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Cuspal Deflection of Premolar Teeth Restored with Composite Re sin Using Either Bulk Fill or Incremental Technique

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I. Introduction

Composite resins are the most commonly used direct restorative materials for restoration of dental cavities, tooth wear and congenital defects of teeth due to their excellent esthetic properties(1).

Technological improvements in composite resins have taken place in response to the growing demands of the patients for esthetics and also the consequent demands of clinicians for materials with similar optical characteristics to those of the natural teeth(2).

In spite of the various improvements of resin composite materials, polymerization shrinkage remains a major contributor to the clinical drawbacks associated with these materials.(3)

Polymerization shrinkage creates contraction stresses in the resin composite restoration and deformation in the surrounding tooth structure (4). The resin composites undergo contraction inherent to the polymerization reaction by (1.5 to 3%) of their volume(5), which can produce two types of problems: **firstly**, weak composite adherence to the dental tissues or gaps formation (6), leading to marginal staining, pulpal inflammation and secondary caries.(7)

Secondly, due to the excessive adhesion between the tooth and the restoration, the mechanical stresses produced by the polymerization shrinkage of the composite are transmitted to the surrounding tooth structure leading to pulling the walls of the tooth and causing cuspal deflection.(8) This problem is perceived by the patient as post-operative pain.(9)

So, we have to overcome this polymerization shrinkage stress in order to obtain adequate marginal integrity and increase the durability of composite restorations.(10)

Reduction of the polymerization shrinkage and subsequently the decreased cuspal deflection may be achieved by incremental application of composite resins.(11) Although commonly used, this incremental application of the composite resins has several drawbacks such as the risk of void formation, contamination, bond failure between layers, difficult application in the conservative cavities and time consuming .(12)

Recently, in order to decrease the cuspal deflection and shortening of the working time the bulk fill composite was introduced, which have less and larger sized filler content (13, 14). Due to having a different monomer, the bulk fill composite produces less shrinkage stress (15), and can be placed in a single 4-mm increment which simplify and speed up the clinical procedure(16)

The influence of bulk filling technique with bulk fill composites and the incremental filling technique with nanohybrid composites on the degree of cuspal deflection will provide us with the information about which one of them has the lowest polymerization shrinkage.

This study aimed to evaluate the cuspal deflection in premolar teeth restored with two different techniques of two bulk fill composite resins and one of nanohybrid composite resin.

II. Materials & Method

1) Teethselection:

A total of thirty freshly extracted intact human maxillary premolars extracted for orthodontic reasons were collected from young aged patients (12 – 18) years old, from the Department of Oral and Maxillofacial surgery of Faculty of Dentistry, Tanta University.

Approval for this study was obtained from Faculty of Dentistry, Tanta University, Research Ethics Committee (REC). The purpose of the present study was explained to the patients and informed consents were obtained to use their teeth in the research according to the guidelines on human research adopted by the Research Ethics Committee (REC) at Faculty of Dentistry, Tanta University.

Teeth were examined using magnification lens of (X3.5) to exclude those with stains, cracks and fractures. They were cleaned thoroughly from all debris, plaque and calculus under running water and scaled using periodontal scaler, disinfected and stored in distilled water in a refrigerator until use within six months of extraction.(17, 18)

2) Specimen preparation:

The root of each tooth was mounted in a cylindrical plastic mold of 2 cm diameter using chemically cured acrylic resin [(18)].

The maximum buccopalatal width (BPW) for each tooth recorded with a NEIKO[1] electronic digital caliper. A mean of three measurements per tooth was used to distribute the specimens into three groups (n=10) so that the BPW mean between groups varied by less than 5%. Any tooth that was 5% larger or smaller than the overall mean was excluded from the study to minimize any variation in the buccal-lingual dimension of the cavity preparation.

The buccal and palatal cusp tip surface of each tooth were acid etched by phosphoric acid etchant gel 37% for 10 seconds then rinsed, dried, and then the Meta bond applied to the etched cusp tip and the bonding was light cured for 10 seconds. Then Nexocomp composite resin was applied to the bonded areas in each tooth to build two cylindrical reference points for cuspal deflection assessment [(18)].

