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Dentin Hybridization - Modern Based Therapy of Restoration of Compromised Dental Structure

KEYWORDS: dentin, adhesive system, scanning electronic microscopy (SEM)

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ABSTRACT *The aim of this study was to highlight the structural characteristics of the dentin hybrid layer generated in the case of two different adhesive systems.*

Methodology: On 25 extracted teeth, deep cavities were produced and two types of adhesive systems were applied: an adhesive system applied consecutively with dentin demineralization and a self-etching adhesive system applied directly to mineralized dentin.

Results: In the control group, SEM examination highlighted the presence of free dentinal tubules and smear surface layer. In the study groups, SEM examination revealed the absence of the smear layer and the forming of a hybrid layer.

Conclusions: Conventional adhesive systems applied consecutively with the self-etching acid have the capacity to produce a hybrid layer of high quality. Self-etch adhesive systems can achieve a strong adhesive bond by dissolving and including the smear layer in its composition.

Introduction

The restoration of compromised dental structures in young people must respect the aesthetic, functional and biological principles. Studies done in the recent years have shown that the highest percentage of failures in dental restorations is consistent with secondary caries and pulp complications [1]. The introduction of modern adhesive systems in the technique of restoration of the dental structures compromised by simple caries lesions had the goal of focusing the efforts in trying to reduce the phenomenon of marginal bacterial micro-infiltration, thus increasing the longevity of dental restoration [2].

All adhesive systems used in practice are based on dentin hybridization, a phenomenon where the mineral phase of the dentinal tissue is replaced at a molecular level with the adhesive resin through its infiltration into the collagen fibril network exposed through acid-etching and thus forming a bonding structure which is not dentin nor resin, called a hybrid layer. This layer has a heterogeneous structure, consisting of 70% resin and 30% collagen [3].

The structure of the dentin represents the biological basis of the modern restorative adhesive therapy. Inter-tubular dentin is less mineralized and contains more collagen organic fibrils. Thus, the peritubular dentin is more sensitive to acid-etching. In regards to the pulp chamber peritubular dentin represents 66%, and intertubular dentin represents only 12% of the dentine surface, while dentinal tubules represent 22% [4].

The form and appearance of the hybrid layer may vary consecutively with the influence of a varied number of factors including the structure and appearance of dentin, type of material and the technique used. An important characteristic of modern adhesive systems is their ability to modify the properties of dentin, turning it from a hydrophilic surface into a hydrophobic one. The weak adhesive bond achieved by early dentinal adhesives was due to their inability to penetrate the smear layer, resulting from cavity preparation and obstruct the dentinal tubules.

Application of modern adhesive systems for the purpose of generating a hybrid layer can be achieved by two different techniques. The first technique is the hybridization by removal of the smear layer through making a total acid-etching of the enamel and of the dentin before applying the bonding agent, in order to remove mineral substances and to expose the collagen fibril network (**Fig.1**).

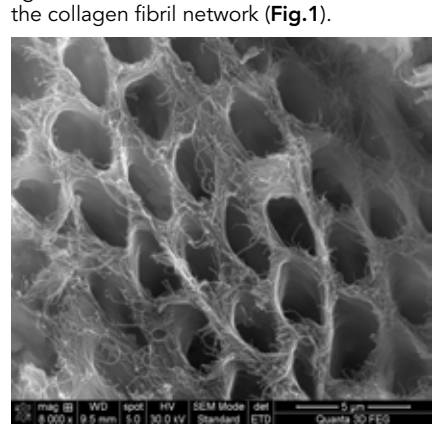

Figure 1 Appearance of collagen fibrils exposed by etching the dentin with phosphoric acid

The second technique is done through the hybridization by keeping the smear layer by using an auto-etching technique, where the acid is applied simultaneously with the primer and even with the adhesive resulting in a shortened time of treatment [3].

The purpose of this study is to highlight the properties, the application conditions and the structural characteristics of the hybrid layer generated in the case of two different adhesive systems: an adhesive system applied consecutively with dentin demineralization and an etching adhesive system applied directly to mineralized dentin.

