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“In vitro” study of a new composite biomaterial for indirect restorations

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The purpose of this study was to evaluate the ability of a new Romanian composite biomaterial to be used for indirect restorations (inlays). In this purpose, 40 standardized class II cavities were prepared on freshly extracted, sound third molars and restored with composite inlays using the Romanian composite Barodent as well as a well known trademark composite. The restored teeth were sectioned mesio-distally and then analysed. The structure of the inlays and the adhesion to the dental tissues were investigated by using scanning electron microscopy and X-ray dispersive energy analysis. The SEM micrographs showed a rather homogeneous structure of the Romanian composite, as well as its quality of adhesion to the dental hard tissues.

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1. Introduction

The use of resin-based composite materials has increased in the last years because of patients’ growing aesthetic demands. These advanced materials are now reported to be the most frequently used in the indirect and direct restorative dentistry [1-4].

From their appearance, composite resins continued to develop, by improving their mechanical, physical chemical properties and also their biocompatibility [5-8]. They all have similar organic matrix, their specific mechanical and physico-chemical behaviour being related to their polymerisation process and nature of the inorganic particles from the filler [9]. By incorporating bigger amounts of inorganic particles into their composition, the hardness, the compressive and flexural strength increase. Thus advanced composite materials have improved surface characteristics regarding wear and polishing, and also superior physical and chemical properties [10]. All the improvements regarding their properties and the development of adhesive systems enlarged their application field, allowing very interesting restorative alternatives for the posterior teeth.

The use of composite resins in direct restorative techniques for the posterior teeth involves a judicious methodology in order to overcome their major disadvantage that is the polymerisation shrinkage causing tensions at enamel-dentin interface, cuspid deformation, tooth fissures and finally microleakage, post-operative sensitivity and recurrent caries. For this reason the use of these systems in posterior restorations should be limited to smaller restorations [11-14].

Indirect inlay systems became popular to overcome the limitations of the direct technique, by minimising its disadvantages, improving clinical conditions regarding the proximal contact, occlusal anatomy and marginal adaptation [15].

Recent indirect composite formulations with improvements in inorganic filler (amount, type and average size) and the molecular weight of monomers that compose the organic phase have enhanced significantly the mechanical characteristics of second- generation composite resins by reducing polymerisation shrinkage, while increasing flexural and tensile strength, resistance to abrasion and fracture, and colour stability[11,16]. In addition the various combinations of light, heat, pressure, and vacuum, as well as the use of nitrogen to enhance the degree of conversion through postcuring, improved the physical properties of second generation indirect resin systems [11].

The purpose of this study was to evaluate the ability of a new Romanian composite biomaterial to be used for indirect restorations (inlays). The structure of the inlays and the adhesion to the dental tissues was investigated by using scanning electron microscopy and X-ray dispersive energy analysis.

2. Experimental

Forty freshly extracted, carie free molars were kept in distilled water about three months before use. Class II (proximo-oclusal) cavities for inlays were prepared using speed diamond burs according to the standard procedure. No bevels were placed at any of the margins of the cavities and all margins and cavity walls were smoothed.

Teeth were divided into two groups of twenty teeth each and they were restored with composite inlays. In

Group I teeth were restored using Barodent, a new composite developed at the Institute for Research in Chemistry Raluca Ripan, ICCRR, Romania, while in Group II a well known composite, the BelleGlass NG (Kerr Corporation, USA) was used.

The composite inlays were manufactured by the indirect procedure. Wash technique impressions were taken using two different viscosities condensation silicones (Zetaplus Putty and Oranwash Light/ Zhermack, Italy), then the impressions were poured using type IV dental stone (Elite Rock, Zhermack, Italy) resulting the models on which the composite inlays were fabricated. The inlays were manufactured by applying the composite in approximately 2 mm layers followed by photo-polymerisation 20 seconds in visible light (400-500nm) using the light curing unit Teklite (Kerr Corp). At the end all restorations were submitted to heat (135°C) and pressure (60 psi) polymerisation in nitrogen atmosphere for about 20 minutes in order to increase the conversion rate of the composite resin and to improve the mechanical properties of the restorations and their dimensional stability.

Before cementation the internal surface of composite inlays was treated with aluminium-oxide 50μm particles then silanated using Monobond S (Ivoclar- Vivadent, Lichtenstein) for 1 minute. For luting procedure a dual cured resin cement was used together with the adhesive system recommended by the manufacturer.

