v. 3, n. 12, 2023

International Journal of **Health Science**

COMPOSITE RESINS: UPDATES AND PERSPECTIVES

Rubens Nazareno Garcia
PhD in Dental Materials (FOP/UNICAMP)
Universidade do Vale do Itajaí (UNIVALI)

João Henrique Backes Nagel
Dentist in private clinic

Carolina Covolan Malburg
Master in Health and Work Management (UNIVALI)
Universidade do Vale do Itajaí (UNIVALI)

Vinicius Laranjeira Barbosa da Silva
PhD of Orthodontics (FOB/USP)
Universidade da Região de Joinville (UNIVILLE)

Betsy Kilian Martins Luiz
PhD in Materials Engineering (UFSC)
Universidade do Vale do Itajaí (UNIVALI)

Abstract: Composite resins are an indispensable item in restorative dentistry. This is because it is an accessible material, which allows less dental wear, in addition to providing excellent aesthetics and good mechanical properties. During the last decades, technology has been promoting a wide evolution in the field of dental resin materials. Not only research on physical, but also mechanical and optical properties has been carried out, increasing the load size, finish and polishability. Recently, methods have been developed to reduce polymerization shrinkage and polymerization stress. Both nanoparticulate resins and "bulk fill" resins are already consolidated in the market, bringing advantages such as greater mechanical resistance and reduction of clinical steps, in addition to unichromatic composites that facilitated the selection of colors. This study aimed to review the literature on composite resins and describe its evolution and perspectives. Based on this literature review, the use of nanotechnology increased the durability of restorations, making them more aesthetic and with better physical-mechanical resistance. Materials with differentiated viscosity for each specific case and unique increments with bulk fill resins result in less stressful procedures for dentists. The research is focused on unichromatic resins, which can mimic the dental substrate, facilitating the color taking. Self-adhesive resins (under study) still have room for improvement in their performance, which will result in a significant decrease in steps, as well as remineralizing materials that can increase the lifespan of restorations.
Keywords: Operative dentistry. Dental materials. composite resins.

INTRODUCTION

Current aesthetic standards have a direct influence on Dentistry and this motivates the development of new and better materials, putting pressure on the scientific community and industries to improve materials and restorative techniques. Composite resin plays an important role among dental materials, as it can restore dental anatomy, function, and aesthetics, in addition to constantly evolving its composition (GADONSKI et al., 2018).

The use of adhesive systems, especially those called universal, facilitated operative techniques, both for enamel and dentin and for other substrates (GARCIA et al., 2016; GARCIA et al., 2021). Also, the professionally applied bioactive desensitizers, which help to form apatite through the release of ions or peptides, or those containing nucleated crystals, are in evidence. For example, we use in our experiments the Teethmate Desensitizer (Kuraray Noritake, Japan), which contains phosphate of calcium in the form of tetracalcium phosphate (TTCP) and anhydrous dibasic calcium phosphate (DCPA), which can decrease the permeability of the dentinal tubules and alleviate sensitivity through the formation of similar crystals to apatite. (SADR, A et al., 2022).

In 1936, Blumenthal used the first self-curing resins as a restorative material. In 1948 Ward chose to replace the application of acrylic acid, which was used together with glycidyl methyl methacrylate powder, with sulfinic acid, which resulted in reduced polymerization shrinkage. However, even with this change, other flaws remained, such as thermal contraction, porosity, and low compressive strength (MENEZES et al., 2020).

Until the 1970s, amalgam was the compound of choice as a restorative material, especially in posterior teeth. Its use and effectiveness depended on great dental wear, in addition, presenting significantly different color from the remaining teeth. Thus, given the options of restorative materials, composite resins made it possible to perform aesthetic-functional restorations in a less invasive way (CARVALHO, 2021).

