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In vitro Study on Mechanical Properties of Polyacid-modified Composite Resins (Compomers)

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Abstract: *At the beginning of the 90's on the market of dental restoration materials appeared compomers, polyacid modified composite resins (PMC). The term compomer suggests a combination of glass-ionomer and composite technology. This has led to confusion about how it relates to dental structures. The properties and adhesion of compomers to dental structures suggest a closer connection with composites than with glass ionomers. They do not have direct chemical adhesion to any tooth structure it adheres similar to the composites through a separate binding agent. However, their proximity to composites does not make them substitutes of composites. Compomers are a versatile class of dental restorative biomaterials, whose clinical benefits are particularly useful in pediatric dentistry.*

Keywords*: polyacid modified composite resins, compomer, adhesion, pediatric dentistry*

1. Introduction

The high frequency of coronary damage due to dental diseases, among which dental caries ranks first, has boosted efforts to improve and diversify filling materials for morpho-functional restoration of damaged teeth and restoration techniques [1].

In the conditions of the continuous expansion of the range of restorative materials and of the amelodentinal adhesion systems, the application of coronary fillings, directly, intraorally, is gaining more and more ground compared to indirect restoration techniques that require laboratory steps to achieve them [2].

Dental composites are synthetic resins used in dentistry as a restorative material and are constantly evolving to obtain better products. One of the most common uses of composite materials is for light-curable fillings. The great advantage of modern composites over traditional restoration materials such as amalgam is superior aesthetics [2]. The physical qualities of dental composites have been improved through the use higher concentrations of nanofillers to increase wear resistance while maintaining translucency; use of more stable polymerization promoters for greater color stability; the addition of radiopacifying agents for improved diagnosis; and the use of dental adhesives.

Glass ionomers together with dental composites are the materials of choice for the aesthetic treatment of dental caries. They are established by an acid-base reaction in 2-3 min and form quite resistant materials, with an acceptable aesthetic appearance [1,2]. Glass ionomers are bioactive and release fluorine. They gradually develop a strong and durable ion exchange layer at the interface with the tooth, which is responsible for their adhesion. Responsible for their adhesion is the exchange of ions at the interface with the tooth, a layer that develops gradually, being strong and durable.

Compomers have emerged as a new subclass of coronary restorative materials in an attempt to occupy a distinct place in the dental restorative biomaterials market and to be a viable and effective

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alternative for the dentist. They sought to combine the advantages of two classes of already established materials, composites, and glass ionomers [3-5].

According to some literature reviews, "compomers" are not a new class of dental restorative materials but are a marketing name given to a dental composite [6].

Their name, polyacid-modified resin composites, indicates that they most strongly resemble resin composites but that they have been modified. Modification involves the introduction of some of the components of glass ionomer cements. This means that as they mature, they take up a small amount of moisture, which promotes an acid–base reaction. They contain hydrophilic components, and they make the water be attracted to the material after curing. The main benefit of this is that it makes compomers capable of releasing clinically useful amounts of fluoride [7-10].

The aim of this study was to evaluate physicochemical qualities for materials from three classes of direct coronary restoration materials: composites, compomers and glass ionomers. We performed tests to be able to comparatively evaluate the mechanical qualities of these materials that determine, in part, their behavior in the oral cavity.

2. Materials and methods

2.1. Materials

The materials studied were the following: two compomers, two composites and two glass ionomers.

Two materials from Dentsply were selected from the class of compomers, a second-generation compomer, Dyract AP, and a third-generation compomer, Dyract Extra, light-curable compomers.

For composites, the Point 4 material of the Kerr company was chosen, which is a microhybrid composite, and Radopacril (experimental composite of the "Raluca Ripan" Institute from Cluj-Napoca, Romania), both materials being light-curable.

Two materials were chosen from the class of glass ionomers, Ketac Molar of 3M ESPE and Kavitan Plus of Spofa, both being self-curing glass ionomers.

The mechanical properties pursued by us in the sealing materials studied were: compressive strength (Figure 1) studied according to ADA SP27, tensile strength (Figure 2a) studied according to ADA, SP 27 and strength at bending (Figure 2b) studied according to ISO 4049/2000.

