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Hygroscopic Expansion Influence on Cuspal Deflection of Tooth Composite Restoration

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Authors' contributions

This work was carried out in collaboration between all authors. Author HMM designed the study, performed the statistical analysis, wrote the protocol and wrote the first draft of the manuscript. Authors EIK and LML managed the analyses of the study and managed the literature searches. All authors read and approved the final manuscript.

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Original Research Article

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ABSTRACT

Introduction: Polymerization shrinkage can result in gap formation between the composite material and tooth structure with subsequent plaque accumulation, which affect the esthetic quality of a restoration and initiate periodontal diseases.
Aim: The aim of this study was to evaluate the effect of hygroscopic expansion on the cusp deflection of tooth composite restoration.
Study Design: Invitro study using human premolars.
Place and Duration of Study: Preventive and operative dental sciences in Alfarabi Dental Sciences, Riydah, KSA between July and September 2017.
Materials and Methods: Eighty (80) human premolars extracted for orthodontic reasons. In each of the extracted premolar mesio- occluso distal cavity (MOD) was prepared and divided into two main groups (40 each) according to the restorative material, each main group randomly divided into two groups according to bonding used (20 each), subdivided into four equal subgroups (5 teeth per each) according to immersion in normal saline, Specimens were stored in saline for four-time interval (immediate, 2, 4 &12) weeks. Cuspal deflection was detected by digital caliper.

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Results: There was a significant difference between the last two groups which filled with composite resin while the control teeth showed no significant difference. The cavities which restored with silorane (P90) resin-based composites and bonded with its consensual adhesive recorded the least Cuspal deformations.
Conclusions: Cuspal deformation was decreased by hygroscopic expansion in teeth restored with a hydrophobic resin composite, while a hydrophilic composite restoration shows over-compensated the polymerization shrinkage causing tooth expansion.

Keywords: Cusp deflection; periodontal diseases; hygroscopic expansion.

1. INTRODUCTION

Patients look for the best color-matching restorations and composite resins can satisfy this goal [1]. The major disadvantage of visible light-cured composites is polymerization shrinkage produces contraction stresses in the resin composite restoration , with subsequent plaque accumulation, which affect the esthetic quality of a restoration and initiate periodontal diseases [2]. As the elastic modulus of the composite increases during curing, an internal stress and deformation is induced in the surrounding tooth structure [3]. This stress is exhibited as bond failure, cuspal deflection, enamel microcracking, pulpal irritation, secondary caries, plaque accumulation with subsequent periodontal diseases initiation and postoperative sensitivity, which in turn can lead to restoration failure requiring restoration [4]. These are believed to cause microleakage, postoperative sensitivity, recurrent caries and eventual loss of the restorations which in turn affect the gingival health. In addition, gaped resin can lead to plaque accumulation, superficial degradation and subsequent gingival inflammation [5]. low surface hardness resulted in failure of restorations [6,7]. Teeth restored incrementally show less gingival microleakage compared with bulk restored teeth. Incremental restoration with the plasma arc light had significantly increased gingival microleakage compared with the turbo – boosted halogen curing light, this gingival microleakage resulted in plaque accumulation and periodontal diseases initiation [8]. When the adhesive strength exceeds the contraction stress, the restoration maintains an internal tension that pulls the cavity walls together, reducing the intercuspal distance (i.e., cuspal deflection) [9]. The magnitude of this inward cuspal movement appears to depend mainly on the cavity size, type, and the type of composite used. [10-12]. Cuspal deflection may result over time in micro-cracks propagation, enamel cracks, crazing, ultimate decrease in fracture resistance of the restored tooth, and, in extreme cases, cusp fracture [1,13-15]. Cuspal deflection can be perceived clinically by the patient as postoperative sensitivity. It is also expected that absorption of water will be accompanied by a hygroscopic expansion of composite which may be able to compensate for the effect of polymerization shrinkage and relieve stresses [16]. In contrast to the rather rapid polymerization contraction and stress development, the hygroscopic relief will proceed slowly and might even take days [17,18]. The rate and magnitude of hygroscopic expansion of a resin material depend on several variables such as the nature of the resin, the type of filler, filler loading, filler-matrix adhesion and the volumetric ratio between the filler and matrix [19-21].

1.1 Aim of the Study

"To evaluate the effect of hygroscopic expansion on the cusp deflection of tooth composite restorations in invitro conditions".

