Researches on the Influence of the Resin Cements Micro-leakage to the Resistance of the Composite Inlays

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The aim of this study is to analyze the stress generated by the shrinkage of lutting materials in restorative therapy with indirect composite inlays; we follow the way of the tension transmission from the lutting material to the restoration and to the dental tissues. In our study it was used a virtual construction of an upper first molar, created with the Finite Element Method. Our conclusions demonstrate that the shrinkage of the lutting resin influence the fracture resistance of the restored teeth, and, of course, the longevity of the indirect inlays.

Keywords: indirect inlays, composite shrinkage, polymerization stress, prosthesis structure, dental treatment

Inlays are very precise prosthetic restorations, with an important role in restoring dental morphology and functions. Their clinical longevity depends on the accuracy of the clinical steps (establishing judicious treatment indications, preparing the substructure, a proper impression and cementation) and technological one, as well.

The use of inlays is increasing wider because they are a conservative alternative to full coverage dental crowns which requires a minimal preparation of the healthy dental tissues. Also known as indirect fillings, inlays offer a well-fitting, a better mechanical resistance, longer lasting reparative solution to tooth decay or similar damage. These restorations are beneficial from both esthetic and functional point of view. Whereas dental fillings are molded into place within the mouth during a dental visit, inlays are fabricated indirectly in a dental lab before being fitted and bonded to the damaged tooth.

The first materials used for dental inlays were gold alloys. Until recently, gold was considered to be the only choice for indirect restorations in posterior teeth, in order to replace the direct metallic fillings.

Because esthetic dentistry has become a major focus in recent years, dental alloys are less used in prosthodontics, but gold inlays remain a benchmark in terms of the durability, longevity, marginal wear and fit [1].

Dental resin composites were introduced initially as restorative materials for anterior teeth. Later, due to the technological improvements, the prospect of restoring posterior teeth with composite was introduced [2]. Yet, the use of direct composite restoration in posterior teeth is limited to relatively small cavities due to polymerization stresses. Direct restorations, as composite fillings, can shrink during the curing process, whereas indirect restorations will not, ensuring a superior fit that make them a better choice [3]. Composite inlays can be an aesthetic alternative to ceramic restorations for posterior teeth. Indirect composite restorations present a more simple fabrication technique, less wear on the antagonist teeth, the possibility of intra-oral repair and lower cost than the ceramic inlays [4]. In addition, in vitro studies revealed that teeth restored with indirect resins showed statistically higher fracture resistance than certain ceramic inlays [5, 6].

Micro leakage is still considered to be a problem for indirect prosthetic constructions, especially for inlay restorations, which represents a highly unfavorable factor [7]. Because of this, adverse effects could appear, such as contraction stress, sensitivity, recurrent caries and pulpal complications [8]. Since polymerization shrinkage is restricted to the luting resins in indirect restorations, the properties of these composites may significantly affect the performance of the restorations, in respect of the sealing ability [9].

The new materials provide an improvement in physical properties, esthetic color, and bonding properties, so indirect resin composite inlay restorations help overcome the problems of polymerization shrinkage and control of anatomic form, compared with direct resin composite fillings. Previous, literature has effectively described the indications and contraindications for the placement of esthetic posterior resin composite inlays. In vitro researches have indicated that the indirect composite inlay materials show very little evidence of wear on opposing enamel. The marginal adaptation of indirect composite inlays has been examined to the best extent that it can be clinically, but more rigorously in laboratory-based studies. These prosthetic appliances in general, appear to maintain restoration margins well, in fact in the initial stage [10-13].

Some recent studies show that for the direct restoration, the stress generated by the polymerization shrinkage is not significant, at the beginning, because the resin is fluid enough to move in the direction of the internal tensions. In later stages, when the material becomes rigid, it cannot be deformed by the induced tension [14-17]. Adhesion to hard dental tissues is ensured by etching the cavity walls and by bonding materials. But this adhesion is ineffective if not diminishing the shrinkage by modern techniques of polymerization.

The polymerization contraction of the composite leads to the occurrence of shrinkage stresses between 2.4 and

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7.3MPa. If the adhesion exceeds this range the interface is not damaged, but tensions may produce cracks in the enamel. The minimal shear strength of interfaces between resin, bonding and enamel or dentine must be about 20MPa.

The effect of polymerization shrinkage is observed on dental hard tissues by changing the distance between oral and buccal cusps. During chemical reactions, the closing speed of the cusps is rapid and steady, and at the end, it is a release of stress that has accumulated during the reaction, which will cause damage to the interface, and possible cracks in the enamel. Decrease of the distance between cusps is between 5.2 - 19.7 micrometers. Considering these problems of marginal adaptation due to the polymerization contraction of the composite resin, it was needful to improve the properties of lutting materials by using more intense light sources such as laser and plasma light generator. However, although the laser polymerized composites have superior mechanical properties, the marginal adaptation is adversely affected as a result of significant shortening of the reaction time and increase the rate of polymerization [18, 19].