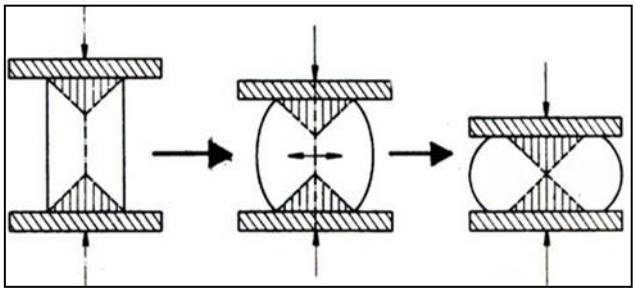

Figure 1. Compression force direction

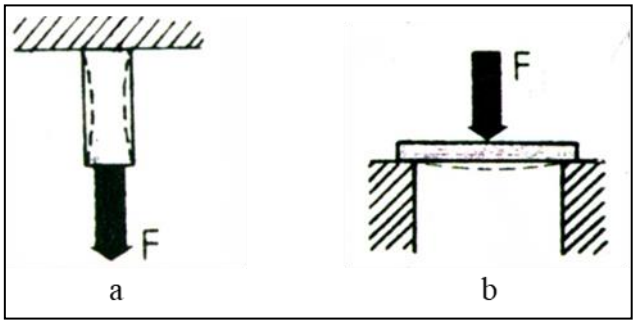

Figure 2. Action force direction of traction and bending force

2.2. Determination of compressive strength

For this study was used a Teflon mold in the shape of a disk with a thickness of 0.8 cm, consisting of two pieces, in the middle of which is practiced a cylindrical hole with a diameter of 0.3 cm and a height of 0.6 cm, the mold being surrounded by a metal ring which has the role of keeping the two half-discs closely connected; 1 mm thick glass plates; a small vise; a thermostatic water bath and a calibrated compressive strength tester with a piston feed rate of 0.5 mm / min.

Each material studied was inserted into the Teflon mold, which at one end was sealed with one of the glass plates. After completely filling the space between the two Teflon half-discs, a second glass plate was applied and the material was compressed inside the Teflon mold using the vise. The specimens made of composite materials and light-curable composites were reinforced by applying a stream of light, with the aid of the light-curing lamp, for 180 s, on both glass surfaces. For glass ionomers, the glass plates are kept under pressure until the material is taken up.

Thus, 5 specimens of each material proposed for the study were made, having the shape of a cylinder with a diameter of 0.3 cm and a height of 0.6 cm. After curing the material, these specimens are removed from the Teflon mold by removing the metal ring and detaching from the glass plates. For light-curable materials, a visible light flux is applied for 60 s in the middle of the test tube length. The specimens are then deburred, thus removing the excess material (Figure 3).

Figure 3. Preparation of specimens for testing

The next step is to introduce the test pieces of composites, compomers and glass ionomers into distilled water, where they were kept for 24 h at a temperature of 37 ± 1ºC.

After being kept in distilled water for 24 h, the specimens were placed in the second bath with distilled water at a temperature of 23ºC, where they were kept for 50 h. When this time elapsed, the specimens were removed from this bath, dried, and the section dimensions were measured with a micrometer. All specimens were subsequently introduced into the compressive strength measuring device.

The determinations of compressive strength were obtained with a universal mechanical testing device brand INSTRONE of the company VEB Thűringer Industrie werk Rauenstein. This device is equipped with an electronic system for transmitting and measuring force and elongation, as well as with a mechanical system for varying the speed of movement of the clamps. The determinations were performed in the force measurement range of 0-400 kg force.

The determinations took place at 23ºC. The diameter d of each specimen was measured, and the force F recorded by the apparatus at the time of crushing the specimen. The speed of movement of the clamps was 0.5 mm per min.

Compressive strength (in Mpa) was calculated using formula:

` $$RC = 9.81xF / 0.785xd2$$

The value of compressive strength was given by the average of at least five determinations. Test specimens that deviated by more than 15% from the mean value were not taken into account, and if more than two specimens deviated by 15% from the mean value, the whole series was repeated.

2.3. Determination of tensile strength

The determination of tensile strength was performed by an indirect test, called the diametrical compression test.

For this study, a disc-shaped Teflon mold was used, consisting of two pieces surrounded by a metal ring that has the role of keeping the two half-discs tight. They have a central shaft in the inner part, made of the same material that penetrates at the time of assembly and seals the two half-discs at one end. A cylindrical space with a diameter of 0.6 cm and a length of 0.4 cm is created between the two portions of Teflon. Also used: glass plates with a thickness of 1 mm; thermostated water bath; calibrated tensile strength tester.