Standardized slot MOD cavity was prepared in each tooth with a straight fissure diamond carbide stone with a rounded end using a high speed handpieceunder water coolant in order to weaken tooth structure and favor cuspal deflection. Thebucco-lingual width of the cavity was 3 mm, and the depth 3 mmmeasured from the occlusalcavosurface margin to the pulpal floor, and all margins were in enamel. The dimensions of each cavity preparation were verified by using the Neiko electronic digital caliper.

The MOD cavities were prepared without proximal boxes so as to minimize the preparation variation [(19)] , Moreover, the buccal and the lingual walls of each cavity were parallel to each other.[(20)]

IGAGING digital electronic micrometer[2] was used for cuspal deflection assessment between the two reference points [(21, 22)].For each premolar, the two guiding paths of chemically cured acrylic resin guide the path of the beaks of the digital micrometer when it touches the reference points for reproducibility and standardization of the procedure of recording the cuspal deflection readings[(18)].

First readings were recorded for the premolar teeth before the prepration of the MOD cavity.

3) Group assignment :

The teeth were divided into three groups of 10 teeth each,all the cavities were prepared to a depth of 3 mm then restored according to the type of composite used:

- **Group 1:** Teeth were restored with TetricEvoCeram® Bulk Fill composite with AdheSE Self etching adhesive.
- **Group 2:** Teeth were restored with Admira® Fusion x-tra Bulk Fill material with Futurabond U Dual cure universal adhesive.
- **Group 3:** Teeth were restored with Filtek™ Z350 XT Universal Restorative System with single bond Universal Adhesive.

4**) Restorative procedure:**

Group 1:(n = 10)

Prior to composite placement a Tofflemire matrix band was placed around the toothand then an adequate amount of AdheSE Primer applied with a brush and rubbed into the entire surface for 15 seconds.Excess Primer dispersed with air until the mobile liquid film is no longer visible. Then the AdheSE Bondwas applied to the entire walls of the cavity and polymerized for 10 seconds using I-led light curing unit [3].Then the prepared cavity was restored according to the manufacturer's instructions with TetricEvoCeram® Bulk Fill composite in one increment (3 mm thickness) ,and polymerized for 20 seconds using I-led light curing unit.

Group 2 : (n = 10)

After matrix band placement as mentioned in group1, a layer of the Futurabond U universal bond was applied to the enamel and dentin with a brush and rubbed then after 20 seconds, air dried for 5 seconds and polymerized for 10 seconds with I-led light curing unit.The prepared cavity was restored according to the manufacturer's instructions with Admira® Fusion x-tra Bulk Fill material in one increment and polymerized for 20 secondsby I-led light curing unit.

Group 3 : (n = 10)

After matrix band placement, the single bond Universal Adhesive was applied to the prepared tooth, then rubbed for 20 seconds and air dried for 5 seconds, then light cured for 10 seconds.

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[1]NEIKO electronic digital caliper (Accuracy: 0.001″ / 0.02mm)

[2]IGAGING digital electronic micrometer (Accuracy +/- 0.00016" and Resolution 0.00005"/0.001mm)

[3]I-led light curing unit (output light intensity is about 1000 mW/cm2 – 1200 mW/cm2, Guilin woodpecker medical instrument company).

The prepared cavity was restored according to the manufacturer's instructions with Filtek™ Z350 XT Universal Restorative System incrementally. The first layer thickness (1.5 mm) polymerized by I-led light curing unit for 20 seconds and the second layer thickness (1.5 mm) polymerized for another 20 seconds.

5) Cuspal Deflection Assessment

The IGAGING digital electronic micrometer was used to record an initial (first) reading between the two reference points in each tooth before the prepration of the MOD cavity. After completing the restoration, each tooth was kept wet by immersion in water, and then air dried just before taking the second reading.[18]The second reading was recorded between the two reference points after 60 minutes from completing the restoration.

