Original Article

Evaluation of cavity size, kind, and filling technique of composite shrinkage by finite element

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ABSTRACT

Background: Cavity preparation reduces the rigidity of tooth and its resistance to deformation. The purpose of this study was to evaluate the dimensional changes of the repaired teeth using two types of light cure composite and two methods of incremental and bulk filling by the use of finite element method.
Materials and Methods: In this computerized *in vitro* experimental study, an intact maxillary premolar was scanned using cone beam computed tomography instrument (SCANORA, Switzerland), then each section of tooth image was transmitted to Ansys software using AUTOCAD. Then, eight sizes of cavity preparations and two methods of restoration (bulk and incremental) using two different types of composite resin materials (Heliomolar, Brilliant) were proposed on software and analysis was completed with Ansys software.
Results: Dimensional change increased by widening and deepening of the cavities. It was also increased using Brilliant composite resin and incremental filling technique.
Conclusion: Increase in depth and type of filling technique has the greatest role of dimensional change after curing, but the type of composite resin does not have a significant role.

Key Words: Composite resin, dimensional, finite element analysis, polymerization, shrinkage, tooth

INTRODUCTION

Direct composite restoration is one of the most common ways of repairing damaged teeth due to trauma or caries. Despite the excellent advantages of this material, some disadvantages such as post treatment sensitivity, recurrent caries, tooth cracks, and marginal discoloration could be mentioned.[1,2]

Sound tooth could biologically respond to mastication tensions, but the cavitated tooth is weakened and the stress distribution pattern is different from the sound tooth.[3]

The shrinkage stress caused by polymerization of composite is transferred to the prepared tooth cavity and the composite restoration and it may cause microleakage, which is responsible for sensitivity and recurrent caries of the repaired tooth. Polymerization stress distribution depends on some variables such as cavity dimensions, composite filling technique, type of light cure process, type of composite and its polymerization properties, and the utilized instruments.[4] In this regard, in recent years, the

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use of engineering methods to evaluate the stress in materials and dental tissues has been widespread, and one of the most useful methods is the finite element method (FEM). With the help of this innovation, the stress in materials and different surfaces of dental tissues could be examined and assessed. Validity of this technique has been approved and emphasized in dental applications.[5] FEM was introduced in 1973 to demonstrate the intrinsic stress in dental researches.[6] Several finite element analysis (FEA) researches showed computed tomography (CT) application with very high coherency and accuracy.[7-10] One of the problems of using resin composites is the polymerization shrinkage. Kleverlaan and Feilzer[11] used mercury dilatometry technique and showed that high polymerization shrinkage and the stress of it was the reasons of bond fracture between composite and tooth. Many investigations have been executed to eliminate or reduce this problem. Kowalczyk[12] demonstrated that the use of fine layer of composite in whole inner areas of the cavity (prelayer) and then applying the remaining composite as wedge or layer was the best technique of incremental filling of the material.

Versluis *et al.*[13] by FEM showed that incremental filling method caused decrease in volume of utilizable composite in cavity and cavity walls were reformatted. Incremental technique has different advantages such as good condensation and adaptation, better curing, and formation of stronger bond. In different methods of incremental technique, maximum movement of cavity walls was done by gingival occlusal technique, and minimum movement was done by oblique technique. Although too many investigations have been made on composite resins, still the exact method of tooth repairing technique with composites has not been recognized, and there are many controversies about it. Hence, more investigations should be made on the mechanism of biomechanical behavior of composite resins.[3] The purpose of this study was to evaluate the dimensional changes of the repaired teeth using two types of light cure composite and two methods of incremental and bulk filling by the use of FEA.

MATERIALS AND METHODS

Imaging with cone beam computed tomography
In this computerized *in vitro* experimental study, the images of an extracted premolar were prepared using a cone beam CT unit with voltage tube 85 kV, exposure dose 15 µA for 3 s exposure time (Scanora CBCT, Soredex, Switzerlan). The images were converted to a computer file with the use of ONDEMAND software (Soredex, Switzerlan) [Figure 1]. Cross sections were hand made every 0.4 mm in crown and every 0.8 mm in root, which were saved as individual images in TIFF format. Then, by the means of point software, the boundaries of enamel, dentin, and pulp, due to their mineralization degree, were determined and specified by different colors.

Modeling and meshing
For tooth modeling, first, picture of tooth different sections was transferred to AutoCAD software. After determination of border lines of enamel, dentin and pulp were transferred to Ansys software (Canonsburg, USA) and were molded the tooth external surface and volume [Figure 2].