For the light-curable materials (Point 4 composite, Radopacril composite, Dyract AP compomer and Dyract Extra compomer) the specimens were made by introducing the material into the space created by the two Teflon half-discs, until it refluxed (Figure 4). The next step was to seal the other end with another glass plate and expose it to the visible beam of light emitted by the light cure lamp for 180 s. Exposure of the test tubes to achieve the setting reaction was performed at both ends of the test piece, after disassembly of the assembly. After finishing the setting reaction, by removing the glass plates and the metal ring, the two half-discs are opened and the test tube is deburred. 5 such specimens were prepared from each material following the procedure as in the previous test of keeping in the thermostated bath.

For self-curing glass ionomers (Kavitan Plus and Ketac Molar), the preparation of the test pieces has as an initial phase the mixing of the powder with the liquid in the proportions indicated by the manufacturer, after which the mixture obtained is condensed inside the cylindrical mold (sealed at one end with the Teflon) with a plastic spatula (Figure 4). After filling the mold, another glass plate is applied to the opposite end and this assembly is held tightly until the setting reaction of the glass ionomers is completed. By dissolving this assembly, the specimens are obtained, in number of 5, for each glass ionomer separately.

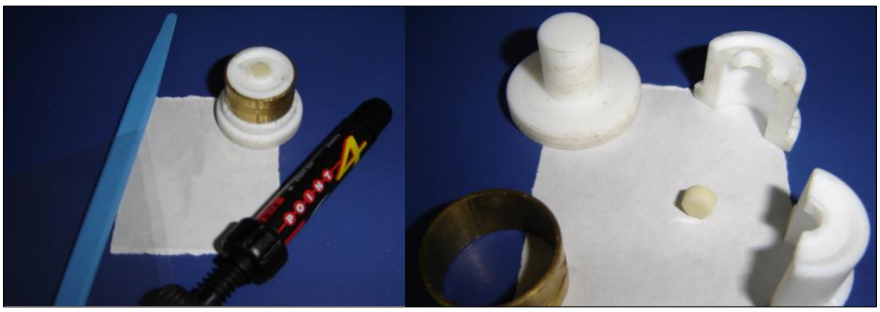

Figure 4. Preparation of the test pieces

The specimens obtained from all six materials were subjected to compression along the cylinder generator. The force F, which acts on the cylinder caught between the plates of the device, determines the appearance of the tensile forces on the plane of the vertical diameter. The travel speed was 1mm / min.

The tensile strength by diametric compression Rt (in MPa) was calculated by applying the formula: $Rt = 2xF / \pi xDxT$. F is the force recorded by the device at the time of crushing the specimen (in N), D is the diameter of the specimen (in mm), T is the thickness of the specimen (in mm). The value of tensile strength was calculated by averaging at least five determinations.

2.4. Determination of bending strength

The bending force applied to the filling material causes a mechanical stress on the entire mass of material, including the hybrid layer at the edge of the filling. It determines the fracture of the object to which it is applied and is directly related to the modulus of elasticity of the material being tested.

The equipment used consists of a disc-shaped Teflon mold, which is 0.8 cm thick and 2.5 cm in diameter, consisting of two pieces. A parallelepiped hole is drilled along its diameter with the

dimensions: length 25 mm, thickness 2 mm and depth 2 mm (Figure 5). The mold is surrounded by a metal ring which has the role of keeping the two half-discs closely connected during the experiment (Figure 6). Two further 1 mm thick glass plates, a small vise, a thermostatic water bath and a calibrated bending strength measuring device with a piston feed rate of (0.75 + 0.25) mm / min or a weight speed of (50 ± 16) N / min.

