about 0.5 mm. The dimensions of the cavity is 2.5 mm width and 2.5 mm depth with all internal line angle is round. The dimensions and shape of maxillary first premolar were derived from the dental anatomy atlas [11].

The material mechanical properties (modulus of elasticity and poisons ratio of enamel, dentin, pulp, composite, amalgam, periodontal ligament, alveolar bone and compact bone) were derived from previous articles [12]. The contact surface between cavity wall and composite restoration will be defined as perfect contact surface, whereas between amalgam restoration and cavity wall will be flexible. All models were meshed and a 100 N load distributed on the buccal incline of the lingual cusp and lingual incline of buccal cusp as shown in Figuer (2)

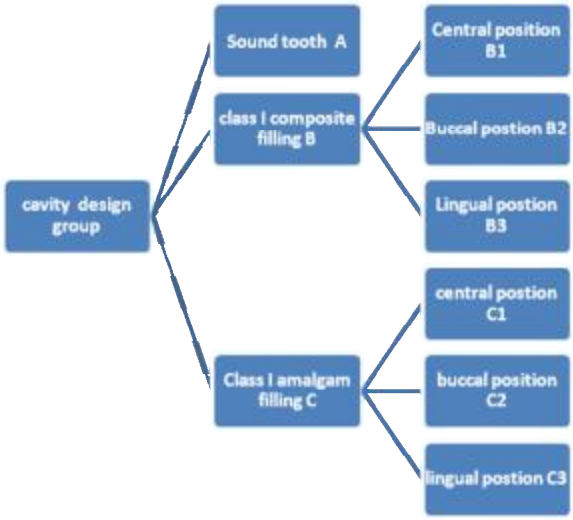

Figure 1: Group designs to be tested in this study

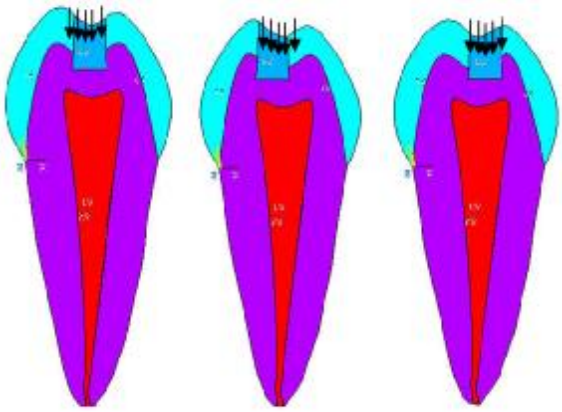

Figure 1: Cavity design and load application position

Table 1: Mechanical properties of model parts

Materials type	Modulus of elasticity MPa	Poisson's ratio	Reference
Enamel	41400	0,30	(13)
Dentin	18600	0.31	
Pulp	0,002	0.45	
Composite	3963	0.3	
Amalgam	48.3	0.35	
PDL	0.0034	0.45	
Alveolar bone	13800	0.26	
Sponge bone	3000	0.35	

RESULTS

Table 2, Figure (3 and 4) revealed that there is an important influence of bucc-lingual cavity position and the materials used in the restoration on the stress and displacement value. The results showed that the maximum Von Mises stress 585.35 MPa in the sound tooth is lower compared with that of tooth with different class I cavity bucc-lingual position filled with amalgam or composite.

The results predict that the maximum Von Mises stress is (899,46, 690.46, and 941.47) in central, buccal, and lingual cavity position respectively using composite restoration and bonding. Whereas the highest stress (1540.37 MPa) appears with a central cavity filled with amalgam compared with buccal (1233.09 MPa) and lingual cavity position (1214.34 MPa) filled with amalgam respectively.

Moreover, there is no important difference in the stress between buccal and lingual cavity position filled with amalgam.Stress distribution patterns were concentrated at a load application point in the sound tooth, then distributed through all tooth structure. With composite restoration the maximum stress concentrated at the junction between the lingual cusp and restoration in central and lingual cavity position. Whereas, at buccal cusp-restoration junction for buccaly position cavity. For amalgam restoration the maximum stress concentrated at the tip of the lingual cusp with a central cavity while in the buccal and lingual cavity position concentrated at bucc-pulpal and lingual-pulpal lines angle respectively.

The results of the displacement vector sum predict that only the lingual cavity position filled with amalgam is very low compared with other groups and there is no important difference value between other groups as shown in Table 2 and Figure 4. The maximum displacement vector using composite restoration is at lingual cusp when the cavity position is central and lingual, while, located at the buccal cusp with vocal position cavity.

