THE EFFECT OF A NANOFILLED COAT ON THE SURFACE WEAR AND FRACTURE RESISTANCE OF A GLASS HYBRID IN CLASS II RESTORATIONS IN PERMANENT TEETH (IN VITRO STUDY)

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ABSTRACT

INTRODUCTION: Minimal cavity preparation of class II lesions and selection of a suitable restorative material are the optimal goals to obtain durable restorations.
OBJECTIVES: To evaluate the effect of a nano-filled coat on the 3D wear and fracture resistance of a glass hybrid restoration after cyclic loading in class II restorations in permanent teeth.
MATERIALS AND METHODS: Compound occluso-mesial class II cavities were prepared in 44 premolars. Teeth were randomly allocated into 2 groups. Group 1 (Experimental Group): n= 22 teeth were restored with Equia Forte Fil plus Equia Forte coat. Group 2 (Control Group): n= 22 teeth were restored with Equia Forte Fil without its coat. All samples were subjected to fatigue by cyclic loading using ACTA type chewing simulator (50,000 cycles). 3D images were obtained before and after cyclic loading using a digital scanner. The wear resistance was evaluated by 3D image super-impositioning technique using CAD/CAM software. All samples were axially loaded till fracture utilizing a universal testing machine. Data normality was checked using Shapiro Wilk test and box plot. Groups were compared using the parametric independent t test. Significance level was set at P=0.05.
RESULTS: CAD/CAM qualitative evaluation of the uncoated group showed massive amounts of wear when compared to the coated group. The coated group also demonstrated a significantly higher fracture resistance than the uncoated group (P<0.0001).
CONCLUSION: The nano-filled coat significantly improved the surface wear and fracture resistance of Equia Forte Fil glass hybrid restoration after cyclic loading in class II restorations in permanent teeth.

KEYWORDS: Fracture resistance, 3D wear, Cyclic loading, Glass hybrid restoration.
RUNNING TITLE: 3D wear, fracture resistance of glass hybrid restorations.

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INTRODUCTION

In 2015, Equia Forte Fil (GC, Tokyo, Japan) was introduced using glass hybrid technology, adding a nano-filled coating material to a highly viscous conventional GIC (1,2).
Equia Forte Fil consists of a powder and liquid component. Equia's powder is made of 95% strontium fluoroaluminosilicate glass with added highly active small particles and 5% polyacrylic acid. Aqueous polyacrylic acid makes up 40% of the liquid portion (3).
Equia Forte Coat is made up of 50% methyl methacrylate and 0.09% camphorquinone. This makes a hydrophilic, low viscosity nano-filled surface coating that effectively seals the GIC surface, increases fracture resistance and reduces abrasive wear in addition to a glaze effect leading to superior esthetics (4-6).
Glass ionomer cements as a restorative material, have been extensively used in no-load bearing areas, especially in class III and V cavities. This is due to their low tensile and flexural strengths that may cause more prevalent surface wear and fractures when compared to other restorative materials like composites and amalgam (7).
However, Equia Forte Fil when released to the market, the manufacturer claimed its high mechanical performance. It is marketed as a substitute for amalgam and composite restorations in class I, II and V cavities as the nano-filled resin coating seals all surface defects of the underlying restoration and provides protection against early material fractures and abrasive wear. Furthermore, it is not technique sensitive and no polymerization shrinkage takes place during setting of the material

which provides a perfect marginal seal. This makes Equia Forte an ideal restoration to overcome the drawbacks of composite resin restorations. It can be used in class II stress bearing areas and it is an optimal choice for pediatric, high risk and geriatric patients (8).

Although many studies reported that the wear resistance of RMGIC is lower than that of composite and amalgam in addition to their high failure rates in class II cavities (9,10), several laboratory studies have also proved that the addition of a surface coating has increased the flexural strength and wear resistance of the GIC to make it comparable to composite resin restorations (5,11). Furthermore, some studies reported outstanding clinical performance for both class I and II glass ionomer fillings in permanent teeth (12-15). Evidence is thus needed to determine whether the addition of a nano-filled resin coat to GIC fillings in class I and II cavities would improve their wear and fracture resistance.