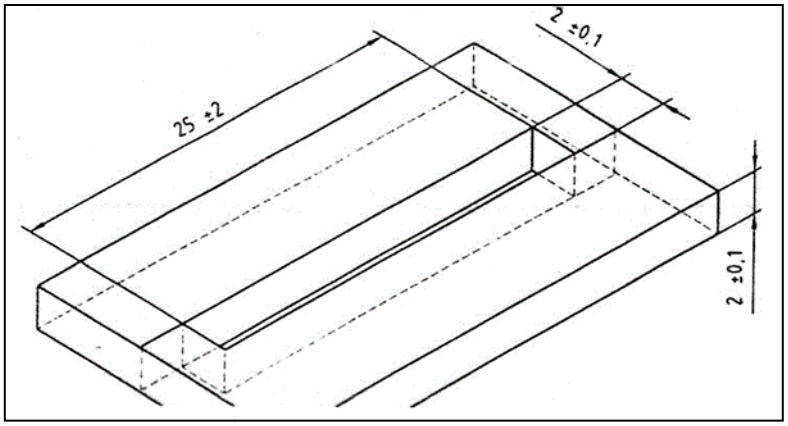

Figure 5. Schematic representation of the test piece for bending strength testing

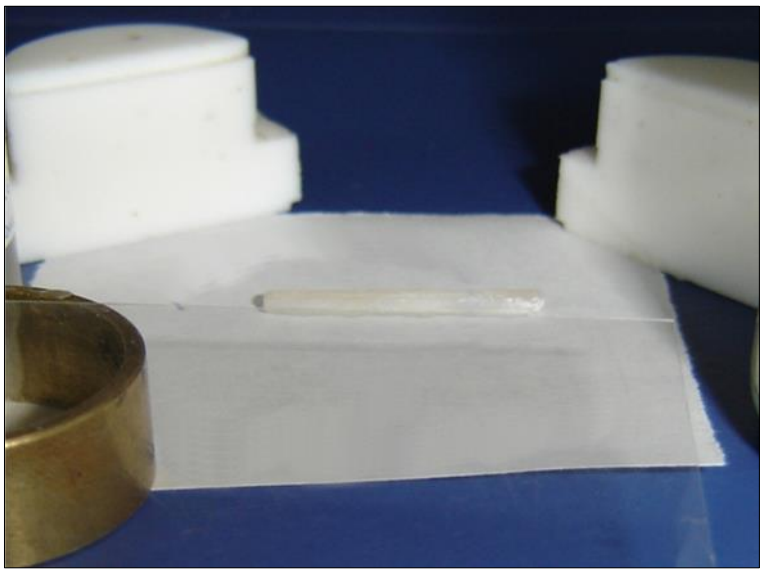

Figure 6. Sample made of composite material after opening the mold

To determine the bending strength, the specimens were supported symmetrically on two supports with a diameter of 2 mm, the distance between the axes of the two supports being l = 20 mm. The force F that produces the bending of the specimen acts centrally on it by means of a cylinder with a diameter of 2 mm. The speed of movement of the clamps was 1mm / min.

The bending strength σ (in MPa) was calculated using the formula:

$$\sigma = 3Fl / 2bh2$$

F is the force recorded by the device at the time of breaking the specimen (in N), b is the thickness of the specimen measured before the test (in mm), h is the height of the specimen measured before the test (in mm), 1 is the distance between the two supports.

3. Results and discussions

The results obtained from the compressive strength tests are illustrated in Figure 7 and Table 1.