Then, volumes were meshed and divided into different elements. The used element was solid 10 nodes and the total number of it varied from 100,000 to 130,000 [Figure 3].

Cavity preparations and restore
Box form mesio-occluso-distal (MOD) cavities [Figure 4] were prepared on the occlusal surface of the tooth in computer with computer simulation. Cavosurface angles were determined 90° [Figure 4]. Classification of different groups according to depths and types of composite, filling materials, and filling techniques is seen in Table 1. According to this table, groups' denomination was, respectively, done with filling methods (Bulk or Incremental), used composite (Brilliant [Coltene Whaledent, Switzerland] or Heliomolar [Ivoclar Vivadent, Liechtenstein]), cavity depth (2 or 4 mm), and cavity width (2 or 4 mm).

Finite element analysis
For meshing, we used edon ol dilos element (dilos 93) and three-dimensional analysis was done. Nearly 120,000 elements were meanly used in each analysis. Enamel and dentin bond strength to composite was considered about 50 Mpa.[14]The qualities of used materials in different parts of tooth based on elastic coefficient and Poisson ratio according to the provided values in Table 2 were put in Ansys software.

Analysis of different conditions was completely used from incremental and bulk techniques. Then, all of peripheral nodes of tooth inferior plane were narrowed in three dimension (X, Y, and Z) and their freeness degree was zero.

Figure 1: The cone beam computed tomography images prepared with ONDEMAND software.
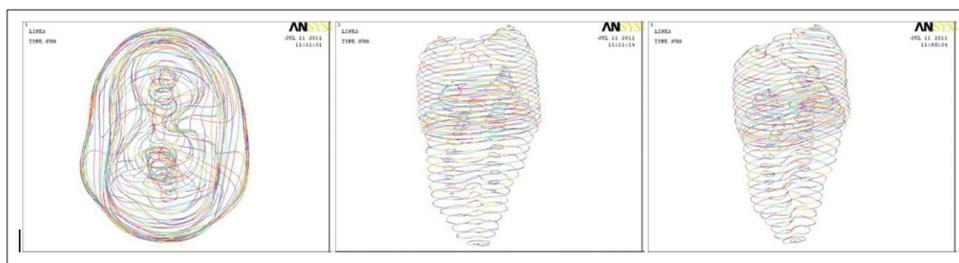
Figure 2: The modeled images of cross sections of the tooth.
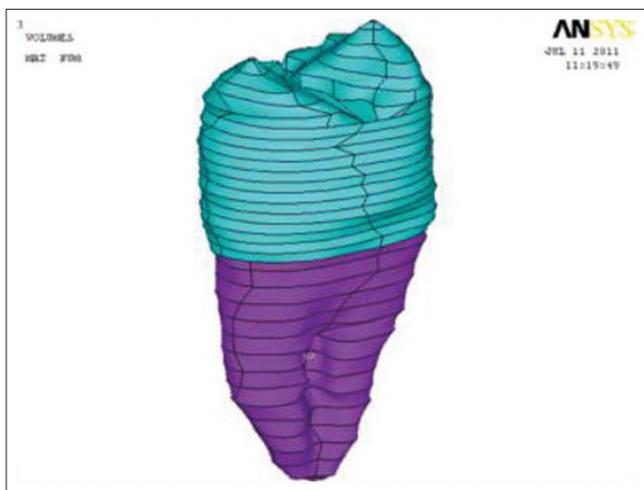
Figure 3: The meshed images of cross sections of the tooth.

In bulk technique with 4 mm depth, degree of conversion in lower layers is less.[15] Then, composite material was divided into three equal parts (~1.3 mm) in depth. In surface part, polymerization shrinkage was considered 2.2% for Brilliant and 1.96% for Heliomolar according to manufacture factory. In median and lower parts, polymerization shrinkage was, respectively, considered 1.8% and 0.8% for Brilliant and 1.8 and 0.7% for Heliomolar.

In incremental technique, analysis was momently done in three phases from pulpal floor to occlusal. In any phase, we considered composite layer with thickness about 1.3 mm and polymerization shrinkage with 2.2% for Brilliant and 1.96% for Heliomolar. The results of the first layer (cavity dimensional change) were established in the cavity and then the second layer polymerization was simulated, and after second layer's dimensional change, third layer polymerization was simulated. The dimensional changes in different groups were calculated.

RESULTS

The most dimensional changes after polymerization were observed in the group with 4 mm width and depth filled with brilliant composite using incremental technique. The least dimensional changes (volumetric) were seen in the group with 4 mm width and 2 mm depth filled with Heliomolar composite using bulk method.