In 2006, James et al, clarified the failure of restorations clinically by including a fatigue component by cyclic loading and then testing load to failure (16). The exposure of a material to cyclic loading induces fatigue which concentrates tensile stresses at contact angles and results in crack formation, surface wear and thus restoration failure. Cyclic loading can imitate the masticatory forces effect on the tested material equivalent to one-year intraoral period (17).

Wear is the progressive loss of substance from a body surface as a consequence of mechanical action (18). Restoration failure may occur due to alterations in surface roughness which leads to increased staining, plaque accumulation, caries risk and periodontal diseases (19).

Evaluation of 3D wear is a conservative accurate test that produces volumetric readings which covers the whole restoration surface. Moreover, digital images can be interpreted to evaluate surface defects and marginal seal (20).

Glass ionomer cements have not been proving success in class II restorations due to their minimal wear resistance, so this study aims to evaluate the effect of Equia Forte Fil nano-filled coat on 3D wear and fracture resistance of Equia Forte Fil glass hybrid restoration after cyclic loading. The null hypothesis tested was the assumption that there is no difference regarding the presence or absence of the nano-filled coat on 3D wear measurements and fracture resistance of Equia Forte Fil after cyclic loading exposure.

MATERIAL AND METHOD

The research was performed at the Pediatric Dentistry and Dental Public Health, Dental Biomaterials Department, Faculty of Dentistry, Alexandria University, Egypt. This study was approved by the research ethics committee at the Faculty of Dentistry, Alexandria University.

Study design: Experimental in vitro study.

Sample size estimation: Sample size was estimated based on assuming 95% confidence level and 80% study power. The mean ± SD of wear depth in RMGI with Equia coat was 11.25 ± 7.15 compared to 19.30 ± 10.17 for the uncoated group (21). Sample size was calculated to be 20 specimens per group. This was increased to 22 specimens to make up for laboratory processing errors. Total sample size= number per group × number of groups= 22 × 2 = 44 specimens. Software: Sample size was based on Rosner's method (22) calculated by G power 3.0.10 (23).

Methods

I-Teeth selection and storage

Forty-four freshly extracted human premolars were collected from the outpatient clinics of Alexandria University Hospitals, Department of Oral and Maxillofacial Surgery, Faculty of Dentistry, Alexandria University, the Public Health Insurance Centers in Alexandria, and private dental clinics. The teeth included were freshly extracted for orthodontic reasons without caries, previous filling, with no developmental defects or cracks. Teeth were examined using a magnifying lens to ensure the absence of cracks. All teeth were cleaned using fluoride free pumice and low speed handpiece then stored in normal saline at room temperature until needed for testing.

II. Grouping (Randomization technique)

The prepared teeth were randomly assigned by (using computer generated random numbers) to one of the two groups 1 and 2.

Group 1 (Experimental group): Twenty-two teeth were restored with Equia Forte Fil plus Equia Forte coat.

Group 2 (Control group): Twenty-two teeth were restored with Equia Forte Fil without coat.

III- Cavity preparation (24)

Standard compound occluso-mesial class II cavities were prepared using high-speed handpiece and 245 carbide bur under water coolant in all teeth. The occlusal box pulpal depth was 1.5mm and its width was 2 mm. The proximal box dimensions were 3 mm in height, 1.5 mm axial depth and 2 mm in width with 90 degree cavo-surface margins.

All line angles were rounded, the buccal and palatal cavity walls were parallel on both the occlusal and proximal portion of the cavity. Cavity dimensions were standardized using mini size digital caliber (DONGRUN, DR-MV0100N, Zhejiang, China). No bevels were made at the margins of the prepared cavities.