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Methodology
• Selection of study specimens

In this study we used 25 intact teeth, mostly premolars without caries processes or fillings, which came from young patients, between the ages of 12-18, who have had extraction indication for orthodontic purposes. For the use of these teeth in this study, the informed consent of patients and their legal guardians was obtained. On these extracted and properly preserved teeth there were produced Class 1 - deep cavities keeping to the principles of cavity preparation and two types of adhesive systems were applied to them:

- The classic-component adhesive system (C-bond);
- The self-etching component adhesive system (Futura-Bond).
- Specimen preparation and establishment of study groups

A control group (C) and four study groups (G1, G2, G3, G4) have been formed:

C: The Control Group consists of a subgroup of teeth that after preparing the cavities, the resulting wounded dentin was treated with phosphoric acid for 15 seconds (C1) to remove the smear layer; the other subgroup consists of teeth layer that did not have the phosphoric acid applied (C2). Also, the control group did not have any type of bonding applied, these teeth having been restored directly with composite.

G1: In this study group, on the exposed dentin surface there was applied the component adhesive system C-bond in a single layer by the total etching technique, following the manufacturer's application instructions.

G2: The second study group there was applied the same component adhesive system C-bond, but in two consecutive layers following the same instructions.

G3: The third study group there was applied the component etching adhesive system Futura-Bond following the manufacturer's application instructions. The application of this did not require the pre acid-etching and thus significantly reduced the working time.

G4: To the teeth included in the study group 4 there was applied the same etching adhesive system (Futura Bond) in two consecutive layers of application by following the manufacturer's instructions. After the application of the two adhesive systems on all the teeth included in the five study groups, each corresponding coronal cavity was restored with light cured composite.

• Preparing the study specimens for the SEM examination
After the preparation of these teeth they were embedded in acrylic and using a diamond disc with a diameter of 20 cm there were made three longitudinal section cuts with a thickness of about 3-4 mm. One section from each group was treated with phosphoric acid for 30 seconds, followed by rinsing with distilled water in order to better visualize the organic matrix impregnated with resin or adhesive.

The resulting sections were immersed in an ultrasonic bath for 10 minutes to remove debris from surfaces, being kept in proper moisture conditions until the SEM (scanning electronic microscopy) examination.

Results
After the exam conducted by SEM, the following results were obtained:

The formulas prepared contained in the control group where the dentin surface was treated with phosphoric acid images show the presence of free dentinal tubules (**Fig.2**) and for the teeth that have not been previously demineralized, it highlights the presence of smear surface layer and dentinal tubules (**Fig.3**).

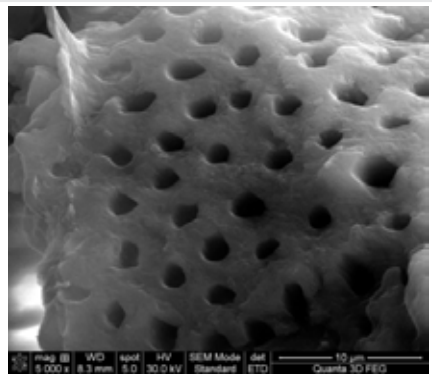

Figure 2 Opened dentin ducts, without the smear layer

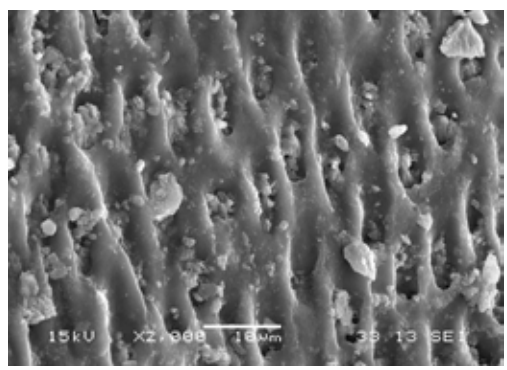

Figure 3 The smear layer on the dentin surface and into the dentinal tubules

In the study group 1 where, on the acid etched dentin surface, C-Bond was applied in a single layer, the SEM examination revealed the absence of the smear layer and the forming of a thinner hybrid layer with an uneven appearance (**Fig.4**). Also it was noticed the formation of a reduced number of adhesive extensions in the dentinal tubules called tags, which are tapered so that they do not touch the dentinal walls in the depth of the tubules (**Fig.5**).