According to result, the dimensional changes were bigger in groups with greater depth, width, and incremental filling technique and brilliant composite.
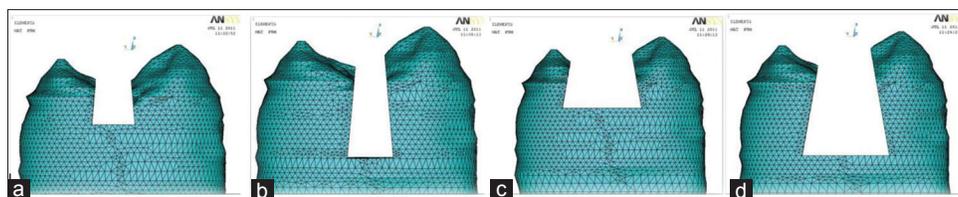
Figure 4: The prepared cavities with 2 mm (a and b) and 4 mm (c and d) width (buccolingually) and 2 mm (a and c) and 4 mm (b and d) depths in occlusal surface of the teeth.

Table 1: Classification of different groups according to depth and width (buccolingually mm), type of composite, and filling technique

Group	Cavity depth (mm)	Cavity width (mm)	Used composite	Filling methods
BB22	2	2	Brilliant	Bulk
BB24	2	4	Brilliant	Bulk
BB42	4	2	Brilliant	Bulk
BB44	4	4	Brilliant	Bulk
BH22	2	2	Heliomolar	Bulk
BH24	2	4	Heliomolar	Bulk
BH42	4	2	Heliomolar	Bulk
BH44	4	4	Heliomolar	Bulk
IB22	2	2	Brilliant	Incremental
IB24	2	4	Brilliant	Incremental
IB42	4	2	Brilliant	Incremental
IB44	4	4	Brilliant	Incremental
IH22	2	2	Heliomolar	Incremental
IH24	2	4	Heliomolar	Incremental
IH42	4	2	Heliomolar	Incremental
IH44	4	4	Heliomolar	Incremental

Table 2: Elastic coefficient and Poisson ratio of available substrates in study

Substrate	Poisson ratio	Elastic coefficient
Enamel	0.33	84
Dentin	0.31	17
Pulp	0.45	2.07
Heliomolar composite	0.37	16.5
Brilliant composite	0.31	10.6

Depth had a greater effect on dimensional changes than width. In doubling of the depth, the dimensional change would be 2.62 times more. While in doubling of the width, the dimensional changes would be 1.03 times more. Dimensional changes in deeper cavities were more than in buccal walls.

DISCUSSION

It was seen that in the cavities with 2 mm depth and width, unlike other groups, Heliomolar composite had more dimensional changes compared to Brilliant composite. According to Table 2, Brilliant resin composite is more elastic and had suffered dimensional change after polymerization at the same cavities. Furthermore, the dimensional change after incremental filling technique was greater than the bulk filling technique. Most dimensional change between all study groups was IB44 group.

Despite the common belief that the polymerization stress of composite resin is less in incremental filling technique than bulk filling technique, but the results of this study showed that the dimensional changes in incremental method were more than bulk method which is inconsistent with the previous hypothesis that was based on the decrease of C factor in incremental layer and less shrinkage using fine layers of composite. It has been seen that polymerization shrinkage of each layer was the reason of dimensional changes and pressure to the cavity walls downward and inward, which resulted in reduced cavity bulk and amount of composite material used and higher stress to tooth restoration complex. In fact, in incremental method, two factors are effective in reducing the cavity bulk: (1) composite volumetric shrinkage and (2) changes in cavity shape, but in bulk method, volumetric shrinkage is the only effective variable.[2] According to Winkler *et al.*'s[2]

study which had the results similar to our study, the remaining stress in bulk technique was less than incremental technique and bulk technique resulted better in shallow cavities. These results were similar with the study done by Versluis *et al*.[1]

In incremental method, less thickness of composite layers results in better curing, higher degree of conversion, and consequently more polymerization shrinkage compared to bulk filling technique.[13]

Curing composite in bulk method could be suggested as a kind of soft exposure. Due to the thickness of the composite, at first, the superficial layer of composite is cured, but it does not reach the maximum degree of conversion. If the higher exposure dose is used, composite conversion degree in the cavity increases, but since composite does not have enough flow, shrinkage stresses are developed inside the composite and are not transferred to the cavity walls.[13]