IV- Teeth restoration

The prepared teeth were cleaned with water and dried before inserting the restorations.

A metallic matrix band was contoured, placed and held tightly against the proximal aspect of the tooth by a matrix retainer.

Equia Forte Fil is supplied as disposable preloaded capsules that were manipulated according to the manufacturer's instructions (8).

For Group 1: The nano-filled coat was added to Equia Forte Fil using micro-tip applicators, and light cured for 20 seconds without air drying.

For Group 2: No coat was applied

V- Storage of the specimens

Each group was put in a separate container in normal saline until needed for testing.

VI-3D Baseline Imaging: (Baseline Readings) (20)

Each specimen was dusted with scan powder using Cerec Optispray (Sirona Dental Systems GmbH, Bensheim, Germany). Digital images were recorded using Omnicam laser camera (Vinyl Serianlno: SO-20900.00-17-147, Germany). The occlusal points of the restorations were saved in the software for measurements and comparisons.

VII-Cyclic Loading (25)

All specimens were subjected to 50,000 dynamic loading cycles using a custom-made pneumatic loading apparatus (ACTA design). The exerted load was alternately switched between a maximum (150 N) and a minimum (80 N) load resulting in an alternating compression of the specimens' loading area. Contact surface damage and premature failure were avoided by placing a sheet of silicon, which was 0.5mm in thickness that was mounted between the loading cusp (natural enamel) and the specimen's surface. The sheet was changed every 10,000 cycles. At any sign of fracture, the load cells detected sudden drop in load and deactivated the device automatically.

VIII-Evaluation Procedure

3D wear using CAD/CAM (20)

3D images were taken again as previously mentioned, and the evaluation of three-dimensional wear resistance was carried out using image super-imposition technique before and after fatigue by using the Cerec software (Cerec 4.2, Dentsply Sirona, Bensheim, Germany). A file extension in.rst format was used to record the occlusal points on the restoration surfaces. By using Cerec inLab software, these files were then converted into stl format. The occlusal thirds of the 3D images were then cropped. After that, a different software, Siemens Unigraphics NX 10, was used to transform the superimposed images into digital solid models (Siemens PLM Software, Plano, TX, USA).

The previously described solid models were placed in equal axes and a certain area on the occlusal surface was chosen with a tolerance value of 0.005 mm and then the volumetric loss on the surfaces was calculated.

Fracture resistance Assessment (24)

Fracture resistance of all samples of both groups were assessed. Using a teflon ring (1.6X 2 cm height) containing chemically cured activated acrylic resin, teeth were embedded up to 2 mm apical to the CEJ. Each specimen was axially loaded into the universal testing machine (5st, Tinus Olsen, England) and the test was carried out 1.5mm from proximal marginal ridge using a 1.5 mm spherical metallic rod tip at a cross-head speed of 1mm/min. Dental surveyor was used to adjust the long axis and the occlusal plane. An audible fracture and sharp drop at load deflection curve (maximum breaking loads) were recorded in Newton using computer software.

Statistical analysis

Data was checked for normality using Shapiro Wilk test and box plot. Groups were compared using the parametric independent t test. Significance level was set at P-value of 0.05. Analysis was done using SPSS version 25.

RESULTS

Marked differences were found between the coated and the uncoated groups. The uncoated group showed massive amounts of wear and irregularity of the occlusal surface (Figure 2) when compared to the other group that showed negligible amount of wear and preserved occlusal anatomy. (Figure 1)

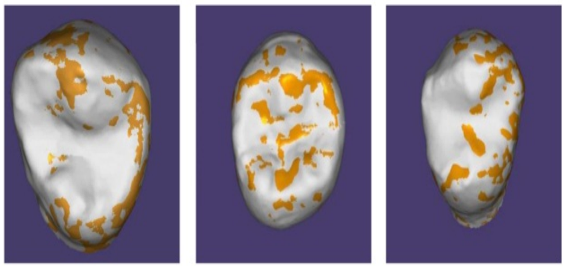

Fig. (1): Superimposed image of 3 different specimens of coated Equia Forte Fil group 1, showing areas of 3D wear in (gold color) compared to original dimensions in (white).

