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Cuspal Deflection of Bulk-Fill versus Layered Resin Composite Restorations

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Abstract
Objectives: *This study was conducted to evaluate and compare cuspal deflection of class II (MOD) bulk-fill Tetric EvoCeram, SonicFill bulk-fill resin composite, and layered Filtek Z250 resin composite restorations.*
Materials and Methods: *Thirty MOD cavities were prepared in extracted human molar teeth. The cavities were divided into three groups (n=10) according to the restorative material used (Sonic fill, Tetric Evoceram Bulk fill and Filtek Z250). Cuspal deflection was evaluated using digital image correlation technique.*
Results: *There were no significant differences ($P<0.05$) between the tested bulk fill restorative materials (Sonic Fill and Tetric Evoceram Bulk fill) and the conventional one (Filtek Z250).*
Conclusions: *Bulk fill restorative materials (Sonic fill& Tetric Evoceram Bulk fill) showed cuspal deflection like that of conventional resin based composite.*
Keywords: *Bulk Fill, Cuspal deflection, Digital image correlation, Incremental.*

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I. Introduction

There is great interest in the beauty since the earliest civilizations; composite resins have become a part of this quest to enhance the esthetics of the teeth and mouth. It is now one of the most commonly used direct restorative materials for anterior and posterior teeth. But one of the inevitable drawbacks of dental composites is its shrinkage during free radical polymerization, which may be as high as 3% by volume.[1-5]

When shrinkage occurs while the resin composite materials are inside the cavity and bonded to the cavity surfaces, stresses develop transferred to the tooth restoration interface. If the bond strength is smaller than these stresses, de-bonding might occur resulting in postoperative sensitivity, marginal discoloration, marginal gap formation and recurrent caries.[6-8] However if these stresses are smaller than the bond strength no de-bonding occurs, but the restoration will maintain internal stresses that pull the cusps together, decreasing the inter-cuspal distance width causing cuspal deformation which might cause microcraks and/or cusp fracture.[9,10]

Many clinical methods have been proposed to reduce the shrinkage stress, such as the control of the curing light intensity,[11,12] flowable resin liner application,[13] indirect resin restoration,[14] and incremental layering techniques.[15] However, no method has been shown to be totally effective in abating the effects of polymerization shrinkage.

Despite the controversy over the advantages of incremental build-up of composites (through which the material is gradually placed in layers of 2 mm or less) this technique has been broadly recommended in direct resin composite restoration, because it is expected to decrease the C-factor (the ratio of bonded surface to unbonded free surface), allowing a certain amount of flow to partially dissipate the shrinkage stress.[16] However, in addition to these advantages, incremental technique has number of disadvantages such as; entrapment of voids between the increments, bond failure between the increments and the time taken to complete the procedure long time is required to place and polymerize each increment.[17-19]

In order to overcome many of the downsides associated with the incremental approach to place resins, new restorative materials have emerged that are marketed as bulk-fill composites. However, dentists who have become accustomed to the incremental cure philosophy when placing light-cured composites quite rightly question what specifically has changed to make these bulk-fill composites a viable alternative.[20]

Bulk-fill resin-based composites are tooth-colored restorative materials with increased polymerization depth, decreased polymerization shrinkage stresses and decreased cuspal deflection rates. They can be applied into the prepared cavities in layers up to 4or 5 mm thick.[21]

According to some researchers these bulk-fill composites offer a number of advantages for restoring preparations such as simplifying the restorative process and saving time. Furthermore, bulk-fill composites eliminate many of the drawbacks that are associated with incremental layering techniques, such as the risk of contamination and voids forming between the increments.[22-24]

Cusp deflection is the result of interactions between the polymerization shrinkage stress of the composite and the compliance of the cavity wall, and is a common biomechanical phenomenon observed in teeth restored with composites. In order to measure cusp deflection, many methods have been developed, involving photography[25], microscopy[26, 27], strain gauge[28,29]interferometery and linear variable differential transformer.[30] Cusp deflection during composite restoration has been reported to be about 10–45 µm, varying according to the measurement method, tooth type and cavity size. The biomechanical analysis of cuspal deflection results provides a guideline for successful composite restorations in the dental clinic.[31]

The aim of the present study was to evaluate the cusp deflection of two different bulk-fill composite resins in class II cavities. A conventional posterior micro-hybrid composite resin was used as a control. The null hypothesis was that bulk-fill composite resins exhibit the same cusp deflection as conventional composite resins that have been applied using the incremental technique.