Barodent inlays (Group I) were luted using the Romanian dual cured resin cement Dualcim (ICCRR), together with an etch-and-rinse adhesive system, Dentadez (ICCRR), an adhesive based on bisphenol A glycidyl methacrylate (Bis-GMA), without solvents. BelleGlass inlays (Group II) were luted with the dual cured resin cement Nexus 2 (Kerr Corp) and the bonding system Optibond SoloPlus (Kerr Corp) which is an adhesive based on 2-hydroxyethyl methacrylate (HEMA), with ethanol as solvent. The adhesive systems and the luting procedures were completed following the manufacturers' protocol. The luting resin cement was applied on the internal surface of the inlay and in the deeper zones of the cavities. Then the restoration was set into the cavity and kept in place with moderate pressure. Excess cement was removed and the luting cement was light-cured for about 40 seconds per tooth surface using a halogen light-curing unit (Optilux 501, Kerr Corp). Then the margins were finished and polished with abrasive discs and rubber points (OptiDisc, Kerr Corp).

The restored teeth were kept for one week in distilled water at room temperature. Then they were fixed in acrylic resin and sectioned mesio-distally using a low speed diamond saw (Isomet, Buehler LTD) resulting 1,5 mm specimens and then they were analysed. The specimen analysis was done by scanning electron microscopy (SEM) and X-ray dispersive energy analysis (EDX) using a Philips L20 electron microscope.

3. Results and discussion

Many studies have been performed in order to find new materials with improved properties for restorative dentistry [5, 11, 17]. As shown by previous papers, Barodent is one of the Romanian composites that successfully fulfil the requirements for indirect restorations [18, 19]. The Barodent composite is prepared as a paste by dispersing the inorganic filler into the organic matrix. The inorganic filler contains barium glass, quartz and colloidal silica as nanofiller whereas the organic matrix is a Bis-GMA based resin (Table 1). The bond between the two different phases was achieved by treating the inorganic filler with a coupling agent (3-methacryloyloxypropyl-1-trimethoxysilane).

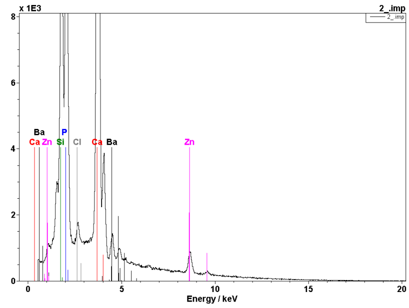
Table 1. The composition of the Barodent composite material.

Producer	Organic matrix	Inorganic filler	
		Components	Barium glass
ICCRR, Romania	Resin based on Bis-GMA	50% barium glass 20% colloidal silica 30% quartz	45% SiO_2 17% B_2O_3 10% Al_2O_3 20 % BaO 8% NaF- CaF_2

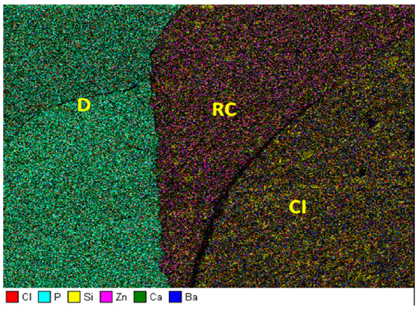
In order to evaluate the ability of the new biomaterial to be used for indirect restorations, Barodent inlays were compared with inlays manufactured from a well known trademark composite material, that is the BelleGlass NG (Kerr Corp) that possesses superior physical properties and is characterised by a reduced contraction of polymerisation. BelleGlass NG contains a hybrid filler dispersed into the organic matrix based also on Bis-GMA resin. The filler is a mixture of nanometric particles of silica, 0.4 μm structural particles and 25 μm particles of prepolymerised filler obtained from barium glass, nanofiller and resin.

The EDX analysis for both Barodent and BelleGlass inlays illustrates the similarity between the chemical compositions of the both biomaterials used for indirect restoration. The EDX map over the section of the restored tooth shows the distribution of elements both in inlay and the dental tissues (Fig. 1a, 1b; Figure 2a, 2b). The EDX map permitted to identify the dental tissue D (Ca, P), the resin cement RC (Zn,Si), the composite inlay CI (Si, Ba, Ca, Al).

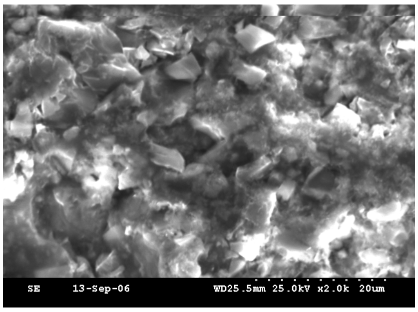
The SEM micrographs for the Barodent inlays (Group I of teeth) showed a continuous interface between the dental substrates and the luting cement, and also a good adaptation between the luting cement and the composite inlay (Fig. 1c, 1d).