The evolution of adhesiveness began in 1955, when Buonocore introduced the technique of acid etching, improving adhesion to the enamel, at that moment. The composite resin was developed approximately in the 1960s, with monomer Bis-GMA being the main component of the organic part. From its introduction to the dental market to the present day, composite resins have evolved significantly. These resins were initially chemically activated in a paste/paste version, later light-activated resins appeared, allowing for less polymerization shrinkage and bubble incorporation. So, resin materials are composed of an organic matrix and inorganic filler particles treated with silane, among others (SCHNEIDER et al., 2016; MENEZES et al., 2020).

Over the years, besides the changes in the composition of resins, there were changes in activation systems. Initially, the activation of the composites went through a chemical reaction, in which the polymerization took place through the mixture of a base paste and a catalyst paste. However, these self-curing resins were prone to staining and polymerization shrinkage, resulting in large spaces between the restoration and the tooth, thus causing recurrent caries and marginal leakage. (MENEZES et al., 2020). Subsequently, the dental products industry introduced light-curing composite resins to the market. (SCHNEIDER et al., 2016).

Until recently, the main lines of research about composite resins were on filler particles, in which the reduction in the size of these particles made it possible to obtain materials with better polishing and greater wear resistance. Currently, the main researches are focused on the polymeric matrix of the materials, since a material with a stable polymeric matrix is capable of presenting a well-attenuated polymerization contraction, moreover, they are also looking for composite resins that can adhere to the dental structure without the use of adhesive systems. (MARANHA et al., 2017).

This study aimed to review the literature on composite resins and describe their evolution and prospects.

MATERIALS AND METHODS

The present study is outlined as bibliographic research. Thus, it was developed through a bibliographic search in the following databases: PUBMED, SCIELO, and GOOGLE SCHOLAR. The selection of articles was determined through limits imposed and related to the proposed objective: to review the literature on composite resins. To filter the publications, the following keywords were used: Composite Resin. Restorative dentistry. Dental materials. Resin composites. Only articles published between 2015 and 2022 were selected and, after filtering, it was observed whether or not they fit into the selected proposal.

LITERATURE REVIEW

HISTORY

Since they were introduced on the market more than 50 years ago, composite resins undergo constant changes in their composition, seeking better masticatory, aesthetic and biological functions. Such alterations resulted in the improvement of the physical and mechanical properties of the material, contributing to increasing the longevity of the restorations. The optical properties, such as translucency, fluorescence, and opalescence, provided a mimicry of the natural characteristics of teeth. Direct composite resin restorations are used as a restorative solution for teeth presenting with shape changes, deficient restorations, and discolored non-vital teeth. The composite resin restorations has some advantages over indirect techniques, such as the lower cost compared to ceramics, and dispensing laboratory steps. (CARVALHO et al., 2021).

The development of dentistry has shown a great rise in recent years, with the discovery of new materials and increasingly efficient techniques. The main interest of a clinician is to be able to perform restorations with aesthetic and functional quality, and for this, the materials must present safety and predictability. Composite resins are described as materials composed by two or more components in their formulation. Due to differences in formulations, they can be used in different ways, as a restorative material, and as a filling core. Regardless of the use, all resins present in their formulation a polymer matrix, filler particles, and silane. Materials that give color to the resins and inhibit polymerization during storage or handling are also part of the composition of composite resins. (MARANHA et al., 2017).

Composite resins have an organic matrix in their general structure, which is the part responsible for strength, rigidity, and stability, and inorganic load that provides rigidity in the most superficial part and better resistance to compression and traction, increasing durability and clinical performance, decreasing polymerization shrinkage and thermal shrinkage and expansion. (SANDES and MENDONÇA, 2021)

The organic matrix is composed of bisphenol glycidyl methacrylate (BISGMA) or polyurethane. Because these compounds have a high viscosity, monomers that have low viscosity, triethylene glycol dimethacrylate (TEGMA) and ethylene glycol dimethacrylate (EDGMA) were added. The composition of the organic matrix influences factors such as polymerization, degree of conversion, and the viscosity of the material. The inorganic matrix is made up of filler particles, which increase the strength of the material and can influence several properties, such as hardness, level of thermal expansion, water absorption, modulus of elasticity, and resistance to fracture. The silane prevents the organic matrix from loosening from the inorganic filler, preventing the formation of air bubbles. (FERREIRA et al., 2017)