2. MATERIALS AND METHODS

Eighty (80) human premolars extracted for orthodontic reasons stored in normal saline were used. The selected teeth were placed 3 mm below the cementoenamel junction in an acrylic mold with dimensions of 15 mm internal diameter, 25 mm external diameter, and 20 mm height. The teeth set in the acrylic mold were fixed with a vice and a large mesio- occluso distal cavity (MOD) was prepared. The mesiodistal proximal box was extended 0.5 mm bucco-lingually, and the width of the axial and gingival walls of the box was 1 mm. The width and depth of the pulpal wall of the MOD cavities were 2 × 3 mm. The central groove was the reference point for cavity depth. The reference point for measuring the specimens before and after the procedure was two metal tips (cut from dental needle C-K Ject, Korea, Queens Singapore) for each specimen (0.5 × 4 mm) that was fixed (using Clearfill SE Bond) horizontally and perpendicular to the long axis of the specimen at the cusp tip of the tooth, one buccally and the other lingually. The end of this tip was located beyond the buccal and lingual tooth contour by 2 mm to be measured by digital caliperto calculate the cusp deflection. The specimens were divided into two main groups (40 each). The first main group was restored with hydrophilic one (Silorane) while the second main group was restored with a hydrophobic resin composite (Z 350). The restoration of the cavities with the restoration followed the manufactured instructions. each main group divided into two groups according to bonding used (G-bond & composite consensual adhesive) (20 each), subdivided into four equal subgroups as follows:

Group A: Using low shrinkable resin composite (Filtek™ P90 Silorane shade A2; 3M ESPE, St Paul, MN, USA) with its adhesive system.

Group B: Using low shrinkable composite (Filtek P90 Silorane shade A2; 3M ESPE) with G‑bond (GC, Tokyo, Japan).

Group C: Using Filtek™ Z350 (3M ESPE) composite withAdhe SE (Ivoclar Vivadent, Schaan, Liechtenstein).

Group D: Using Filtek Z350 (3M ESPE) composite with G‑bond (GC). Specimens were stored in water for four-time interval (immediate, 2, 4 & 12) weeks Each group will be further divided into equal subgroup (5 teeth each) according to immersion in normal saline. Cuspal deflection was detected by digital caliper. The reading of the cusp deflection was The buccal and lingual cusp movements were recorded for 2000 s and the measured value (as a function of time) was stored on a computer through a data acquisition board. The results were statistically analyzed using ANOVA followed by Student–Newman–Keuls post hoc tests (p = 0.05).

3. RESULTS

After the storage period(3months) the results reveal that, cavities which restored with the silorane (P90) resin-based composites recorded less cuspal deflection than the methacrylate-based (Filtek Z350) group. the cavities which restored with silorane (P90) resin-based composites and bonded with its consensual adhesive recorded the least Cuspal deformations.While methacrylate-based (Filtek Z350) group bonded with G bond recorded the highest cuspal deflection. there was a statistical significant difference (P<0.05), between group A (P90 with its adhesive) and both group D (Filtek Z350 with adhesive), and group C (Filtek Z350 with G-bond). Regarding interaction between group C (Filtek Z350 with G-bond) and group D(Filtek Z350 with adhese adhesive) results revealed that there were no statistically significant differences (p>0.05).

4. DISCUSSION

The composite shrinkage creates stresses within the material at the tooth structure interface, that might manifest clinically as cuspal deflection, which in turn compromises the synergism of the bond at the tooth restoration interface possibly

Table 1. List of the materials which were used in this study

Composite	Trad name	Manufacture
Silorane	Filtek™ P90 Silorane	(3M ESPE,St Paul, MN, USA)
Low shrinkable	Filtek™ Z350 (3M ESPE)	3M ESPE
composite	Adhe SE G Bond	(IvoclarVivadent, Schaan, Liechtenstein)
		(GC, Tokyo, Japan)

Table 2. Mean values and standard deviation for cuspal deflection of the tooth restored with composite restoration under water with different storage times

Composite	Bonding	Immed	2w	4w	12 w	Paired sample t-test (p value)
Silorane	Adhesive (group A)	**-2.8**±0.23	**-1.2**±0.22	**-0.4**±0.19	**-0.2**±0.18*	**0.00**
	G bond (group B)	**-4.3**±0.18	**-1.6**±0.24	**-0.6**±0.15	**-0.4**±0.22	**0.42**
z350	Adhesive (group C)	**-5.3**±0.21	**-2.1**±0.18	**-1.1**±0.12	**-0.6**±0.18*	**0.03**
	G bond (group D)	**-6.9**±0.17	**-4.2**±0.22	**-2.3**±0.17	**-0.8**±0.22*	**0.1**