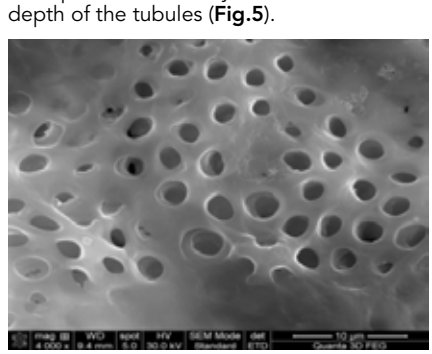

Figure 4 Irregular hybrid layer with the presence of dentin ducts (the adhesive resin has not penetrated)

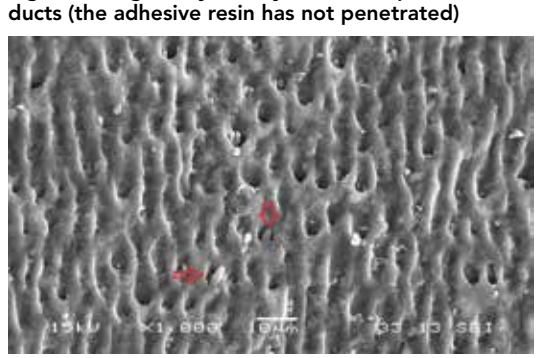

Figure 5 Dentinal tags in the dentinal tubules (image of

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the dentin surface from a side wall of the cavity)

On the preparations included in study group 2, where the dentinal adhesive was applied in two layers, there is the presence of at thicker and more uniform hybrid layer through impregnation with resin adhesive of a more extensive dentin surface (**Fig.6**) and the formation of tags in the dentinal tubules with an aspect and length similar to those from study group 1 (**Fig.7**).

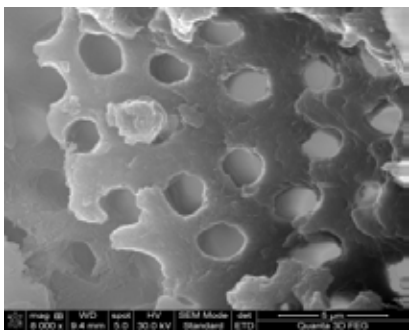

Figure 6 The uniform aspect of the dentin layer hybridized with dentinal tubules where the resin adhesive penetrated forming dentin tags

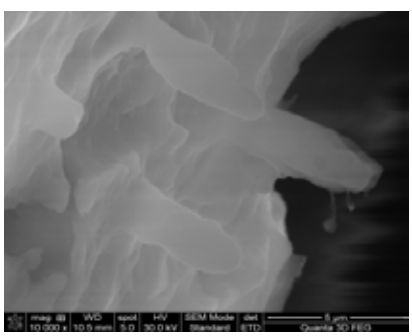

Figure 7 SEM image of the cone-shaped dentin tags formed in the dentinal tubules

On the preparations included in study group 3, which applied a single layer of self-etching adhesive Futura-Bond, the SEM images show the presence of an uneven hybrid layer of medium thickness, which includes the smear layer resulting from the cavity preparation, and the presence of a large number of empty dentinal ducts where the resin adhesive did not penetrate (**Fig.8**).

Figure 8 The uneven appearance of the hybrid layer formed in the study group 3 - A large numbers of empty dentinal ducts

In study group 4 where the etching adhesive material is applied in two layers is observed the uniformity and the increased layer thickness of the hybrid layer resulted from dissolving and including the smear layer in its thickness (**Fig.9**).

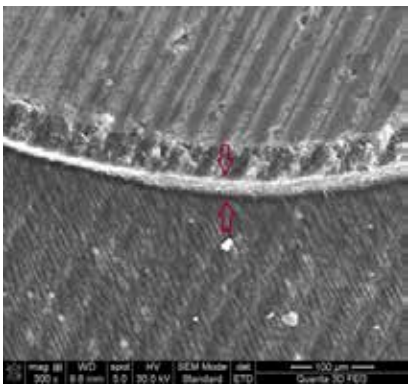

Figure 9 Good tooth-resin adhesion with an uniform appearance of the hybrid layer, including a smear layer

It is also observed the formation of dentin tags inside the tubules, but these are thinner and shorter than those formed in study groups 1 and 2 (**Fig.10**, **Fig.11**).