6)Thermocycling and load cycling procedures :

By using thermocycling machine[4], the restored teeth were thermocycled for 5000 cycles between 5° and 55°C with a dwell time of 30 second and transition time 10 second. This reported to simulate 6 months of clinical service [23].

After this procedure, the restored teeth were mounted to a stainless steel cylindrical mold filled with rubber base material to act as peridontium medium surrounding natural teeth, then teeth were subjected to a maximum vertical load[5]of 1 Kg with cyclic frequency of 1 Hz for 50000 cycles [24].The third reading between the two reference points were recorded after thermo cycling and load cycling procedures.

Figure (1) Thebucco-lingual width of the cavity 3 mm verified by using the NEIKO electronic digital caliper.

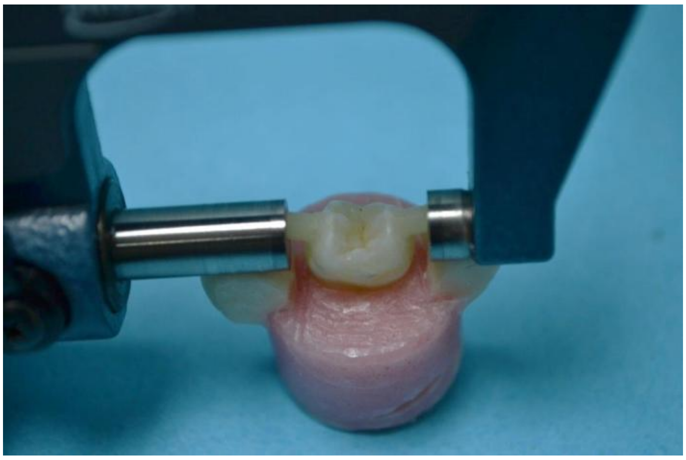

Figure (2) IGAGING digital electronic micrometer for cuspal deflection assessment between the two reference points and two guiding paths of chemically cured acrylic resin formed to guide the path of digital micrometer.

[4]Alexandria university, Faculty of Dentistry
[5]Model LRX – plus; Lloyd Instrument Ltd., Fareham, UK.

Statistical Analysis

All the data were collected, tabulated and statistically analyzed at a 95% level of significance. Data were presented as means and standard deviations (SD). One-way ANOVA was used for comparison between the mean cuspal deflection values of the tested groups. Tukey's post hoc test was used for pair-wise comparison between the means when ANOVA test was significant. The significance level was set at $p < 0.05$.

Table (I): the difference between the mean & SD values of cuspal deflection between first reading and second reading for all the three groups

µm	Cuspal deflection between first reading and second reading		
	Group I	**Group II**	**Group III**
Mean	35.4	26	37.4
St. Dev.	21.11	20.3	22.96
P value		**0.103**	

- P values for comparing between all groups using ANOVA TEST statistically significant at $p \leq 0.05$

Table (II): the difference between the mean & SD values of cuspal deflection between second reading and third reading for all the three groups.

µm	Cuspal deflection between second reading and third reading		
	Group I	**Group II**	**Group III**
Mean	12.4	**7.3**	14.6
St. Dev.	8.8	8.4	16.5
P value		**0.413**	

- P values for comparing between all groups using ANOVA TEST statistically significant at $p \leq 0.05$

Table (III): the difference between the mean & SD values of cuspal deflection between first reading and third reading for all the three groups.

µm	Cuspal deflection between first reading and third reading		
	Group I	**Group II**	**Group III**
Mean	47.8	**33.3**	52.0
St. Dev.	34.91	26.7	44.46
P value		**0.083**	

- P values for comparing between all groups using ANOVA TEST statistically significant at $p \leq 0.05$

III. Discussion

The purpose of this in-vitro study was to evaluate the effect of two types of bulk-fill composites on cuspal deflection of maxillary premolar teeth comparing them with the conventional composite, and in attempt to compare between the bulk fill and the incremental filling technique.

Polymerization shrinkage has been of major concern to dental clinicians placing direct composite restorations in posterior teeth. Its level measured indirectly by the amount of cuspal deflection.

