FEM Study Regarding Materials Retention Used for Abfraction Adhesive Restoration

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This study compares, by means of the finite element method (FEM), the behaviour of the restorations done with the same material, the same adhesive system and under the action of the same force values applied to four 3-D lower premolar finite element models, representing four different cavity shapes. An extracted lower premolar which presented an abfraction lesion has been used. The restoration was achieved by using etch–and-rinse adhesive systems and Giomers. The premolar was scanned and the resulting sections were processed and converted into a 3D digital format. Thus, a model of finite elements which presented a restored wedge-shaped cavity in the cervical dental area was obtained. Then, by modifying the shape and dimensions, there were created another 3 modified-shape cavities. Forces of different magnitudes (90-150N), exerted at a 45 degree angle on buccal cusp, have been applied. If adhesive system tensile strength is about 25MPa, this limit is reached at 120N only for the third model. For Beautifil FO2 the tensile strength is not reached when maximum forces are applied (150N) and for Beautifil II, the tensile strength is reached only for model 4, when a force of 150N is applied. In order to increase the retention of the abfraction restoration, changing the shape of the cavity should be associated with the use of Giomers and adhesive system with tensile strength exceeding 25MPa.

Keywords: cavity shape, noncarious cervical lesions (NCCL), abfraction, finite element method (FEM), Giomer, adhesive system.

The restoration of abfraction, which is a lesion belonging to non-carious cervical lesions group, (NCCL) is a difficult one because of sclerotic dentin, the occlusal overstress, restorative materials properties, etc. From a clinical point of view, abfraction is described as V-shaped or wedge-shaped lesion, situated in the cervical area of buccal surface of the teeth, subjected to occlusal overload [1-4]. The tensions resulting from occlusal overstress are distributed to the tooth and the restoration material, as well (the composite resin, adhesive system), being responsible not only for the development of wedge-shape cervical lesions (abfraction), but also for the loss of restorations [5,6].

As a result of clinical experience, it has been noted that restoration of the abfraction lesions has a poorer retention than other restorations. The clinical decision to restore abfraction lesions may be based on the need to replace form and function or to relieve hypersensitivity of severely compromised teeth or for aesthetic reasons [7]. In the second case, it has been demonstrated that the use of Geristore hybride ionomer in the treatment of abfraction presented a better desensitisation, with a longer term action, in comparison with the use of Gluma desensitizer [8].

Important factor affecting retention failure is the elastic modulus of the restorative materials. In order to restore class V lesions, it has been showed that microfilled composite is the most suitable restorative material followed by flowable composite, glass ionomer cement and resin modified glass ionomer cement [9]. These materials of higher modulus of elasticity will enable better stress distribution [9].

Compomer class V restoration could be the treatment of choice in noncarious cervical lesions, due to their special properties resulted from the combination of fluoridated glass filler with acid modified monomers (good adhesion to dentine and release fluoride ions continually, functioning as acid buffers along the interface with the tooth structure). But the compomer class V restorations will have a poor prognosis if they are placed before or without an occlusal equilibration [10]. Still when using compomer for class V restoration, care should be taken because of mikroleakage, the silane treatment of the acid conditioned enamel margins lacking no statistically significant influence in reducing this phenomenon, but the additional silane treatment of previously acid etched dentin, significantly reduces microleakage at the gingival interface [11].

Giomers show improved properties and favourable elastic modulus in comparison to usual resin composites and their unique chemistry is able to achieve ion uptake from household dental hygiene products such as toothpaste, providing sustained benefits to adjacent tooth structure over the life of the composite [12].

The aim of the study is to compare, by means of the finite element method (FEM), the most comprehensive in vitro investigation method in restorative dentistry that allows for realistic simulations [13, 14], the behaviours of the restorations performed with the same material, the same adhesive system and under the action of the same force values applied to four 3-D lower premolar finite element models, representing four different cavity shapes.

Finite element method comprises analyzing stress, deformation and propagation of the fracture line in a structure. When a force is applied to a structure, deformation and stress arise, and if stresses are excessive and go beyond the elastic limit, can cause fractures in the materials [15].