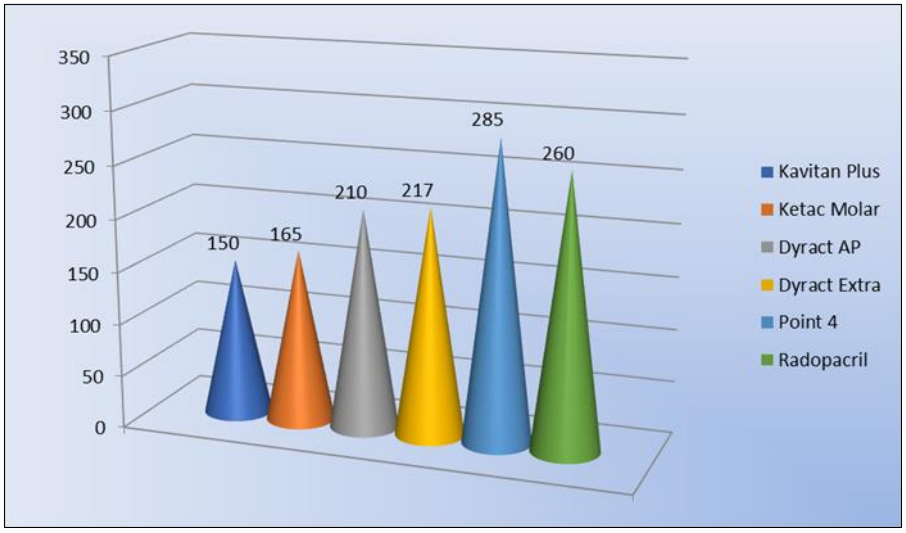

Figure 7. Compressive strength

Table 1. Compression strength values

Kavitan Plus	Ketac Molar	Dyract AP	Dyrac Extra	Point 4	Radopacril
150 MPa	165 MPa	210 MPa	217 MPa	285 MPa	260 MPa

From the comparison of the values of compressive strength of the three classes of materials studied, it was found, in the studied compomers, much higher values than in the case of glass ionomers. AP dyract has lower compressive strength values than the studied composites.

The compression resistance value for the Dyract Extra compomer is higher. There is a clear evolution of the value of compressive strength between the 2 compomers, due to the improved inorganic composition and the distribution of glass particles in the resin.

The two composites Point 4 and Radopacril, by dispersing the small powder particles between the large particles, lead to the reduction of the interstitial spaces, and the small particles take over the compression effort.

The results obtained from the tensile strength tests are illustrated in Figure 8 and Table 2.

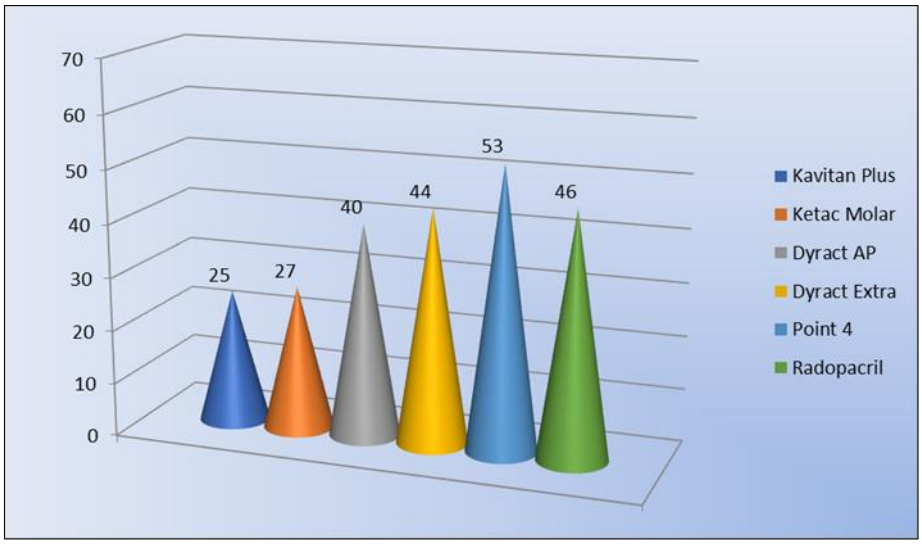

Figure 8. Tensile strength

Table 2. Tensile strength values

Kavitan Plus	Ketac Molar	Dyract AP	Dyract Extra	Point 4	Radopacril
25 MPa	27 MPa	40 MPa	44 MPa	53 MPa	46 MPa

Tensile strength has low values for glass ionomers, and compomers have higher values than their glass ionomer predecessors. These tensile strength values are lower in the case of composites opposite composites, which have higher values.

Among the studied materials, the Point 4 composite has the highest value of tensile strength. The compomers have evolved from one generation to another, the values obtained for Dyract Extra give this compomer better premises of the *in vitro* behavior to the demands by the traction forces. The tensile strength of these materials can be influenced by the distribution of the inorganic phase in the resin, the percentage of loading with the inorganic component, as well as the shape of the filler particles. The values of tensile strength guide the clinician in choosing the right material depending on the type of cavity.

The results obtained from the bending strength tests were illustrated in Figure 9 and Table 3.

Glass ionomers had very low values of bending strength compared to composites, while composers evolved to values of bending strength close to those of composites, which leads us to the idea that mechanically compomers have evolved to mechanical properties of composites. These materials have become usable in terms of bending strength in the oral cavity under conditions almost similar to composites for both the anterior and lateral area.