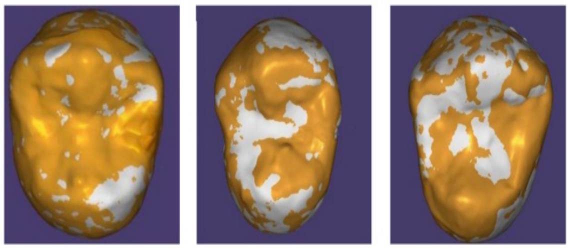

Fig. (2): Superimposed image of 3 different specimens of uncoated Equia Forte Fil group 2, showing areas of 3D wear in (gold color) compared to original dimensions in (white).

Fracture resistance evaluation was done using Independent t Test. The coated group, failed with fracturing at a mean force value of 592.34 ± 92.52 Newton. Whereas, the uncoated group, fractured at a mean force value of 402.55 ± 116.28 Newton. The coated group showed a significantly higher fracture resistance than the uncoated one ($P < 0.0001$) . (Table 1)

Table (1): Comparison of Fracture Resistance of Equia Forte Fil group with coat (Group 1), and Equia Forte Fil without coat (Group 2).

Fracture resistance	Group 1 (n=22) *	Group 2 (n=22) *
Mean (SD)	592.34 (92.52)	402.55 (116.28)
Median	588.93	405.48
Min - Max	448.20 – 768.40	209.00 – 588.26
Independent t Test	5.990	
P value	<0.0001**	

*n= number of teeth

**Statistically significant difference at P value≤0.05

DISCUSSION

The present study overall results, indicate that the nano-filled coat significantly improved the surface wear and fracture resistance of a glass hybrid restoration after cyclic loading in Class II restorations. This encourages the use of Equia Forte Fil glass hybrid system in clinical situations in both primary and permanent teeth.

The null hypothesis of the present study was rejected, since there was a significant difference between the presence or absence of the nano-filled coat on 3D wear measurements and fracture resistance of Equia Forte Fil after cyclic loading.

Class II cavity preparations have always been a challenging procedure faced by the clinicians. Minimal cavity preparations minimizing the loss of hard dental tissues as much as possible and the perfect selection of the restorative material are optimal goals to avoid failure and fracture of class II restorations.

In this study Equia Forte Fil, a glass hybrid restoration was chosen as it has been claimed to be suitable to use in class I, II and V cavities. Furthermore, several clinical trials and in vitro studies have proven their good mechanical performance in both primary and permanent teeth. (26,27)

As extracted natural teeth are subject to dryness, teeth were cleaned and stored in normal saline soon after extraction to prevent them from dehydration (28) until needed for testing. Using artificial saliva was avoided so that the remineralization/demineralization process and fluoride release at tooth material interface would not affect the final results.

Standard class II occluso-mesial cavity preparations were performed, and cavity dimensions were standardized using mini size digital caliber (24). The same operator performed all the cavity preparations and restorations to avoid inter operative variability.

A popular method to obtain failure data for a restorative material is to perform a static test that reveals failure after exposure to excessive loads. James et al, (16) stated that nucleation, propagation and coalescence of cracks are consequences of restoration fatigue. Scratches on the surface and voids in the interior reflect crack nucleation at stress bearing areas. Therefore, exposure of a material to cyclic loading which simulates intraoral masticatory forces gives more realistic results of failure loads by inducing surface wear.

Dental restoration fatigue is usually produced as a result of masticatory forces effect over time (29-31). This study was an in vitro experimental study, therefore, cyclic loading test using 50,000 cycles was chosen to produce approximately 3 months of intraoral wear (32).