CLASSIFICATION OF COMPOSITE RESINS

Composites were classified according to various characteristics, such as size, content, and filler types as well as physical and mechanical properties. (SANTOS, 2018). The first composite resins that appeared were the macro particulates, currently in disuse. They were classified as such due to the size of the inorganic filler particles, which had measurements between 10 and 100 μm, and represented 60% of the total volume of the resin. These resins contained glass, strontium, or barium particles in their filler. Due to the size of their inorganic particles, they had high surface roughness and suffered abrasive wear in their matrix, causing the hardest filler particles to be exposed, producing a rough surface, which resulted in a higher rate of surface staining. (FERREIRA et al., 2017; MENEZES et al., 2020).

Microparticulate composites present colloidal silica particles in their formation, which is an inorganic filler component. Colloidal silica forms in this material an agglomerate of 0.01 to 0.1 μm and its function is to diminish restoration surface roughness and also decrease low translucency, which are common problems in resins with conventional and small particles. However, as the silica particles are very small, the material is formed by 40 to 80% of its volume by resin, thus presenting a lower elastic modulus, a higher coefficient of thermal-linear expansion, and higher water absorption. They are materials indicated for flat areas that do not require great mechanical stress, therefore, negatively influencing its long-term performance. Microparticulate resins are easy to fracture but have a high polishing capacity. It is a type of resin to be used in the most superficial layers of esthetic restorations which do not receive high load. (MARANHA et al., 2017)

Microparticulate composites presents a large amount of organic matrix, causing a high degree of pigment absorption, which results in staining, especially in thin margins. (ARRUDA., 2018).

Hybrid composites emerged with the proposal to present good mechanical properties and still obtain a surface smoothness superior to that found in microparticulate composites. (MARANHA et al., 2017).

Hybrid resins are characterized by having a greater amount of filler, at least one of which is colloidal silica, reaching a concentration of 70 to 90%, and flow-type hybrid resins can reach a lower concentration of filler particles by weight. The advantages of these resins consist of greater mechanical resistance in situations of occlusal stress with relative surface polishing and their disadvantage is related to maintaining this polishing in the long-term. (ARRUDA., 2018)

Within the classification of hybrid resins, we can also add hybrids of small particles that present in their composition an amount of colloidal silica with a size of 40nm. The micro-hybrid presents in their composition filler particles with a size between 0.4 and 1.0μm. (MARANHA et al., 2017)

The micro-hybrid composite resin, by having its particles reduced, ends up having a greater capacity for polishing maintenance. This resin is nowadays the main choice for class IV restorations due to its polishing potential and mechanical strength. (ARRUDA., 2018)

Looking for materials with smaller filler particles, with the incorporation of a high concentration of filler in the organic matrix, nanoparticulate resins were developed. This group of composites has particles with nanometric measurements, ranging from 1 to 10 nanometers. (FERREIRA et al., 2017)

Nanoparticulate and nanohybrid compounds were introduced as a material that provides excellent initial polish combined with good gloss retention, being the state of the art in terms of filler formulation. They are available in two forms of nanoparticles: loose particles and groups of nanoparticles, the so-called "nanoclusters". Nanoparticulate resins use the nanometer particles along the resin matrix, although, nanohybrid resins result in the combination of nanoparticles and conventional filler particles. Nanoparticles are individually charged particles formed mainly with spherical shapes. The "nanoclusters" consist of free clusters of approximate size from 2 to 20nm. Nanohybrid resins are variable in size, allowing a homogeneous distribution of the filler particles in the matrix, as the nanoparticles perfectly occupy the spaces between the larger particles, characteristics similar to micro-hybrid resins. (BENEDETTO, 2020)