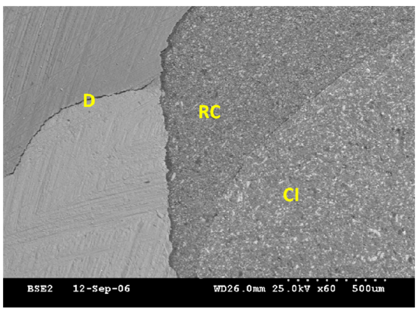
(a)



(b)



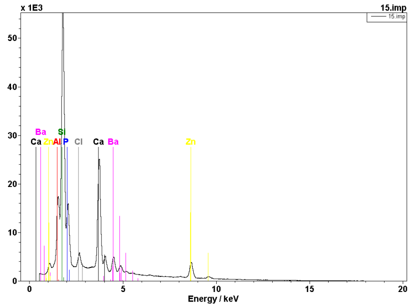
(c)



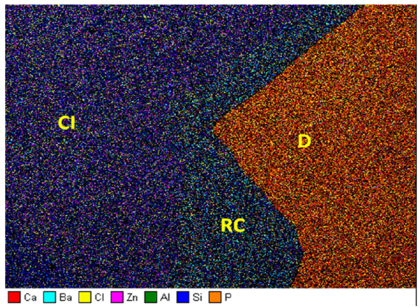
(d)

Fig. 1. a) X-ray dispersive analysis; b) Elements distribution map; c) SEM image for Barodent biomaterial; d) SEM image of Barodent inlay.

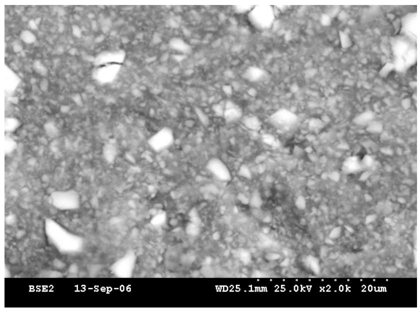
The SEM micrographs for BelleGlass inlays (Group II of teeth) showed that the adhesion between the restorations and the dental tissues was uniform and continuous without gaps (Fig. 2c, 2d).



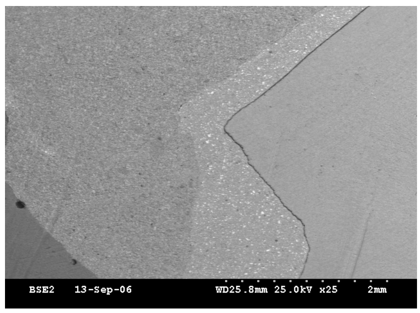
(a)



(b)



(c)



(d)

Fig. 2. a) X-ray dispersive analysis; b) Elements distribution map; c) SEM image for BelleGlass biomaterial; d) SEM image of BelleGlass inlay.

The scanning electron microscopy was used to evaluate the continuity of the tooth-cement-inlay interfaces and to visualise the structural uniformity of the cement layer. The SEM analysis put in evidence the structure of the materials and their adhesion to the dental tissues.

SEM images for Barodent biomaterial showed its rather homogeneous structure, with different size particles, as well as particles' polydispersion. EDX analysis allowed the identification of the inorganic filler in the Barodent composite, due to its characteristic elemental composition: Si, Ba, Al,Ca,Na,Mg. The inorganic filler with relatively large particles of irregular shape and size is in the favour of a good micromechanic bond between the luting cement and the restoration. In the same time, it could damage the composite mechanical properties because of the tensions that can arise on the points and edges of the particles.

At tooth- resin interface, a thick, continuous adhesive layer could be observed. This can be correlated with the adhesive high viscosity due to the lack of solvent. The high viscosity as well as the hydrophilicity of monomers causes a reduced infiltration into the underlying dentin, the adhesive remaining on its surface. A continuous interface between the luting cement and the glass inlay was observed, probably related with the fact that the formulas of the both materials contain the same monomers.

For BelleGlass composite, a thin and continuous adhesive layer could be observed at luting cement-dentin interface, this suggesting a relatively low adhesive viscosity and a better infiltration into the dentin. The penetration of the adhesive into the underlying dentin is favorised by the presence of the hydrophilic monomers and ethanol that act as a „water chaser". The water from the demineralised dentin is removed without causing its collapse and thus creates some optimal conditions for the infiltration of the adhesive resin.

SEM micrographs for BelleGlas*s* inlays showed the characteristic microstructure of the composite containing large, medium and small, nanometric particles. It can be noted that in this case, the quantity of particles with small dimension is greater than for the Barodent composite, that allows a bigger amount of inorganic filler.

4. Conclusions

The use of a new composite material for dental indirect restorations was investigated in order to evaluate the inlays structure and ability to achieve good adhesion to the dental substrates. For inlays application, Barodent composite showed similar characteristics to those revealed by BelleGlass material.

SEM analysis illustrated that the new composite in combination with a dual cured resin cement and an etch – and-rinse adhesive system allows a proper seal of the tooth structure minimising future microleakage and postoperative sensitivity to the indirect restoration.

It can be concluded that the use of inlays manufactured from the Romanian biomaterial in combination with a dual-cured luting cement is in the favour of a good marginal adaptation of the indirect restorations.

Due to their quality and also to their compatibility with the bonding agent, the barium glass biomaterials could be successfully used in restoring larger cavities, offering a good alternative when the limits of the direct composite restorations are overtaken.

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