Another possibility to increase the strength of the composite luting material is the use of ultrasonic techniques. Fluid composite resins lead to marginal surpluses; on the other hand, a thick material leads to undersized margins. Ultrasonic technique presents certain advantages; due to the application of the sonic energy any thick composite resin turns into one with low viscosity. Based on this observation, it is possible to use viscous composite resin for luting the inlay restoration, due to their higher mechanical resistance, compared with resins with low mineral laden. Besides, practitioner will be able to remove more easily the resin excesses because, the composite material surplus will return to its original viscosity once the ultrasonic energy is interrupted [20-26].

The purpose of this study was to assess the micro leakage of composite inlays, analyzing the modification of the luting resins.

Experimental part

To compare the stress produced of the restorative materials it was used a virtual model created with the Finite Element Method. The designed model simulate a maxillary first molar with a class I cavity preparation. Anatomical data were based on anthropometric measurements performed on extracted human teeth extracted after orthodontic or periodontal damage.

Stages of building this structure by Finite Element Method were as follows: displacement vector defining, assembling the stiffness matrix of the structure, determination of the stresses solving the system of equations, determining quantities within the finite element [17, 18]. For static analysis is necessary to know the material properties: Young's modulus and Poisson coefficient. The dentinal, enamel and pulpal structures were generated, finally resulting in generation of the virtual model of a first upper molar. Along with the virtual model of the sound tooth that will serve as a benchmark for comparison, we built a model of an upper molar with a class I cavity, whose morphology is restored by inlays. This cavity is 4 mm in cervico-occlusal direction and 5 mm in mezio-distal direction. The model of the tooth is considered to be restored with composite aesthetic inlays Charisma (Heraeus-Kulzer), presented in figure 1.

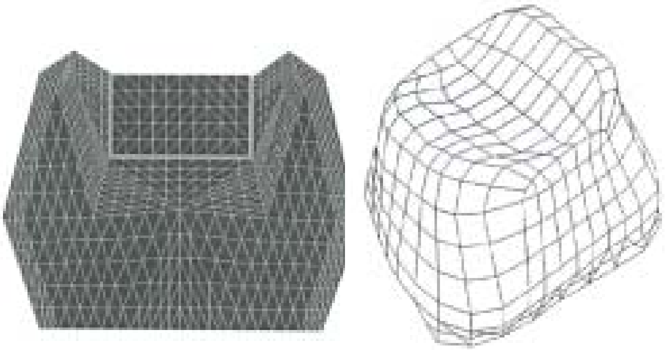

Fig.1. The virtual model of the sound tooth and prepared tooth

Shrinkage stresses occurred during polymerization was calculated taking into account the characteristics of the fixing material: viscosity, plasticity and elasticity. The polymerization time has been subdivided in a large number of short intervals, and then Young's modulus and polymerization shrinkage were calculated for each polymerization contraction period.

In our study we used three different lutting resins: Filtek Flowable, 2 – bond - 2 resin cement, and RelyX™ ARC in order to calculate the material properties depending on the polymerization time. To avoid errors in the calculation of stresses in the nodal positions, we used a convergent method for calculating the stress.

Because the interface tensions are discontinuous, we used the traction vector to establish the mechanical stress. We considered the space in the interface as being 50, 75 and 100mm.

This vector was calculated as the product of the tension and the normal vector at the tooth-restoration interface. For the composite inlay we considered a Young modulus of 18GPa and analyzed the tensions in the dental prosthetic joint caused by polymerization shrinkage.

It was also followed the tension in dental walls, generated by the polymerization shrinkage of the lutting resin.

Results and discussions

Polymerization shrinkage stress generated by the studied composites was analyzed for each time interval. As the lutting material undergoes shrinkage, Young modulus is increased, thus the material becomes more rigid. Composite materials, being elastic, will deform under the shrinkage stress and will induce higher tension in dental tissues compared to dental ceramics that are more rigid (fig. 2).

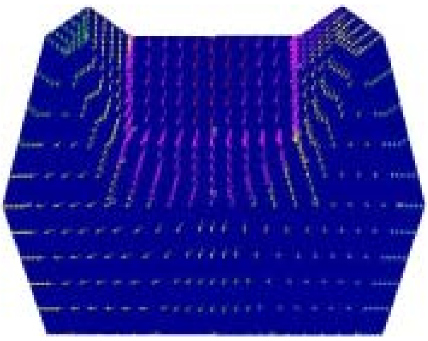

Fig.2. Vectors orientation for composite inlay

Stresses were calculated using the formula: Stress = Young's modulus x deformation. Knowing the values of modulus of elasticity and the deformations during polymerization, we were able to calculate the stress forces transmitted in dental structures for each time interval (tabel 1).