Nanocomposites have advantages such as lower polymerization shrinkage, improved mechanical properties, favored optical behavior, better gloss, better color stability, and less wear. Filtek Z350 composite resin (3M ESPE), an example of one of these nanoparticle composites, features zirconia particles and silica, with an approximate size between 5 and 20 nm, and pre-polymerized nanoparticles ranging from 0.6 to 1.4 micrometer. This resin has significantly advanced in terms of the clinical performance of universal composite resins. Until the launch of this product, dentists who wanted to obtain better aesthetic results, with direct restorations on anterior teeth the best choice was microparticulate resins. (GADONSKI et al., 2018)

POLYMERIZATION

In order to obtain the optimal characteristics of a composite resin, it is important to evaluate the degree of transformation-conversion of monomers into polymers. The degree of conversion usually achieved by composite is around 60%. The principles that influence the degree of conversion of composite resins include the types of light curing units used, the distance the professional uses the light curing unit, and the type of resin composite, as well as the amount of composite resin introduced into the cavity to be restored. (SANDES and MENDONÇA, 2021).

Several factors can influence the amount of light received by the top and bottom of a restoration, such as the distance from the curing light tip to the restoration, the light curing power, the color and opacity of the resin, the thickness of the increments, and the material composition. If the restoration does not receive enough energy, several problems can arise such as low polymerization conversion rate, decrease in hardness, increase in pigmentation, decrease in elastic modulus, increase in wear, increase in marginal infiltration, and poor bonding to the dental substrate and the adhesive. (BENEDETTO, 2020)

The latest advances in curing technology have come in light-emitting diode (LED) of light curing units (LCUs). These devices have become popular due to their many operational advantages, such as shorter exposure time, longer service time, lower weight and thermal effects compared to halogen lamps, and their predecessors in ultraviolet (UV) light. The first and second-generation LED-LCUs were able to polymerize 2 mm thick resin samples in 20-40 s and emitted a narrow mono wave light spectrum (450-470 nm), which corresponds to the spectral peak of absorbance of the camphorquinone. (KAYA et al., 2018).

POLISHING

The quality of restorations is highly dependent on the precision of the finishing and polishing techniques used. Finishing and polishing procedures, which refer to adjusting the contour of restorations to obtain the desired anatomy, to reduce roughness and scratching, are essential for maintaining a healthy periodontium and the marginal integrity of the restoration. In addition, polished surfaces minimize plaque adherence, gingival irritation, unfavorable esthetics, surface discoloration, and secondary caries. For surface polishing procedures, the most commonly used materials are aluminum oxide impregnated disc systems, silicon oxide-based silicon tip systems, and fine-grained sandpaper strips, in addition to felt discs. To have a smooth, polished and shiny surface, it is necessary to use a sequence of instruments in decreasing order of granulometry, thus minimizing surface roughness (BAIERLE., 2017)

ADHESIVENESS

Adhesive systems are responsible for bonding the restorative material to the dental structures. They are composed of a combination of resinous monomers of different molecular weights and viscosities, resinous diluents, and organic solvents. The first studies on etching and adhesion were performed on enamel by Buonocore, when he proposed, in 1955, etching the surface of dental enamel with acid treatment. Adhesiveness is a property acquired with the application of substances such as acids, solvents, and monomers, whose purpose is to change the structure and physiology of enamel and dentin. (FERREIRA et al., 2017)

Adhesive systems can be classified into two groups: self-etching adhesives and conventional adhesives. The self-etching adhesive can be one-step or two-step. They are called self-etching because in their composition there is an acidic monomer that has the ability to condition and apply the primer to the tooth structure simultaneously, this makes the professional gain a lot of clinical time. Conventional adhesive systems were the first to be used as composite resin adhesives. This type of adhesive system can be performed using two or three steps. In the three-step system, it is necessary to etch the enamel with phosphoric acid, then apply the primer and separately the adhesive. Two-step etching has the primer and acid applied together. (MARANHA., 2017; GARCIA et al., 2017; GARCIA et al., 2021).