DISCUSSION

Although experimental study data to verify the model and confirm the accuracy of the obtained solutions is mandatory, FEA may assist to solve complicated biomechanical problems. In this study we tried to find the suitable posterior cavity position bucc-lingually that preserve sound tooth structure under vertical occlusal forces. For strengthening of the weakened teeth, it was suggested that the adhesive restorations preserve tooth structure [14-15]. Based on this idea, two fillings non-bonded amalgam and bonded composite were selected to fill the cavities in this study to compare how much resistance can be reconstructed in such cavity design.

The present study indicated that posterior cavity preparation showed high von Mises stress values in maxillary first premolar filled with amalgam and composite insequence compared with sound tooth structure. This may be due to discontinuities in the tooth structure filled with unbonded restoration [16-17]. The results predict that the stress level was lower in all cavities filled with composite compared to the cavities filled with amalgam in different cavity position. This might be related to the bonding of the composite restoration to the tooth structure that retained part of the tooth structure continuity that lead the composite restoration to transmit part of stress to the tooth structure compared with amalgam. Looking to the stress pattern, the maximum stress concentrated at the load point application and then distributed through tooth structure with different levels, in sound tooth and teeth filled with a composite restoration. This may be due to continuities in the model structure, because the interface between tooth structure and composite restoration simulated as a perfect contact. This result is in agreement with a study, which investigate the stress distirbution in tooth structure and found that the relative high stress values were computed at the surface under loading [18]. Whereas, the stress with an amalgam restoration concentrated at the angle between the pulpal floor and buccal or lingual wall according to the cavity position. This might increase the possibility of initiating the fracture plane from this angle toward the external surface of tooth structure [17]. The increase in the stress in the tooth stucture in some area leave the tooth to be more susceptible to fracture [4]. Regarding the displacement sum the results shown that it is low with the amalgam and particularly lingual position cavity, which may be due to discontinuities in the model structure.

In the present study, the only cavity position that restored the stress level to be nearly to that of the intact teeth is buccal position cavity filled with a composite. This result predicts that the buccal position cavity filled with a composite is less susceptible to fracture compared with other cavity position and this might be due to 1) bonding between the tooth structure and composite and this is in agreement with results of studying the fracture of posterior teeth in adult [19] . Furthermore, studying the restored tooth by a combined bonded enamel and dentin with composite showed significant higher fracture resistance compared with tooth prepared but not restored [20]. Studying the Fracture resistance of posterior teeth restored with modern restorative materials found that the tooth restored with Admira composite and bonding showed no significant difference when compared with the unprepared teeth[21]. 2) It is well known that palatal cusp of maxillary premolars fractures more frequently than buccal cusp [4, 22-23]. The buccal position cavity filled with composte should contribute to better biomechanical behavior of tooth-restoration complex, consequently might provide the long-lasting clinical results [13].

A FE analysis study on both amalgam and composite showed similar stress distribution for MOD cavity, however the stress recorded with composite was higher than that restored with amalgam [13]. The results, conduct that selection of the cavity position and restoration type is important to obtained a preservation of tooth structure. Preservation of sound tooth structures

is the primary goal of modern restorative dentistry. Due to their unfavorable anatomy, maxillary premolars with cavities preparation are at great risk of fracturing if restored without regarding protective principle [4, 24].

In conclusion, based on the numerical simulations applied in this study and analysis results predict that reestablishment of the stress level of maxillary premolars subjected to class I cavity preparations is cavity bucc-lingual position and restorative-system-dependent.

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Table 2: Maximum von Mises stress and Displacement vector sum

Filling materials	Cavity position	Von Mises stress (MPa)	Sum displacement (mm.)
Sound tooth	Sound tooth	585.35	0.590533
Composite	Central	899,46	0.66269
	Buccal	690.46	0.608534
	Lingual	941.47	0.666677
Amalgam	Central	1540.37	0.599928
	Buccal	1233.09	0.592125
	Lingual	1214.34	0.156054