** significant difference at p ≤0.05*

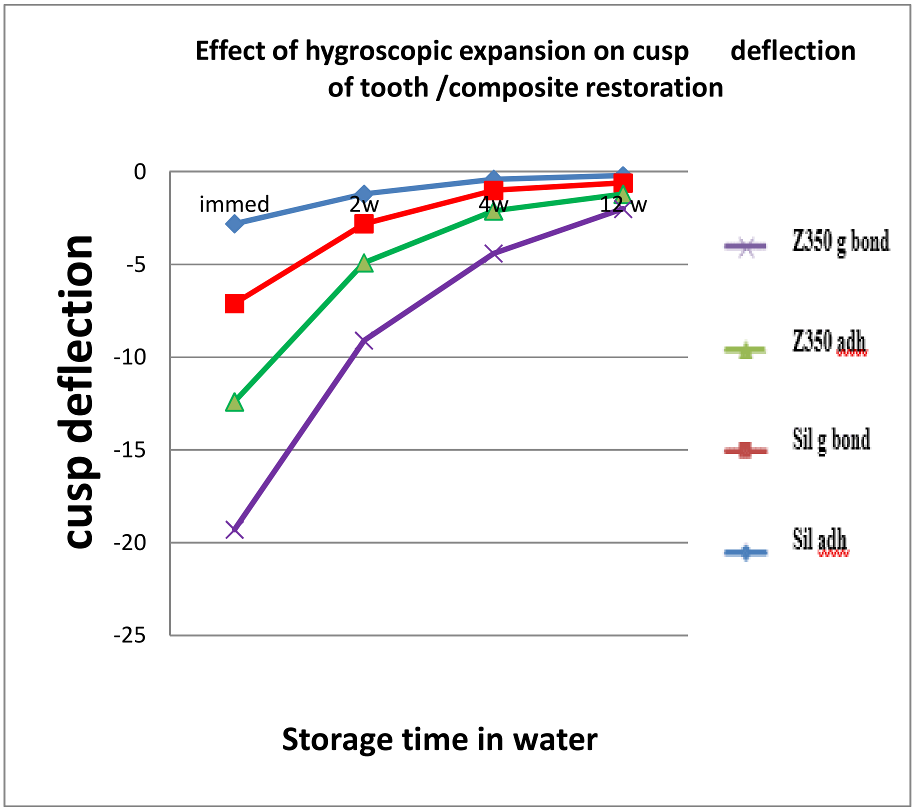

Fig. 1. Histogram of the mean score (5 each) of cuspal deflection of the tooth restored with composite restoration underwater with various storage times

leading to bacterial microleakage and ultimately to marginal discoloration, secondary caries, pulpal inflammation and plaque accumulation with subsequent periodontal diseases [22,23]. Polymerised resin-based restorative material is continuously exposed to water in the oral environment. Water uptake into the resin phase may account for relaxation of the residual stresses that are set up within the matrix during the polymerisation shrinkage [24,25]. Swelling of the resin matrix via hygroscopic expansion also contributes to the reduction in the size of the marginal gaps that may be concomitantly present [26,27].

There are two contrasting processes during water sorption by composite restoratives in the oral aqueous environment. Firstly, water can leach out unreacted monomers, if present, it can lead to loss in mass, shrinkage and changes in mechanical properties [28,29]. Secondly, water diffusing into the material leads to mass increase and usually can cause a progressive bulk expansion until equilibrium is achieved [30-33]. Deflection of the cusps through light irradiation of the restorative resin - based composite material will only occur if there is sufficient resistance to polymerization shrinkage associated with the adhesive properties at the tooth/restoration interface. Typical resin composites applied in restorative dentistry exhibit volumetric shrinkage values from less than 1- 6%, depending upon the formulation and the curing condition [34,35]. Recently, a new category resin matrix for dental composite was developed based on ring - opening monomers [21]. This hydrophobic composite is derived from the combination of siloxane and oxirane, and thus has the name silorane [22]. The major advantages of this innovative restorative material are its reduced shrinkage and its mechanical properties comparable to those of methacrylate - based composites [34]. In the current study, all the cavities which restored with resin - based composite exhibited cuspal deflection. The significant increase in cuspal deflection of cavities restored with the methacrylate - based (Filtek Z350) compared with the Silorane (P90) resin - based composites might be attributed to many factors, firstly the ring opening chemistry of the Siloranes enables at the first-time shrinkage values lower than 1% volumetric shrinkage and increased mechanical parameters as E-Modulus and flexural strength comparable to the methacrylate based composites [36]. Secondary, increased hydrophobicity of the Siloranes which lead to decreased water sorption, solubility, and associated diffusion coefficient compared with conventional methacrylate-based composites [37]. The specimens of both (Filtek (Z350) and Silorane (P90) composite which bonded with (G-bond) recorded high cuspal deflection than those bonded with adhesive. This may be attributed to Voids were consistently found throughout the G Bond adhesive layer and may be due to the lack of HEMA and phase separation.G Bond does not contain HEMA, a low viscous monomer that increases dentine wetting and solubility of other adhesive monomers that may account for short and thick resin tags. Furthermore, acetone, a co-solvent in G-Bond, may induce phase separation and precipitation of adhesive components due to the changing water: acetone ratio during evaporation [38]. This lead to the formation of the hybrid layer of comparable thickness to two-step self- etch adhesive (silorane adhesive system) but might be of lower strength hence, cannot withstand functional and shrinkage stresses which leads to more cusp deflection.

5. CONCLUSION

Cuspal deformation was decreased by hygroscopic expansion in teeth restored with a hydrophobic resin composite, while a hydrophilic composite restoration shows over-compensated the polymerization shrinkage causing tooth expansion.

CONSENT

It is not applicable.

ETHICAL APPROVAL

It is not applicable.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

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