II. Materials & Methods

Two high viscosity bulk fill resin-based composite materials (Tetric Evo Ceram and SonicFill), and one conventional universal composite (FiltekZ250) were investigated in this study (Table1). Each restorative material was used with its proprietary adhesive system. A well controlled light emitting diode (LED) (Blue Phase meter, Ivoclar/Vivadent AG, Schaan, Liechtenstein) curing unit with light intensity of 800mW/cm^2 was used for polymerization.

Table1: Materials used in the study.

Restorativesystem	Manufacturer	Resin	Filler	Filler size
SonicFill	Kerr Corporation	Bis–GMA,TEGDMA,EBpDMA	Silicondioxide,bariumglass	Unreported
Optibond soloplus (two-stepetch-and-rinse		HEMA,GPDA,Mono(2-methacryloxyethyl)phthalate,Ethylalcohol,Water.		
TetricEvoCeram BulkFill(nanohybrid)	IvoclarVivadent	UDMA, Bis-GMA	Bariumglass, ytterbiumtrifluoride, mixedoxideprepolymer	550nmavarege Range(40 -3000nm)
ExciteF(two-stepetch-and-rinse	IvoclarVivadent	Etchant:73%phosphoricacidwithcolloidalsilica Adhesive:HEMA,DMA,phosphoricacidacrylate,silicondioxide,initiator,stabilizersinanalcoholsolution.		
FiltekZ250(microhybrid)	3MESPE Konstanz,Germany	Bis-GMABis-EMA,TEGDMAUDMA.	Zirconia/silicaparticles	0.01-3.5µm Average:0.6µm
SingleBond(two-stepetch-andrinse)	3MESPE	Bis-GMA,HEMA,DMA,polyalkenoicacidcopolymer,initiator,water,ethanol.		

Thirty freshly extracted human molar teeth free from caries, restorations, cracks or other defects were selected for this study. All selected teeth were cleaned with a hand and ultrasonic scaler from any soft tissues or hard calculus deposits. The selected teeth were stored in physiologic saline with 0.05% sodium azid (to prevent bacteria or fungus growth in the storage medium) until the experiment time.[26]

The selected teeth were assigned into three equal groups (n=10) according to the restorative materials used. A 3-cm polyvinylchloride tube was filled with acrylic resin (Acrostone, Egypt) material in the dough stage. The selected molar teeth with their roots were embedded at the tube center and parallel to its long axis; to a level of 2 mm below the cement-enamel junction simulate the position of the tooth in the alveolar bone and also to prevent the reinforcement of the crown by the base. Specially designed Jig was used to standardize the correct position and angulation of each tooth inside PVC ring [26].

Root surfaces were dipped into melted wax to a depth of 2 mm below the C.E.J to produce a 0.2 to 0.3 mm layer nearly equal to the average thickness of the periodontal ligament. Then the molar teeth were mounted in acrylic resin cylinders. Four spheres are inserted in the plastic ring around the tooth sample functioned as a stable reference areas.[26] Fig. 1.

Figure 1. Tooth fixed with four reference plastic points.

After polymerization of acrylic resin, each tooth was removed from the resin cylinders. By dipping in the root in a hot water bath, wax spacer was removed from the root surface and from the alveolus of the acrylic resin cylinders. Polyether impression material (Imprgum, ESPE, Seefeld, Germany) was delivered into acrylic resin, then the teeth were reinserted into their respective cylinders and the polyether impression material was left to set. Excess polyether impression material was removed with a scalpel blade to provide a flat surface 2 mm below the CEJ of each tooth.

Standardized large slot MOD cavity preparation was prepared using a high speed hand piece fixed in especially designed jig and fixer (designed at Production Engineering and Mechanical Design Department, Faculty of Engineering, Mansoura University, Egypt). The device allowed accurate movement of the hand piece, results in a nearly standardized cavity width (3± 0.3 mm) and depth (4± 0.3mm).

After every five cavity preparations the bur was changed. The cavity depth was 4 mm from the cavity occlusal cavosurface margin to the pulpal floor. The buccal and lingual walls were prepared parallel without occlusal convergence. The slot MOD cavities were prepared without proximal boxes in order to reduce the preparation variation. All the cavosurface margins were prepared without beveling, and all internal line angles were rounded [5].