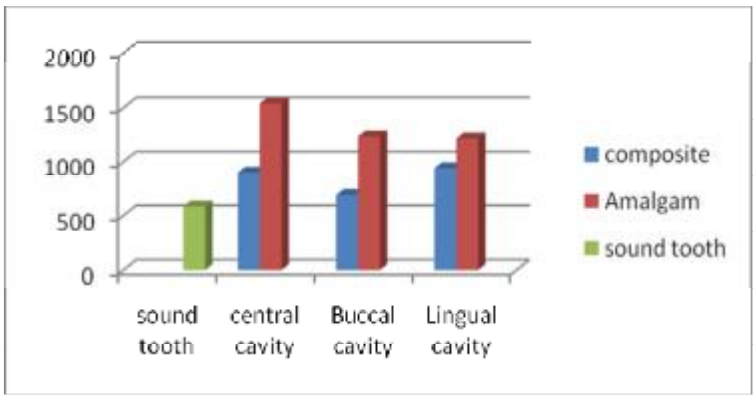

Figure 2: Maixmum Von Mises stress recorded according to the model in MPa

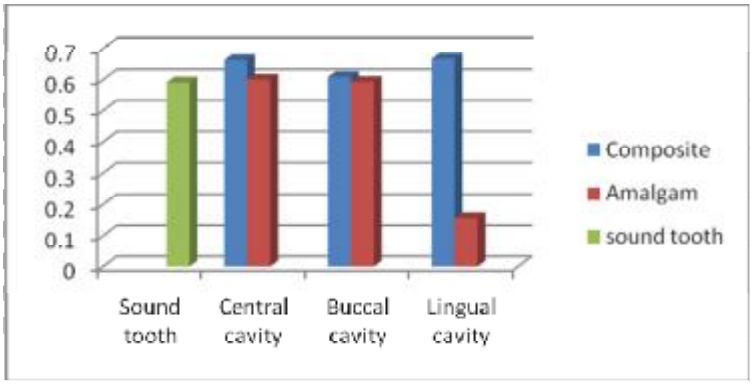

Figure 3: Displacement vector sum in mm according to cavity position and filling materials used.

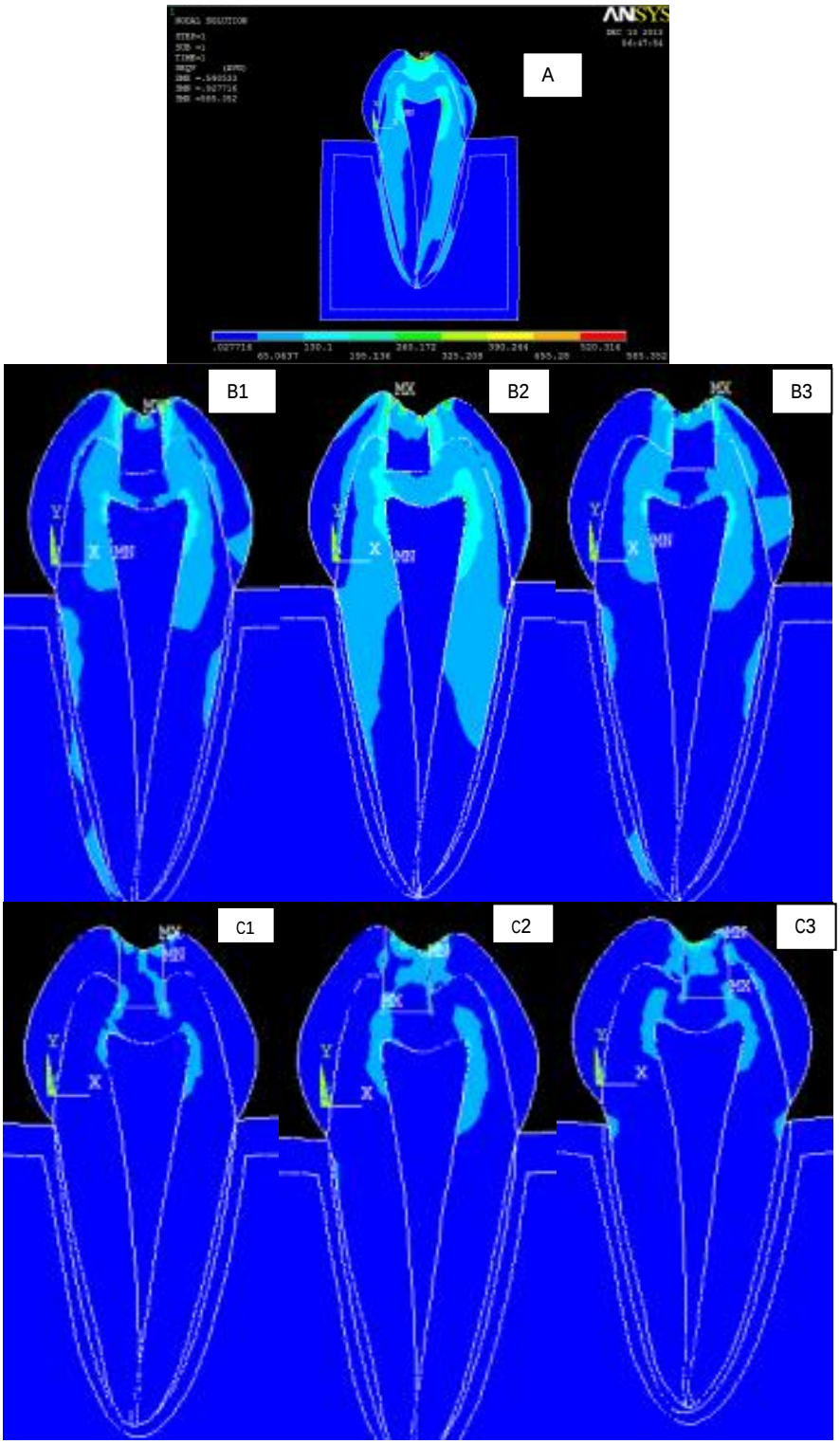

Figure 4: Stress pattern of the maximum Von Mises stresses according to the model. A sound tooth structure, B1,B2, and B3 are of composite restoration in central, buccal and lingual cavity position respectively. C1, C2, and C3, are of amalgam restoration in central, buccal and lingual cavity position respectively.