Cuspal deflection indicates deformation of the tooth structure, which signifies the presence of shrinkage stresses. Which are generated by shrinkage and development of elastic modulus during polymerization, but they arise only if the composite has been bonded to the tooth structure.(25).

Lee and Park(26) ,indicate that the amount of polymerization shrinkage and cuspal deflection are highly correlated. The materials that showed a lower shrinkage value also demonstrated lower cuspal deflection.

Measurement of cuspal deflection using natural teeth could produce many discrepancies between specimens due to the variations in the tooth size, anatomy and modulus of elasticity between teeth. So, the aim in this study of using maxillary second premolars was based on the fact that the buccal and palatal cusps are nearly at the same level, of near-equal size, and centrally placed with respect to each other, thus, reducing the variability between the selected teeth(18).

The selection of distilled water as a storage medium was because it could be replaced periodically to minimize deterioration and bacterial growth and rejecting any chemicals which may affect the materials (27).

Standardized large MOD cavities were prepared in each premolar to maximize the possible cuspal deflection resulting in a high C-factor. The preparations were designed to weaken the remaining tooth structure these cavities could be considered typical of large amalgam replacement cavities, and the number of such restorations currently placed in clinical practice is increasing since improved matrix and bonding systems have made the use of composite resin restorations more viable (21). The greater deformation in large restorations resulted in increase of the stress in supporting dental structure (28).

As **Lopez et al**. [29]demonstrates that significantly higher cuspal deflection is observed in MOD restorations, showing that the degree of dental removal influences the cuspal flexure from polymerization shrinkage of composite restorations,the degree of cuspal deflection is directly related to loss of tooth structure.

The digital micrometer was used for the assessment of cuspal deflection in this study similar to previous studies [21, 22, 29].**Do et al**. mentioned that the polymerization shrinkage stress cannot be measured directly [25] , cuspal deflection was highly correlated to the polymerization shrinkage .So a lot of methods were used to measure cuspal deflection including microscopy, strain gauges, direct current differential transformers, and linear variable differential transformers [6, 19, 30].

Cuspal deflection assessment using digital micrometer is a reliable, accurate and highly-sensitive method yet it is much simpler to apply compared with other methods [22]. Moreover, this method allows keeping the teeth wet during the period after light-curing of the restorations and before taking the second reading with the micrometer [18].

The two reference points of composite resin had two guiding paths for the beaks of the digital micrometer to ensure precise reproducibility of their position hence ensuring accurate cuspal deflection readings. This is because if the reference points had no guiding paths, it would have been difficult to reposition the beaks of the digital micrometer in their original contact position with the reference points[21].

Because that most of the polymerization shrinkage of composites occurred within the first 20 seconds from light curing, Cuspal deflection in the second reading was made after sixty minutes from restoration of the teeth.

The cuspal deflection was slower and took longer time than polymerization shrinkage before it reached a plateau between (300 – 500) seconds [26].

A lot of studies assumed that most of the polymerization shrinkage occurs in a short period of time, particularly with a high–power-density curing light, where approximately 85%-90% of polymerization shrinkage occurs within 20 seconds of light curing, even though a slight increase continues [26, 31, 32].

Bouillaguet et al.[33]assessed cuspal deflection during composite polymerization up till 240 seconds following light curing, using electronic speckle pattern, where they found that about 50% of the total tooth deformation occurred in the 40 seconds irradiation period , although some cuspal displacement continued through 240 seconds after irradiation. so in this study the assessment of cuspal deflection was after 60 minutes to assess maximum cuspal deflection after restoration of the premolar teeth and to allow time for stress relaxation after polymerization of the resin composite.

Third reading showing no significant difference in cuspal deflection recorded after thermo-cycling and load cycling, in some premolar teeth showing that there is some increasing in the intercuspal distance in all experimental groups but the cusps did not fully achieve their original dimensions in any of the groups [21].

In this study, the polymerization shrinkage of the composite resins in all tested groups resulted in an inward deflection of the cusps, is in agreement with other studies [21, 33-35].