The results demonstrate that there are no differences in the behaviour of the three types of fixing resins; the factors influencing quality of dental prosthetic joint are the mechanism of polymerization and the space between

Time (min)	Elasticity (GPa)	Polymerization shrinkage (%)	Force values in dental walls (N)
4	0.49	1.87	149.6
6	0.95	2.25	180.0
8	3.01	2.37	189.6
10	4.20	2.40	192.0
12	5.75	2.48	198.4
14	7.25	2.52	201.6
16	9.02	3.10	248.0

Table 1
THE POLYMERIZATION SHRINKAGE AND FORCE VALUES CORRELATED TO TIME

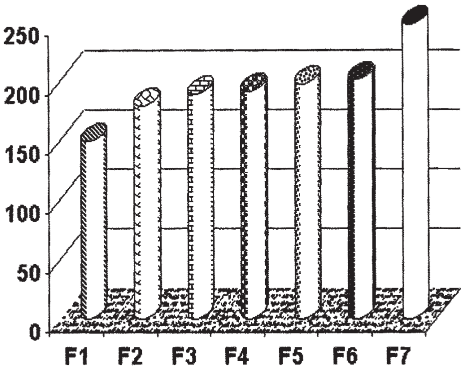

Fig.3. The forces values on tooth-restoration interface

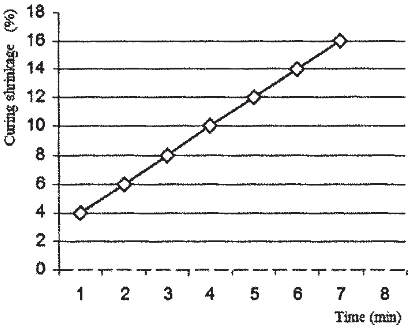

Fig.4. Curing shrinkage (%) according to time (min)

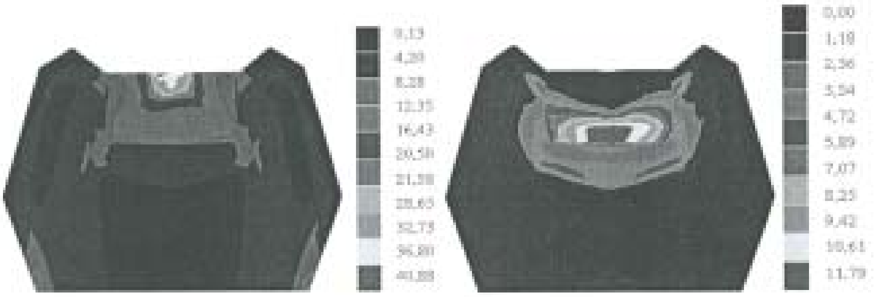

Fig. 5. Deformations induced into the dental tissues and restoration during the curing reaction

tooth and restoration. The polymerization shrinkage also depends on the reaction duration.

What we could notice was the aspect that one of the factors which influence the stress induced by the curing reaction is the shrinkage velocity (F) and the reaction time (fig. 3).

As much as the irradiation intensity corresponding to the wave length value is bigger the reaction velocity is bigger and the curing is more intense and the shrinkage occurs in a shorter time.

The curing shrinkage generates forces orientated through the light source; as the value of these forces is much bigger in comparison to the adhesion force to the dental structures, the gap between tooth and restoration is more important (fig. 4).

The stresses induced during curing reactions are transmitted to the dental structures and to the restoration also (fig.5).

Conclusions

Our study noticed that shrinkage of the lutting cement used to fix a composite inlay can induce a gap between the tooth structure and the restoration. The curing shrinkage generates stresses between 2.4 and 7.3 Mpa. If the adhesion value is bigger than that value, the jonction does not crack but fisures can occur into the enamel. The lowest resistance to shear strength of the composite-dental structures joint has to be 20 Mpa. As much as the resin quantity is more reduced, the marginal adaptation is better, the risk of fissure is reduced so the longevity of the restoration is longer. An important factor that has to be evaluated is the velocity of shrinkage during the curing reaction; that depends on the light concentration of the curing device into a time unit. As much as the iradiation value coresponding to eficient wave length value is bigger, the reaction velocity is more important. Our researches noticed that the stresses occured during the setting reaction, are transmited to the restauration. Because composite resins inlays have an important elasticity, will orientate the stress through the walls of the cavity. That explain why, when we use larger restauration placed in important cavities, fractures will be more frequent. As much as the marginal adaptation is better, and the gap between the restoration and cavity is smaller, the stresses will be smaller.

Appreciating the risk of fracture for the composite inlays we can emphasize that these prosthetic appliances can be ussed especially in small cavities on premolars.

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