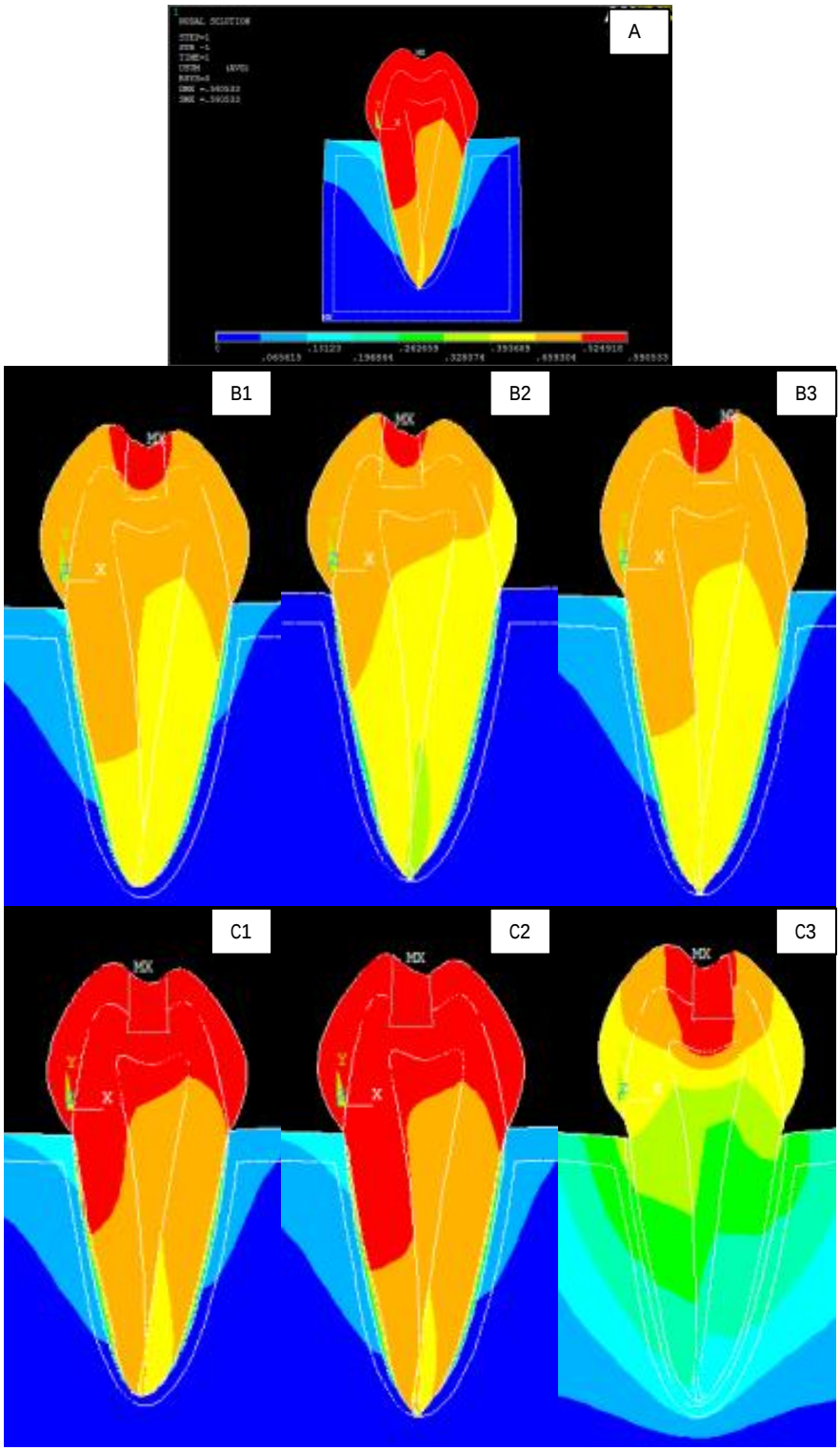

Figure 5: Pattern of the displacement vector sum, according to the model. A sound tooth structure, B1,B2, and B3 are of composite restoration in central, buccal and lingual cavity position respectively. C1, C2, and C3, are of amalgam restoration in central, buccal and lingual cavity position respectively.