A Tofflemire matrix band was contoured and placed around the teeth and held firmly at the proximal aspects of the teeth. (Total etch dentine bonding systems were used among all products to reduce variability in results that might have occurred if some self-etching systems had been used).[27]

A total-etch technique with 37% phosphoric acid gel. Phosphoric acid gel was applied directly from the syringe to cut enamel first, wait 15-20 sec, then applied to all exposed dentin for 15 sec. The etchant gel was rinsed off with a stream of water for 15sec, preserving a clean, contamination-free field. After gentle air drying for 1 second, a moist dentin surface was dried gently using oil free air. Teeth were subdivided randomly into three subgroups (n=10) according to the restorative material used. Adhesive procedures were performed following manufacturer's instructions.

Each restorative material was used with its corresponding adhesive system follow:

a. Incremental layering using Filtek Z250:

Immediately after blotting the excess moisture from the dentin by gentle air drying, two coats from single bond adhesive were applied with gentle agitation using a fully saturated applicator; with 20s waiting period in between the coats. Gentle air thinning was performed for five seconds to evaporate solvents, and then light cured for10seconds.

The composite resin was applied incrementally in two horizontal increments with approximately 2-mm thickness. Each increment was gently condensed with clean non sticky composite condenser in order to ensure complete adaptation to the underlying resin and tooth structure (Optrasculpt modeling tip, Ivoclar/Vivadent). The occlusal anatomy was shaped as exactly as possible avoiding overhangs. Each 2-mm increment was irradiated for 40 seconds with the LED with curing tip touching the slopes of the cusps of the tooth. After removal of the matrix curing from the facial and lingual aspects of the proximal boxes to ensure complete polymerization. The light intensity of the curing unit was periodically checked with radiometer and was found to be constantly above 800 mW/cm^2.

b. Tetric Evo ceram bulk fill

After acid etching a single layer of ExciTE F adhesive was applied to the etched surfaces and scrubbed for 10 seconds. Then the excess material was removed with a gentle stream of air and light-cure for10 seconds**.** The entire cavity was filled with single increment, adapted to the cavity with condenser and the light cured with LED curing unit.

c. Sonicfill technique

After gentle air drying with air for 1 second two coats of the adhesive were actively applied for 15 seconds with a saturated brush tip to the enamel and dentin, until the surface appeared glossy. Air thin for 3 seconds and the adhesive was light-cured for 20 seconds with a visible light unit.

Resin was applied to the cavity with the assistance of a specially designed sonic hand-piece. The customized composite is provided in a uni dose capsules. The hand-piece was attached to the air-water line by using a coupler adaptor, and then activated by the traditional rheostat pedal. The rate for dispensing resin composite was set with the switch at the base of the hand-piece by numbers from one to five (one is the slowest and five is the fastest, the mode rate speed was used by adjusting the rate to be on number three). Sonicfill uni dose tip was inserted in the sonicfill handpiece with moderate hand pressure and screwed tightly in a clockwise rotation.

With the unidose composite tip in the proximal portion of the cavity, to avoid air trapping, the sonicfill handpiece was activated by depressing the foot pedal, the cavity was filled. With the help of sonic energy vibration, resin composite was extruded in a soft, nearly flowable as the viscosity drops by 87%. Once the cavity was filled and the handpiece was removed, composite begin storages in its original high viscosity state. A small diameter 1.5mm tip allows access to very small cavities.

The handpiece was slowly withdrawn as the cavity was filled, with the tip staying within the material to ensure well adaptation and avoid entrapment of air. A round-ended condenser (Optrasulpt) was used to press down on the material and wipe away excess at the margins. Sonicfill composite resin material is non-sticky and does not slump, so quick and easy sculpting and carving to the desired anatomical form was made with a bladed instrument. Upon completion, the restoration was light-cured from the occlusal for 20 seconds with a curing light providing high output. After removing the wedge and matrix, the restoration was light-cured again for 20 seconds from the buccal and the lingual aspects.

After applying the restorative materials, finishing and polishing with politip-P (Politip-p, Ivoclar/Vivadent); step one finishing with gray cup and step two polishing with green one. Specimens were photographed using USB Digital microscope with a built-in camera (Scope Capture Digital Microscope, Guangdong, China) connected with an IBM compatible personal computer using a fixed magnification of 45X. The images were recorded with a resolution of 1600×1200 pixels per image.

A marker particle placed on the specimen is detected by the camera and recorded as red green blue (RGB) color data onto the image storage device. After the color histogram analyzed according to preset RGB threshold values. The images were analyzed using Image-tool software (ImageJ1.43U, National Institute of Health, USA).Within the Image software, all limits, sizes, frames and measured parameters are expressed in pixels. Therefore, system calibration was done to convert the pixels into absolute real world units. Calibration was made by comparing an object of known size (a ruler in this study) with a scale generated by the soft ware. All the collected data were subjected to One way ANOVA statistical analysis test using the statistical package for Social Science (SPSS Inc, Chicago, IL, US).