El-Safty et al.[36]mentioned that bulk-fill composite materials are likely to fulfil some important requirements, notably low polymerization shrinkage, ease of use, improved depth of cure (≥4 mm) and enhanced physical characteristics.

Therefore, two types of bulk fill composites (Admira® Fusion x-tra and TetricEvoCeram) were chosen to be compared with conventional composite (Filtek™ Z350 XT) in cuspal deflection

Admira® Fusion x-tra Bulk Fill material showed a lowest significant mean of cuspal deflection in comparison to TetricEvoCeram Bulk Fill composite resin andFiltek™ Z350 XT Universal composite resins after restoration (and thermocycling and load cycling.

Admira Fusion x-tra is the first all-ceramic universal bulk fill direct restorative material. It was based on nanohybrid ‘organically modified ceramics’ technology (ORMOCER®), a silicon oxide matrix and silicon oxide fillers to provide for minimal polymerization shrinkage up to 50% (1.25% by volume) than conventional composites, Its filler content of silicon oxide 84% by weight, no content of classic monomers.

Ormocers described as three dimensionally cross-linked copolymers. It consists of ceramic polysiloxane, which has low shrinkage in comparison to the organic dimethacrylate monomer matrix seen in composites. The polysiloxane chains in ormocer, polymerisable side chains added to react during curing and form the setting matrix. These inorganic molecules are longer than Bis-GMA, which could explain the material's lower volumetric shrinkage.

Ormocers were formulated in an attempt to overcome the problems created by the polymerization shrinkage of conventional composites and also because they include low shrinkage, high abrasion resistance, biocompatibility, and protection against caries [37].

Civelek et al.[38] reported that Admira (ORMOCER®), has low polymerization shrinkage (2.1%±0.1) than the other conventional types of composites as Filtek Flow (3.5%±0.1) and Ariston AT (2.3%±0.1).

Taubok et al. [39]identified that the experimental ormocer based bulk-fill resin composite developed the significantly lowest linear polymerization shrinkage and shrinkage force. The low shrinkage of the ormocer matrix can be ascribed to its resin system consisting of inorganic–organic copolymers instead of classic monomers (e.g. Bis-GMA, UDMA and TEGDMA).

The temperature fluctuation is of consequence because the coefficient of thermal expansion of hybrid composites (35 $\times 10^{-6}$ ppm/^{0}C)) is approximately three times that of the tooth (dentin=11 $\times 10^{-6}$ ppm/^{0}C; enamel=17 $\times 10^{-6}$ ppm/^{0}C), while that of ormocer is claimed to be between the two. So ormocer is expected to expand and contract much more like natural tooth structure than composite, thus significantly reducing the marginal gap formation [(40)].

In TetricEvoCeram Bulk Fill, the manufacturer states that, besides having a regular camphorquinone/amine initiator system, he has introduced an ''initiator booster'' (Ivocerin) able to polymerize the material in depth and have been incorporated a filler technology of shrinkage stress reliever.

TetricEvoCeram Bulk Fill incorporates several different types of filler (barium aluminium silicate glass with two different mean particle sizes, an „Isofiller", ytterbium fluoride and spherical mixed oxide) in order to achieve the desired composite properties. TetricEvoCeram Bulk Fill has an overall standard filler content of approximately 61% (vol.) and 17% „Isofillers" in which a shrinkage stress reliever with a low modulus of elasticity. It acts like a microscopic spring, attenuating the forces generated during shrinkage.

The mean values of Tetric EvoCeram Bulk Fill with higher filler fraction presented polymerization contraction closer to the conventional resin composite (Filtek Z350 XT), the polymerization contraction of them ranged between (1.58% and 3.36%) [(41)].

This agree with the results obtained in this study as the mean value of Tetric EvoCeram Bulk Fill (35.4 µm)after resoration and (12.4 µm) after thermocycling and load cycling , were closer to the mean value of Filtek Z350 XT (37.4 µm) after resoration and (14.6 µm) after thermocycling and load cycling

The reduced shrinkage of bulk-fill materials may be due to their low flexural modulus and low filler loading [(42)]. The filler and resin composition in restorative materials specifically designed for bulk-filling must account for light attenuation. One approach has been to increase the translucency of bulk-fill restorative materials to enhance the depth of cure [(43)].