When composite resins are cured, light passes through the composite attenuates, which means that deeper layers of composite resin are less cured. Any factor that decreases the light intensity passing through the composite will lower the conversion rates of the composite resin. If inadequate levels of conversion are achieved during polymerization, mechanical properties and wear resistance are reduced. With incomplete curing, leachable residual monomers and initiators become greater biocompatibility issues, and color instability can also become a problem. When light-cured composite is used in deep cavities, the use of bulk technique results in incomplete polymerization and decreases in mechanical qualities of the restoration. This also leads to stress release in deep areas of composite bulk. While in incremental technique, curing is more complete and composite would have better qualities.[16,17]

According to Figure 5, dimensional changes in incremental technique and each of composites have been, respectively, augmented by increase in cavity width and depth but in bulk technique have been, respectively, augmented by increase in cavity depth and width. These are indicative that dimensional changes in cavity with different width and depth are more than controlled with composite placement technique and in cavities with 2 mm in depth and more width; bulky composite placement is more than desirable. However, in deeper cavities, incremental placement was suggested for decrease of gap under the composite restorations, and for decrease of
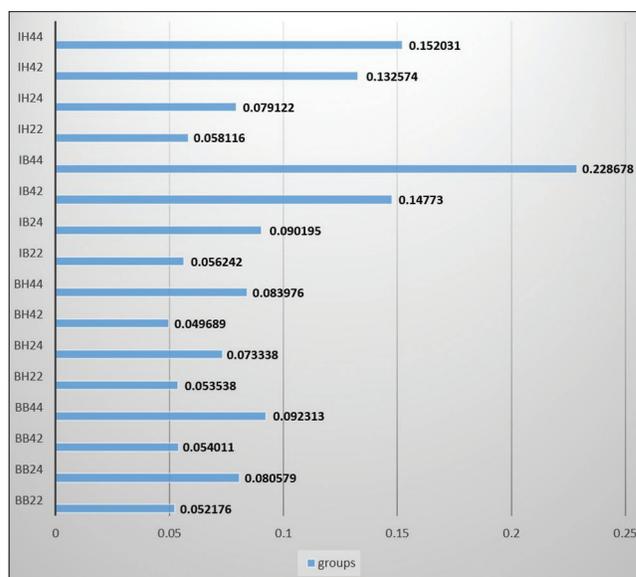
Figure 5: Maximum dimensional changes in groups.

dimensional changes, using of other techniques was suggested, for example, oblique incremental placement, light exposure from buccal and lingual surfaces, and sandwich technique. Lopez[18] stated that MOD cavities had the most cuspal deformation in the repaired cavities with composite, but the buccolingual width of the cavity does not affect the cuspal deformation.

The viscoelastic properties such as polymerization shrinkage, polymerization reaction rate, and modulus of elasticity are very important in the pattern of contraction stress.[19,20] Thus, the different formulations of composite resins such as amount and type of resin matrix, filler level, and quantity of initiator and inhibitor should be considered in the contraction stress development.[21]