Table 3. Bending strength values

Kavitan Plus	Ketac Molar	Dyract AP	Dyract Extra	Point 4	Radopacril
32MPa	30MPa	75MPa	83MPa	115MPa	95MPa

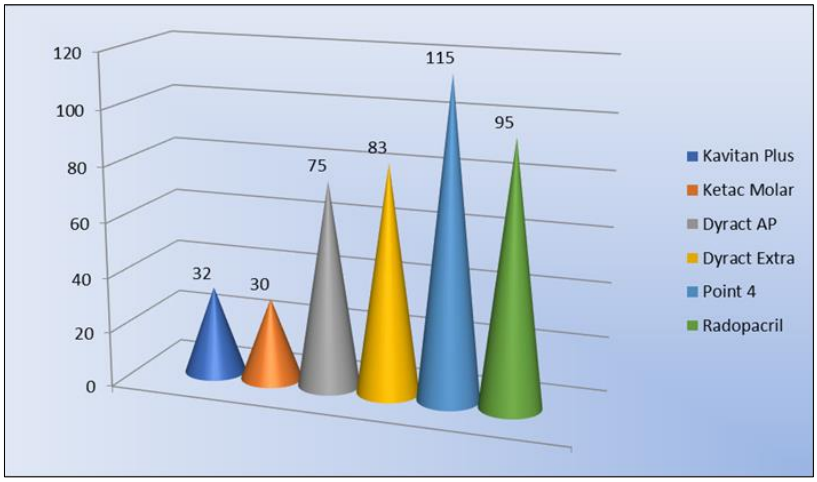

Figure 9. Bending strength

The cumulative results of our *in vitro* studies on compressive, tensile and bending strength are illustrated in Table 4.

Table 4. Results of *in vitro* compressive, tensile and bending strength studies

Materials category	Glass. I	Glass. II	Compomer generation II	Compomer generation III	Composite	Composite
Commercial name	Kavitan Plus	Ketac Molar	Dyract AP	Dyract Extra	Point 4	Radopacril
Compression tension streght	150Mpa <	165Mpa <	210MPa <	217MPa <	285Mpa >	260Mpa >
Traction strengths	25Mpa <	27Mpa <	40Mpa <	44MPa <	53Mpa >	46Mpa >
Bending strength	32Mpa >	30Mpa <	75MPa <	83MPa <	115Mpa <	95Mpa >

Tensile strength, compressive strength and diameter of the base materials are considered to be important, because they usually replace a large part of the tooth structure and have to withstand masticatory forces for many years [11-13].

There are numerous studies on the mechanical properties of compomers in terms of compressive strength, diametrical tensile strength, rupture and surface hardness. In general, these properties do not differ much from those of conventional composite resins. The mechanical property of compomers, however, which differs significantly from that of conventional composite resins is the fracture strength [14]. The authors of this study concluded that, given this low resistance to crack propagation, compomers should not be used in stressful areas.

El-Kalla Ibrahim and Garcia-Godoy Franklin in a study on the compressive and bending strength of three compomers compared to a resin-modified glass ionomer and a composite concluded that these properties in compomers were superior to the glass ionomer but inferior to the material composite [15].

Flexural, compressive and tensile strengths vary between classes of materials for coronary restorations. In general, the strength properties of composite materials are superior to compomers, which are stronger than resin-modified GICs (glass ionomer cement), which are much stronger than conventional GICs [16-21].

Cattani-Lorente and colleagues concluded in their study that the higher mechanical strength of Dyract to glass ionomer cements is determined by its composite character [22].

Glass ionomer cements are used in clinical situations where they are not disadvantaged by their physical properties: low abrasion resistance, lack of hardness, early sensitivity to water and porosity [23, 24]. Therapeutic success is given by the protection of glass ionomers against hydration or dehydration [25].

4. Conclusions

From the performed studies it is noticed the evolution of the compomers from one generation to another towards values close to the mechanical characteristics of those of the studied composite materials.

Thus, the high values of tensile, bending and compression strength make the Dyract Extra compomer (third generation compomer), a material usable both in physiognomic restorations in the anterior area and in the restoration of cavities in the lateral area.

The fact that the studied glass ionomers have lower values of mechanical properties compared to composites and compomers, justifies their main indication represented by the filling of class V cavities without high occlusal pressures or their use as basic fillings under composites, compomers or amalgams.

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