BULK FILL RESINS

In 2010, a new generation of composite resins called Bulk-Fill was launched on the market, with the proposal of insertion in a single increment of up to 4 or 5 mm (according to the manufacturer). Initially, the flow type emerged, with the indication for filling the base of very deep cavities, and later they were developed in a regular consistency, subject to dental carving (MOURA, 2021).

Bulk-fill resins, or single-fill resins, can be classified according to consistency into fluid or regular consistency resins. In general, the main property that characterizes this material is the low degree of contraction after polymerization, which allows the use of these materials in layers of 4–5 mm, leaving aside important characteristics such as the C factor and incremental technique, always discussed in the technique of restoration with conventional resins. (CANEPELLE and BRESCIANI, 2016).

When the cavity is quite extensive and deep, the incremental technique requires a greater amount of time and consequently entails a greater possibility of possible contamination during the procedures. By presenting a superior flow in the cavity, when compared to conventional composite resins, bulk fill composite resins certify a better filling of areas and angles that are difficult to be filled. (SILVA NETO, 2019)

This single increment technique was only possible due to the translucency characteristics of these resins, allowing greater penetration of light, and also due to the incorporation of special monomers that reduce the polymerization stress (MOURA, 2021).

Bulk-fill resins have greater translucency and, for this reason, the percentage of charge particles is reduced, but they have a higher percentage in weight compared to microhybrid and nanohybrid resins, resulting in less light dispersion and consequently increasing light penetration in the depth of restoration. (BENEDETTO, 2020). Bulk fill composites are made up of a mixture of organic matrix filler particles, polymerization indicator molecules, and bifunctional bonding agents (silane). They have low voltages, related to the reduction of polymerization, and excellent light transmission characteristics, due to the reduction of light dissipation in the connection between matrix and inorganic particles. Bulk fill resins can be presented in two forms, low viscosity (flow) and high viscosity. Flow is indicated as a base restorative material and requires an increment of 2 mm of a conventional composite resin to be added over its last layer to ensure greater wear resistance, as it has a lower surface hardness due to the lower amount of inorganic filler in its composition. Bulk fill resins that have present high viscosity can be inserted only along the entire length of the cavity. (FERREIRA et al., 2017).

It is essential to point out that to achieve light curing of the bulk fill resins at the depth established by the manufacturers, light curing units with minimum potential of 800 megawatts per cubic centimeter must be used, being the most correct use of light curing units with a power of 1000 megawatts per cubic centimeter, due to the loss of energy that occur influencing the reaching in the deepest parts of the restorations. (SANDES and MENDONÇA, 2021)

Another factor that must be considered is the type and quantity of photoinitiators present in the composition of the resins, as well as the quality of polymerization of the composite. The photoinitiator most used today is camphorquinone and despite being used in low amounts, there is a great influence on the color of the material because it has a yellowish color that changes to transparent when photoactivated. The composition of the material, the type of photoinitiator system, and the conversion rate of the material play an important role in the stability of the resins, preventing the degradation of the organic matrix and the change in the degree of absorption of the material, thus avoiding color changes in the material. restoration (MOURA, 2021)

Aiming at a greater increase in cavity depth without losing strength at the time of polymerization, bulk fill composite resins transformed the translucency and opacity of their components and also reduced the number of inorganic particles, since the entry of light is directly linked to the portion of particles present. To be able to transform the monomers into polymers, photoinitiators with greater light impregnation are used (KAYA et al., 2018)

Flow-type resin materials are composites with less viscous filler particles, which better adapt to the cavity walls. The vast majority of the material comes in syringes that facilitate its distribution in small preparations that would be difficult to fill. These materials have the advantage of their penetration in every irregularity, forming layers with minimum thickness, improving or even eliminating air bubbles, and also presenting high flexibility, opacity, and availability in different colors. However, some of the disadvantages of this material are the high polymerization contractions due to the smaller amount of filler particles, causing its mechanical properties to be reduced. Filling using bulk fill flow resins has the disadvantage of incomplete polymerization, maintaining a significant residual portion of the dimethacrylate monomer in the polymerized resin composite. The reduced filler content increases the capacity of polishing, however, its resistance to surface degradation is reduced, being a material indicated for low-stress areas or conservative occlusal restorations. (ROCHA, 2018)