The reduced polymerization shrinkage stresses and subsequent cuspal deformation of bulk-fill resin composite materials is attributed to optimized resin matrix, initiator chemistry, and filler technology [(44)].

Many studies have stated that the incorporation of UDMA and Bis-EMA and the increased filler volume content in high-viscosity bulk-fill composites that reduce the amount of resin in the composite material resulted in reduction in the contraction stress that is a direct cause for significantly less polymerization shrinkage [(4, 7, 45)].

According to the manufacture, the resin system for Filtek™ Z350 XT consists of a blend of UDMA (urethane dimethacrylate) and Bis-EMA (Bisphenol A polyethethylene glycol dietherdimethacrylate). UDMA and Bis-EMA resins are of higher molecular weight, resulting in less shrinkage and to adjust the viscosity of TEGDMA and PEGDMA used in minor amounts.

Rosatto et al[(46)], reported that all bulk-fill composites had lower post-gel shrinkage than the conventional composites. The use of bulk-fill filling technique resulted in lower cuspal strains and shrinkage stresses. Furthermore, teeth restored with bulk-fill composites had higher fracture resistance.

The lowest mean in the second group would suggest a low technique-sensitive procedure with the bulk-fill system compared with incremental placing of the conventional resin composites. Although an increase in filler loading in resin composite leads to a reduction in shrinkage, this has been shown to result in higher contraction stresses.

In this study, the result show that there is no statistically significant differences in cuspal movement. As **Campodonico et al**[(47)], found no difference in cuspal deflection between the bulk-filling material and a conventional resin composite.

Benetti et al [(41)]**,** concluded that high viscosity bulk-fill resin composites (TetricEvoCeram Bulk Fill) demonstrated, to some extent, polymerization contraction values similar to the conventional resin composite. That was similar to the results of the present study as the mean value of cuspal deflection of bulk fill materials (TetricEvoCeram Bulk Fill) and conventional composits (Filtek Z350 XT) were nearly similar to each other.

Kim et al[(48)], showed that bulk-fill composite and conventional composite exhibited similar polymerization shrinkage stress. This could be due to the different methodological approach used to assess the polymerization shrinkage stresses.

All insertion techniques using composite resin produced measurable cuspal movement,bulk filling technique has been suggested to produce lower shrinkage stresses [(49)], but sufficient depth of cure may require an incremental technique.

The incremental insertion techniques can reduce the negative effects of polymerization shrinkage by reducing the bulk of composite cured with each layer. Increasing the ratio of unbonded to bonded surfaces has also been suggested to reduce the curing shrinkage by allowing unhindered ''flow'' in the unbonded surface layer [(19)].

In general, deeper preparations showed significantly higher cuspal deflection. The use of incremental insertion reduced the overall amount of flexure over bulk insertion at standard cavity depth (4 mm). however, there were no significant differences among the different incremental insertion techniques used.

Bulk-filling techniques widely used recently following the development of materials with improved curing (50, 51), controlled polymerization contraction stresses (52, 53), and reduced cuspal deflection (54).

Using this approach, the number of increments required to fill a cavity reduced in comparison with traditional incremental filling techniques. In contrast to the maximum 2-mm increments recommended for conventional resin composites, manufacturers recommend 4- or 5-mm increments of the bulk-fill resin composites. The use of the bulk-fill technique undoubtedly simplifies the restorative procedure and saves clinical time in cases of deep, wide cavities (41).

Similar to this study (18), a two-layer incremental method was chosen because 2 mm usually is regarded as the maximum thickness for curing a composite and because the placement procedure was more controllable and thus more consistent.

IV. Conclusion

Under the limitation of this study, the results suggest that:

1) All types of composite and insertion techniques caused measurable cuspal deflection.
2) The bulk filling materials and technique caused minimal cuspal deflection than universal type of composite and incremental technique of insertion.

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