Analysis by FEM is particularly useful in detecting risk areas, giving us the possibility to study the distribution of stresses and strains of a mechanically loaded structure [16].

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Table 1
REQUIRED CONSTANT DATA

Material	Elastic modulus (GPa)	Poisson Ratio (ν)
Enamel	80.35	0.33
Dentin	19.89	0.31
Pulp	0.02	0.45
Periodontal ligament	0.0689	0.45
Cortical bone	13.7	0.30
Spongious bone	1,37	0.30
Gluma Solid Bond	4	0,35
BeatifilFO2 (low flow)	8.4	0.35
Beautifil II	11	0.35

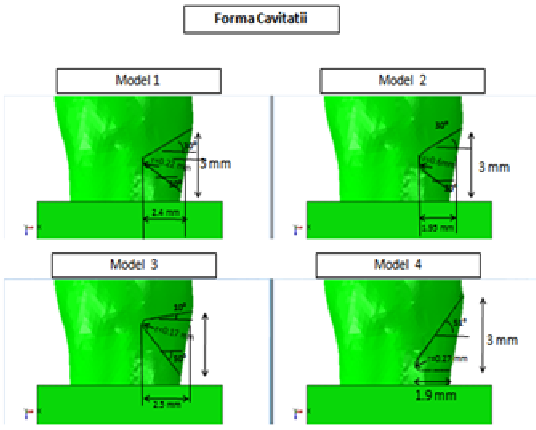

Fig.1. Shapes and dimensions of cavities

Experimental part

For the study, a lower premolar extracted for periodontal reasons was used; it presented an abfraction with a smooth, hard, shiny surface, without any carious process. The premolar was kept in physiological serum for 24 h, then in T chloramine until the time of the experiment. The tooth was cleaned with a rubber cup and abrasive paste (Clean Polish, Kerr). A superficial dentin layer was removed and the edges were smoothed by means of a round burs (RA 1, Dia Tessin) on low speed. Restoration was achieved using etch and rinse (ER) 3-step adhesive systems (Gluma Solid Bond, Heraeus Kulzer) and Giomers (Beautifil low flow FO2 and Beautifil II, Shofu Dental Corporation).

For this study, Giomers were chosen due to their improved properties in comparison to usual resin composites and favourable elastic modulus (table1). Giomers contain a multifunctional glass core that undergoes an acid-base reaction during manufacturing and is subsequently protected by a surface modified layer. This surface pre-reacted glass (S-PRG) filler is a bioactive, trilaminar structure which forms a type of stable glass-ionomer allowing ion release and recharge, while protecting the glass core from the damaging effects of moisture, greatly improving long-term durability [12]. S-PRG filler uniquely releases 6 ions: Fluoride, Sodium, Strontium, Aluminum, Silicate, and Borate; S-PRG filler has been shown to inhibit plaque formation, and possess remarkable acid neutralization capabilities [12].

The restored premolar was scanned by means of the Micro CT, while the resulting sections were processed by means the DICOM software. The scanned images were converted into a 3D digital format by means of the MIMICS software and processed in Abaqus /CAE in order to be analysed through the finite element method.

Thus, a model of finite elements which presented a restored wedge-shaped cavity in the cervical dental region (model 1) was obtained, while the necessary data was taken from available literature [12, 17-20] (table 1).

On this finite elements model, by modifying the shape and dimensions, as shown in figure 1, there were created another 3 modified-shape cavities.

A wedge-shaped cavity with a very rounded axial angle was created on the second model.

On the 3rd and 4th models, wedge-shaped cavities with unequal sides were made, with the cervical side longer than the occlusal side on the 3rd model, thus making an 80 degree angle with the long dental axis; at the same time, on the 4th model, the cervical side was shorter than the occlusal one and perpendicular to the long axis of the tooth. In the end, the 4 premolar finite elements models with 4 different types of cavities are presented (fig. 1).

In the case of a functional occlusion, there is a vertical stress on the lateral side of the arch; the average occlusal force is 100N, but it may vary between 70 and 150N [21]. At the same time, this force may vary according to the exact position of the tooth in the arch, the gender of the patient, the type of tooth (the force has a low value with the incisors and a maximum with the first molar) [22].