UNICHROMATIC RESINS

Color is an element of great importance for aesthetic restorations, and exerts a great influence on the final result of the restorations. For this reason, dentists have resorted to the use of different types of composite resin in the same procedure, to achieve the color and aesthetics as similar as possible to natural dental elements. (CARVALHO, 2021)

The companies Tokoyama (OMNICHROMA) and FGM (Vittra Unique) have developed composite resins that aim to optimize these restorative treatments, using only one resin throughout the restoration process. This way, clinical time is reduced, and the risk of error in color selection is excluded, as these materials still have good polishing and good flexural strength. These chromatic mirroring resins, with the chameleon effect, can copy the color of the dental substrate right after its light cure. It is a versatile material that can be used in all grades of Black and can restore colors from A1 to D4 on the

Vita Classical scale, excluding the need for layering, reducing working time, and reducing the number of resins used in dental offices. (CARVALHO, 2021)

The intelligent chromatic technology in Omnichroma was debuted by Tokuyama Dental America, where the material uses spherical filler of uniformly sized particles. Omnichroma fillings change the light that is transmitted along the red to the yellow area of the color spectrum, matching the patient's adjacent teeth color. (ELIEZER, 2020). Omnichroma resin is a state-of-the-art composite material with fillers that change the way light beam is transmitted, allowing a single-color increment of material to virtually match all teeth. It is the first restorative material, made from a composite resin that matches any tooth, of any color. (CARVALHO, 2021)

TECHNOLOGICAL TRENDS

The development of new dental materials is linked to the reduction of clinical chair-time, seeking to simplify the technique used. In recent years, restorative composites called self-adhesive composite resins have emerged. The purpose of self-adhesive resins is that the steps of acid conditioning, acid washing, drying of the substrate, application of the adhesive system, and insertion of the resin are carried out simultaneously. This fact can be very useful in care, especially in pediatric dentistry or patients with special needs due to the significant reduction in steps. (NAKATO et al., 2017).

Recently, self-adhesive and flowable composite resins are gaining popularity because of their simplified application technique. With their application technique, they can be used in the repair of defective composite resin restorations without the need to replace the entire restoration, which could lead to a greater wear to the dental element. (SISMANOGLU, 2019). Additionaly, resin coating technique has been used since the early 1990s in an effort to improve the dentin bond strength of resin cement and internal adaptation of indirect restoration1). The use of resin coating also facilitates the cementation process and reduces the postoperative sensibility, since the dentin sealing and hybridization are achieved immediately after cavity preparation (Giannini et al., 2015).

All self-curing materials sold to date are of the flow type. However, several studies show that the bonding of self-adhesive resins is still inferior compared to the separate use of the adhesive system and conventional resins. This has been attributed to the fact that the acidity of the monomers in self-adhesive materials is not low enough to promote extensive penetration of the resin through the tooth surface and that the viscosity presented by its fluid material is not yet low enough to guarantee an adequate adaptation to cavity walls (FUGOLIN and PFEIFER, 2017)

Another current field of research is on self-healing materials, which are capable of restoring mechanical integrity after the damage has occurred. Recovery is not always complete, but they allow for the extension of restorations. Early attempts to develop self-healing composites using a microcapsule approach resulted in a material with a significant recovery of fracture toughness, however, there are still concerns about its biocompatibility (MOREIRA et al., 2022)

CONCLUSION

The use of nanotechnology increased the durability of restorations, making them more aesthetic and with improved physical-mechanical strength.

Materials with different viscosity for each specific case and unique increments with bulk fill resins can lead to the reduction of clinical chair-time, also research is focused on unichromatic resins and self-healing materials.

The self-adhesive resins (under study) still have room for improvement in their performance, which will result in a significant decrease in steps as well as self-healing materials that can increase the life of restorations.

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