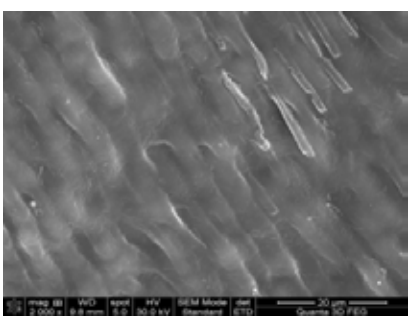

Figure 10 Layout aspect of the dentinal tags formed inside the dentinal tubules in study group 4

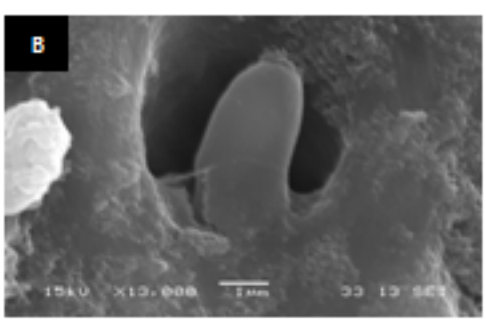

Figure 11 Comparative aspect of the dentinal tags formed through infiltration of the self-etching adhesive system (A) and the classic-component adhesive system (B)

Discussion

The results obtained from the SEM analysis show that for all four study groups G1-G4, in which there were applied two types of adhesive systems, the findings showed the forming of a hybrid layer on the dentin surface and inside the dentinal tubules. The most important aspect to be considered is the humidity dentin which is to be hybridized. Thus, through the drying of the demineralized surface, the dentin undergoes a contraction of 65% of its volume because the hardness of the mineralized dentin is of 19000 MPa while the hardness of the demineralized dentin is only 1 MPa. Basically, the dentin matrix floats on water and then, when the water evaporates, the fibril network collapses and this prevents the infiltration of resin and hence the formation of the hybrid layer [5].

One of the major objectives of the self- etch adhesives is

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to prevent any problems of incomplete hybridization of the dentin surface that appear when using global etching techniques which are manifested by the appearance of demineralized areas that are not properly infiltrated by the resin adhesive [6]. In the case of self-etching adhesives, the smear layer is dissolved and incorporated into the structure of the hybrid layer that is formed on the surface of dentin.

In comparing the groups that differ in the number of layers of adhesive applied, it was observed that the hybrid layer surface is more uniform and homogeneous for study group 2 compared with study group 1. The first layer of glue fulfills the role of a primer when applied separately, i.e. it removes much of the residual water and it initiates the infiltration of the monomer adhesive in the collagen fibril network. After the application of a second layer of bonding, the freshly applied monomer together with solvents dissolve the globular particles of residual resin adhesive previously formed. These are formed due to a faster diffusion of water in organic solvents, so that the monomers cannot remain dissolved in the solvent, and the phase of component separation occurs [7].

In addition, the application of two consecutive layers of resin adhesive reduces the permeability of the hybrid layer which obstructs the movement of fluids along the dentine structure affecting the tooth-restoration bond [8].

In comparing study groups 3 and 4 together, it appears that study group 4, where there were applied two coats of adhesive, the hybridized dentin surface has a more uniform aspect, and the adhesive bond formed is stronger because water absorption does not occur, and the layer of dentin on which a layer of acid monomer has already been applied, is protected by a waterproof adhesive layer. Other authors [9] have shown by the use of micro-Raman spectroscopy that the demineralization of dentin with phosphoric acid extends to a depth of more than 10μm, while the resin infiltrates the demineralized area just over a distance of 8-10μm, thus the depth of the collagen fibers exposed by etching is left unprotected.

Conclusions

Conventional adhesive systems applied consecutively with the global self-etching acid have the capacity to produce a hybrid layer of high quality if the application conditions are respected, given the fact that the highest difficulty is related to obtaining an appropriately moist dentin.

Self-etch adhesive systems can achieve a strong adhesive bond by dissolving and including the smear layer in its composition, the main advantage being the reduced working time and the possibility of drying the dentin surface without the risk of collagen fibrillar network collapse.

Given the structural characteristics of dentin, the results confirm that the self-etch adhesives are more effective in superficial cavities where the number of dentinal tubules is reduced while the classic adhesives participate to the forming of strong adhesive bond in deep cavities due to the large number of dentin tubules.

The restoration of dental structures in children and young adults, consecutively the simple caries, has to respect the principle of conservation and proper protection of the pulp-dentinal complex.

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