III. Results

One way ANOVA test showed that there was no statistically significant difference between the three tested restorative materials; Table 2. The highest mean value was recorded for Z250 and the lowest for Tetric Evo ceram Bulk fill. Table 3; Fig. 2.

Table 2. Means and SD of cusp deflection values of the tested groups

Data							ANOVA	
	Range			Mean	±	SD	F	P-value
Z250	2.22	-	12.05	4.909	±	2.717	1.274	0.296
TEBF	1.09	-	6.38	3.527	±	1.858		
SF	2.31	-	6.75	4.745	±	1.608		

*Significant difference at $P<0.05$.

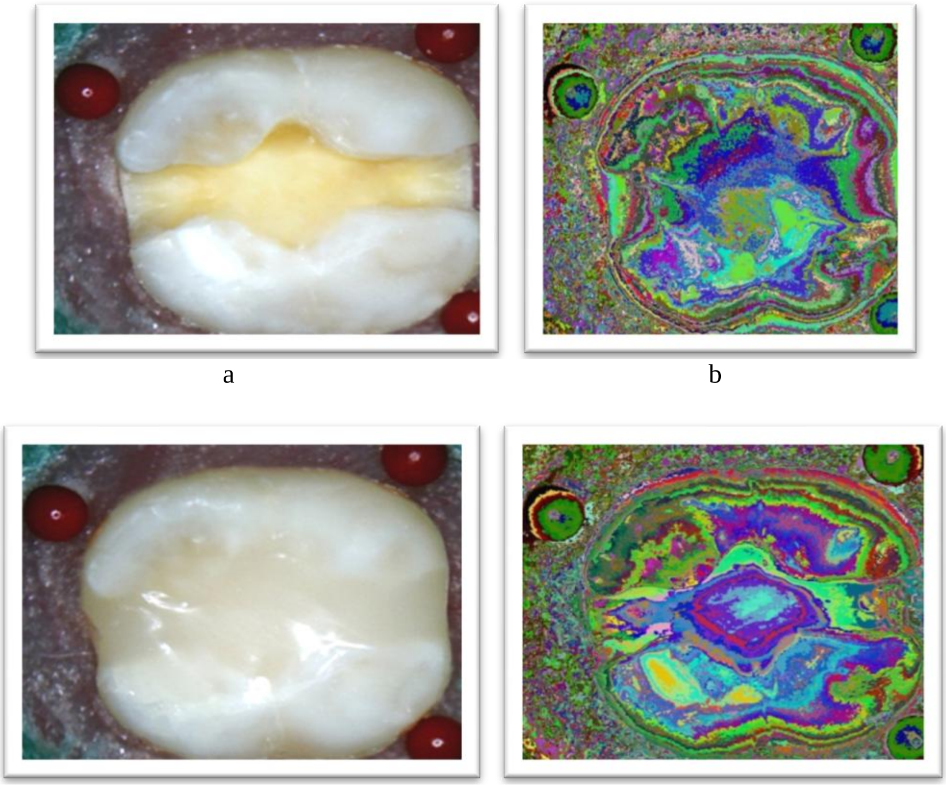

Fig. 2; a-d: Images recorded by USB microscope for one sample for Tetric Evo Ceram Bulk-Fill.

Table 3. Values recorded by USB microscope for one sample of Tetric Evo Ceram Bulk-Fill.

MinFeret	FeretAngl	FeretY	FeretX	Feret	Max	Min	Mean	Area	Label	
NaN	NaN	NaN	NaN	NaN	255	0	132.124	1920000	Red	1
NaN	NaN	NaN	NaN	NaN	255	0	130.704	1920000	Green	2
NaN	NaN	NaN	NaN	NaN	255	0	123.276	1920000	Blue	3
NaN	NaN	NaN	NaN	NaN	255	1	128.697	1920000	(R+G+B)/3	4
NaN	NaN	NaN	NaN	NaN	255	1	130.283	1920000	0.299R+0.587	5
NaN	NaN	NaN	NaN	NaN	255	0	127.217	1920000	Red	6
NaN	NaN	NaN	NaN	NaN	255	0	128.791	1920000	Green	7
NaN	NaN	NaN	NaN	NaN	255	0	123.866	1920000	Blue	8
NaN	NaN	NaN	NaN	NaN	255	1	126.62	1920000	(R+G+B)/3	9
NaN	NaN	NaN	NaN	NaN	255	1	127.757	1920000	0.299R+0.587	10