In order to simulate the most dangerous effects on a restored tooth, forces of different magnitudes were exerted on these models at a 45 degree angle and applied mainly to the premolar buccal cusp. The values of the forces applied were: 90N, 105N, 120N, 150N.

The tested forces, within functional occlusion, do not produce dental modifications, but, when applied at 45 degree angle, they create non-functional conditions, permitting an actual simulation of overstrain.

Results and discussions

Results on the adhesive system

When assessing the behaviour of the adhesive layer, for models 1, 2 and 4, the adhesive system's tensile strength which is approximately 25MPa is reached at a value of approximately 90N force. Anything over this value faces a risk for the adhesive to detach. In terms of the adhesive tested, the most favourable cavity is on the 3rd model (fig. 2).

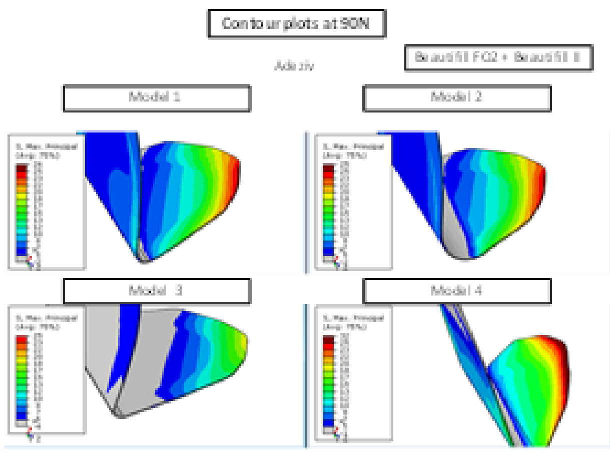

Fig.2. Adhesive tension distribution at 90N

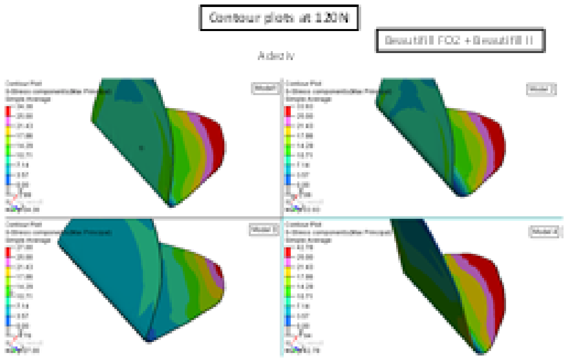

Fig.3. Adhesive layer tension distribution levels at 120N

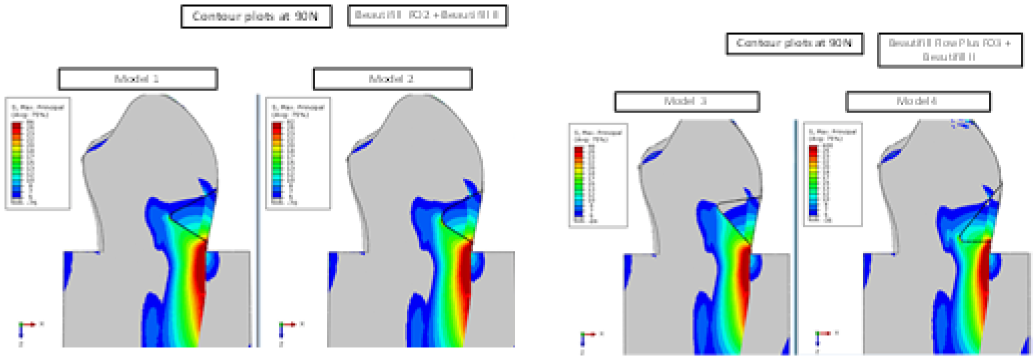

Fig.4. Tension distribution in distal angles of restorations for the models at 90 N