In other studies, it has been observed that the difference in composite material does not significantly affect polymerization shrinkage and dimensional changes,[15] but in the repaired cavities with Brilliant composite, the dimensional changes were a little more than the repaired cavities with Heliomolar composite which is due to the lower elastic coefficient of Brilliant composites. The most dimensional changes were in the free surface of composite because composite has more ability to change and flow in free surfaces, and the energy release of polymerization shrinkage in this area was easier [Figure 6 and 7]. In other studies, it has been observed that most of the shrinkage stresses were at the top ends of the layers where the bond is in more danger.[12]
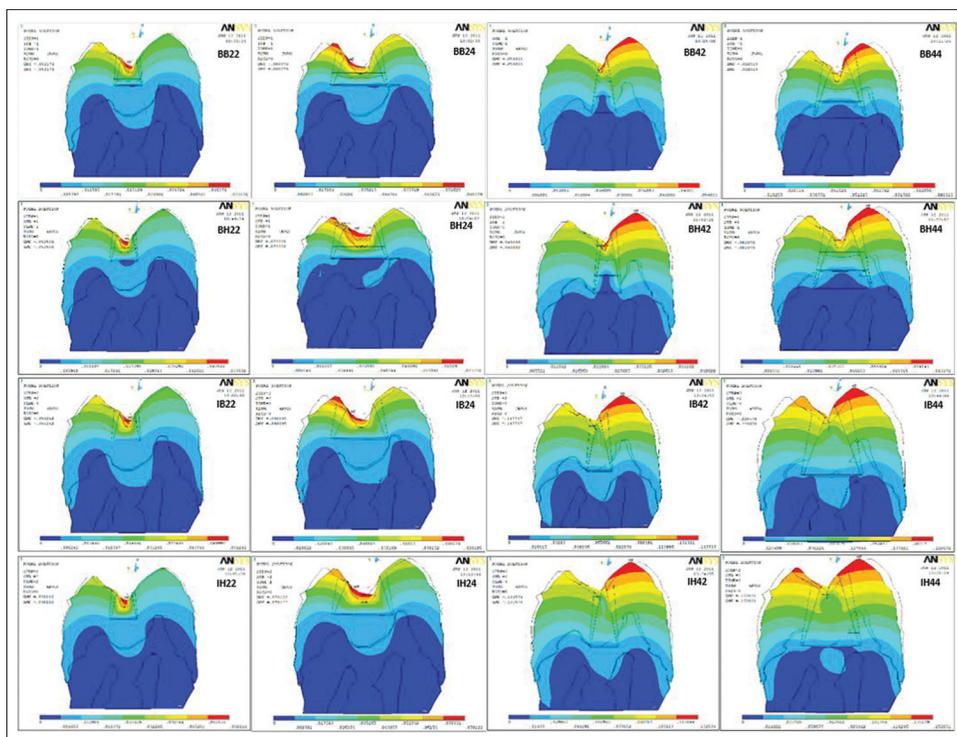
Figure 6: Teeth proximal view of before and after polymerization shrinkage. Cuspal deflections were seen.
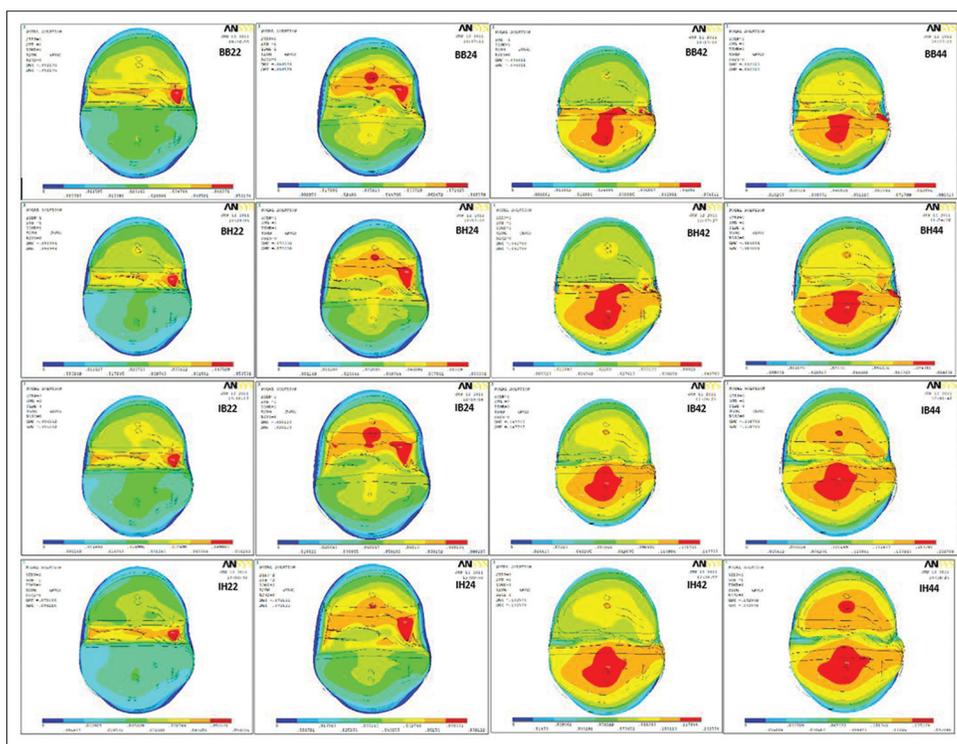
Figure 7: Teeth occlusal view of before and after polymerization shrinkage.

CONCLUSION

In the present study, it was resulted that:
1. The increase in cavity depth had the greatest effect on the dimensional changes after polymerization
2. Bulk filling technique had smaller dimensional change than incremental technique if it does not negatively affect the physical qualities of restoration because of lower degree of conversion

3. Brilliant composite had a little more dimensional changes than Heliomolar composite which is due to the lower elastic coefficient of Brilliant composites.

Conflicts of interest

The authors of this manuscript declare that they have no conflicts of interest, real or perceived, financial or nonfinancial in this article.

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