In the present study, an alternating load of a maximum 150 N and a minimum 80 N was applied to the tested specimens. These loads were selected to mimic the average of intraoral occlusal load that is approximately 120 N during mastication (33).

Evaluation of 3D wear was carried out in this study using a CAD/CAM system as it is a conservative test which does not need cutting or sectioning of the specimens to evaluate them under stereo or scanning microscopes. Furthermore, it can produce volumetric readings accurately which covers the whole restoration surface. Moreover, digital images can be interpreted qualitatively to evaluate surface defects and marginal integrity (20).

In this study, marked differences were found between the experimental and control group. The uncoated group showed massive amounts of wear and irregularity of the occlusal surface compared to the coated group which showed negligible amount of wear and preserved occlusal anatomy. The coat filled any small surface defects, thus improving the material mechanical properties, reducing wear, voids and cracks and producing a smoother harder surface which explains these study findings.

Although it was noticed that there were no studies evaluating the effect of Equia Forte Fil nano-filled coat on 3D wear, our findings matched other studies (34, 35) that showed higher surface hardness -which is a method to measure wear resistance- of Equia Forte Fil restorations when adding its nanofilled coat than its use without coat.

Fuhrmann et al, (34) discussed the properties of glass hybrid restorations used in stress bearing areas. They compared fracture resistance and surface hardness of conventional glass ionomer versus glass hybrid new technology and composite resins. They concluded that new glass ionomer restorative materials fracture toughness was similar to the conventional ones. However, surface coating significantly increased their surface hardness and thus wear resistance.

Handuku et al, (35) also supported our findings since they discussed the effect of nano-filled resin coating on glass ionomer cement hardness. Results showed that the nano-filled resin coating applications on Equia Forte Fil significantly increase the surface hardness. The study also mentioned that the hydrophilic, low-viscosity nano-filled resin coating reduced the abrasive wear and the possibility of the restoration fracture significantly.

On the other hand, the study results contradicted those reported by Kielbassa et al, (36) who addressed the in vitro wear of high-viscosity resin-coated GIC in comparison to glass hybrid restorative systems. They concluded that the nano-filled coating of Equia Fil or Equia Forte Fil does not provide effective protection against advanced abrasive wear over a long period of time. However, both materials provided excellent abrasive wear resistance when compared to the conventional GIC which showed massive substance loss.

In the present study, coated Equia Forte Fil group also demonstrated a significantly higher fracture resistance than the uncoated group. This finding was supported by the manufacturer's claims. Moreover, it was noticed that the coat added cohesiveness and strength to the glass hybrid restoration molecules, as the coated group was fractured as whole unit while the uncoated group was fragmented into small pieces during fracture. The superior fracture resistance of the Equia Forte Fil glass hybrid restorative system in this study seems to be a direct effect of the nano-filled resin coating agent, which when applied to the surface of the restoration has significantly increased the material resistance to mechanical forces.

The findings of this study were in accordance with Totad et al, (37) who tested the fracture resistance of MOD cavities prepared in maxillary premolars. These were restored with different capsulated restorative materials, GC Equia Forte Fil, GC Fuji IX extra, and GC miracle mix Capsule. Teeth restored with GC Equia Forte Fil were most resistant to fracture and was nearly as strong as the control group (non-prepared teeth) when compared to the other two materials which suggests that GC Equia Forte Fil can be used as a potential restorative material in posterior teeth.

A possible limitation to this study, is that the cyclic loading test did not perfectly provide similar conditions that mimic the oral cavity as the test was carried out at room temperature and in absence of both saliva as a lubricant and of food as a challenging substrate during masticatory simulation process which would have their implications on the performance of the material.

CONCLUSIONS

The nano-filled coat improved the surface wear and fracture resistance of a glass hybrid restoration after cyclic loading in class II restorations in permanent teeth.

CONFLICT OF INTEREST

The authors declare that they have no conflict of interest.

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