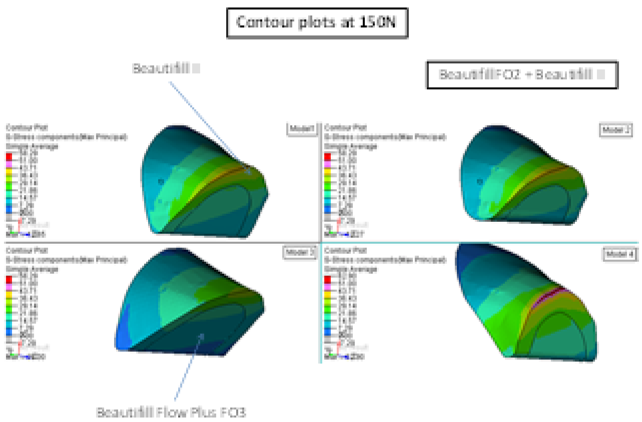

Fig.5. The tension distribution in Giomers Beautifil FO2 and Beautifil II at 150N

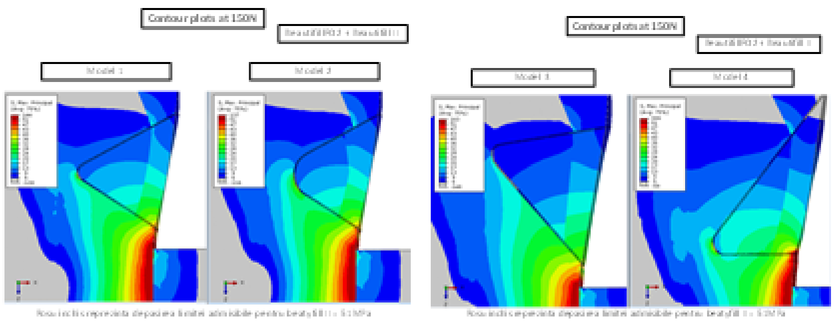

Fig.6. Tension distribution for models at 150N (distal angle of the restoration)

Adhesive evaluation at a 100N force shows that the highest tension levels appear in model 4, and the lowest levels in model 3.Models 1 and 2 show similar cervical tension levels. The 3rd model is the only one that seems to cope with this force.

If adhesive system tensile strength is about 25MPa, this limit is reached at 120N only for the third model (fig. 3).

Results on the restoration material

At a 90 N force, there has been observed a uniform tension distribution in materials especially for Giomer Beautifil FO2 (fig. 4).

Beautifil II has a tensile strength of 51 MPa. It is to be noted that this limit is reached only for model 4 when a force of 150N is applied, and it is not reached when maximum forces are applied (150N) for models 1, 2 and 3 (fig. 5 and 6).

Beautifil FO2 has a tensile strength of 115MPa. This limit is not reached when maximum forces are applied (150N) (fig.5).

The aim of the study was to compare, by means of the finite element method (FEM), the behaviours of the restorations performed with the same materials, the same adhesive system, under the action of the same force values applied to four different cavity shapes.

Regarding the adhesive system, wedge-shaped cavity with a short occlusal side seems to favour retention because if adhesive's system tensile strength is about 25MPa, this limit is reached at 120N only for this model.

Tension levels exceeding this amount are likely to cause the restoration to detach because of the adhesive. The amount of tested forces falls within the normal values of mastication forces, but the direction under which they are exerted transforms them to non-functional forces. If the adhesive system fails under these conditions, it is presumed that the adhesive restorations will not resist under higher pressure, despite the fact that restorative material limits are not met.

Regarding the restoration material, combining chemical adhesion and restorative materials of appropriate elastic properties shows promise of long-term success [23].

The present study pointed out uniform tension distribution in both forms of Giomer, regardless the amount of applied force and the Giomer's tensile strength limit is not reached when maximum forces are applied. This restorative material could become of choice if the properties of the adhesive system are improved.

Combining adhesive materials of different consistence, aiming at supporting material retention is recommended also by J-K Park [24], who concluded that when restoring notch-shaped NCCL, combining method such that apex was restored by material with high elastic modulus and the occlusal and cervical cavo-surface margin by small amount of material with low elastic modulus was the most profitable method in the view of tensile stress that was considered as the dominant factor jeopardizing the restoration durability and promoting the lesion progression [24].

Conclusions

A wedge-shaped cavity with a shorter occlusal wall, restored with Giomers and adhesive with a tensile strength exceeding 25MPa could be the solution taken in order to increase the dental abfraction restoration retention.

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