IV. Discussion

Many authors used cuspal movement to study the influence of restorative procedures and restorative materials' properties on teeth. Shrinkage measurements by using non-contact methods has been carried out by using laser beam scanning, or video-imaging techniques. [32-34]

In the present study, non-contact optical methods using digital image correlation was used to measure polymerization shrinkage of composite resin. The digital image correlation method gave more detailed and useful information about polymerization shrinkage. With the use of digital image correlation, instead of just overall shrinkage, full-field shrinkage strains showing local details can be achieved as the whole surface of the specimen is under observation.[33]

In the present study, a large slot MOD cavity preparation was performed on molar teeth in order to weaken tooth structure and favor cuspal deflection and mimic the clinical situations. Lopes et al. mentioned that the degree of cuspal deflection is directly related to loss of tooth structure. Also they stated that, as the cavity size increases, more RBC material is required, producing more shrinkage forces and consequently more cuspal deflection.[35] Karaman et al. reported that there was no significant difference in the cuspal deflection before or after cavity preparation; so, the base line measurements were recorded after tooth preparation.[32]

There was no statistically significant difference between the tested materials used regarding the cuspal deflection measurement. For the microhybrid composite resin, Filtek Z250 exhibits lower polymerization shrinkage, superior curing characteristics and higher fracture toughness. The resin system in this composite has been modified by eliminating the Bis-GMA content and reduction of TEGDMA. The resin consists of Bis-EMA and UDMA and a small amount of TEGDMA. Also the results may be due to high molecular weight of resin and high filler content which yielded fewer double bonds to cross-link so, less polymerization shrinkage stresses. The incremental technique by which the microhybrid composite was applied to the cavity is thought to decrease polymerization shrinkage stress by reducing the C-factor (flow of composite resin through unbounded surfaces).

Reduced polymerization shrinkage stresses and subsequent cuspal deformation of bulk-fill resin composite materials were attributed to optimize resin matrix, initiator chemistry, and filler technology.[33] The increased filler volume content in high-viscosity bulk-fill composites is reported to be a direct cause for significantly less polymerization shrinkage. The higher filler load decreases the amount of resin in the composite materials and thus reduce the polymerization shrinkage.

For sonicfill composite resin system, low cuspal deflection measurements may be attributed to its high filler loading. Sonicfill systems contain nanohybrid composite resin with great filler loading (83.5%wt). These results can also be explained by the working principle of the Sonicfill system; composite used is a highly filled resin with special modifiers that react with sonic energy. Kim et al. reported that bulk-fill composite and conventional composite exhibited similar polymerization shrinkage stress.[36] Optimizing the filler sizes in SonicFill composites could be a contributing factor to the lesser polymerization contraction stresses. According to the manufacturer, sonicfill composite resin has ultra-efficient curing characteristics that ensure full 5mm depth of cure this due to the incorporation of greater amount of photoinitiators.

When sonic energy is applied through the handpiece, the modifier causes the viscosity to drop (up to 87%), increasing the flowability of the composite. When the sonic energy is stopped, the composite returns to a more viscous, non-slumping state. The Sonicfill system cannot be classified as a flowable composite as the flowability is adjusted by the practitioner through the handpiece with five levels of speed and when the sonic activation stopped, the material becomes similar to a universal composite.[36]

For Tetric Evo ceram bulkfill, the results may be due to the slight increase in the filler content, or due to decreased polymerization shrinkage of these materials.[36] Tetric Evo ceram bulkfill contain shrinkage stress reliever which are fillers with low modulus of elasticity (10MPa). These fillers works on keeping chemical cushion between the coarse filler particles and improves the elasticity of the restoration.

In addition, Tetric Evo ceram bulkfill contains a new highly sensitive and reactive light initiator systems (Ivocerin) in addition to familiar initiators such as camphorquinone and acylphosphineoxide. This new polymerization booster is based on dibenzoyl germanium derivatives, features with an absorption spectrum similar to that of the widely used camphorquinone. Ivocerin shows improved quantum efficiency due to its higher light absorption rate in the visible wavelength range and so higher light-reactivity.

V. Conclusion

Based on and within limitation of the present study, the following conclusions can be assumed:-

1. Bulk fill restorative materials (Sonic fill& Tetric Evoceram Bulk fill) showed cuspal deflection like that of conventional resin based composite.
2. All the tested restorative systems failed to achieve polymerization shrinkage free conditions.
3. Digital image correlation is a valuable tool for assessment of cuspal deflection.

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