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CLASSIFICATION OF FILLING MATERIALS

Abstract

After a brief review of current restorative materials and classifications, this article discusses the latest developments in polymer-based direct filling materials, with emphasis on products and studies available in the last 10 years. This will include the more recent bulk-fill composites and self-adhesive materials, for which clinical evidence of success, albeit somewhat limited, is already available. The article will also introduce the latest cutting edge research topics on new materials for composite restorations, and an outlook for the future of how those may help improve the service-life of dental composite restorations.

Keywords: *dental composites, polymerization, clinical longevity, caries*

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Plomb materiallarının təsnifatı

Xülasə

Mövcud bərpaedici materiallar və təsnifatların qısa nəzərdən keçirilməsindən sonra, bu məqalədə son 10 ildə mövcud olan məhsullara və tədqiqatlara diqqət yetirilməklə, polimer əsaslı birbaşa doldurma materiallarında ən son inkişaflar müzakirə olunur. Bura, bir qədər məhdud olsa da, müvəffəqiyyətin klinik sübutları artıq mövcud olan daha yeni toplu doldurucu kompozitlər və öz-özünə yapışan materiallar daxildir. Məqalədə həmçinin kompozit bərpalar üçün yeni materiallara dair ən son tədqiqat mövzuları təqdim ediləcək və onların diş kompozit bərpalarının xidmət müddətini yaxşılaşdırmağa necə kömək edə biləcəyi ilə bağlı gələcəyə baxış təqdim ediləcək.

Açar sözlər: *dental kompozitlər, polimerləşmə, klinik davamlılıq, kariyes*

Introduction

More recently, especially in the last 15 years or so, the technological advances have focused on the organic matrix, with a heavy emphasis on producing low-shrinkage and low stress materials. The rationale is that polymerization shrinkage and the consequent stress that develops at the tooth-restoration interface produces gaps, which in turn, make the restoration more prone to recurrent decay (Gianordoli-Neto, Padovani, Mondelli, De Lima Navarro, Mendonça, Santiago, 306-310).

This premise has been challenged in the past few years, especially because materials that have been shown to present low shrinkage/stress in in vitro testing were not able to outperform so-called conventional materials in clinical trials (Pfeifer, Ferracane, Sakaguchi, Braga, 2008: 87). More recent advances include bulk-fill composites and materials claiming to be self-adhesive to the tooth, with the main goal of simplifying the technique-sensitive restorative procedure to avoid inherent operative errors. As it stands, composite restorations present an average life span of about 10 years or less, with the main reasons for failure being secondary caries and fracture (Baracco, Fuentes, Ceballos, 2016: 991-1001). Therefore, even with the tremendous advances made in the recent past, there is still room for improvement.

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Micro-hybrid composites were then developed. Together with nano-hybrid materials, they comprise the most abundant categories of composite currently on the market. These materials have also been extensively characterized in the literature, both in in vitro and clinical studies (Beck, Lettner, Graf, Bitriol, Dumitrescu, Bauer, Moritz, Schedle, 2015: 31). They are considered to be universal composites, recommended for use in anterior and posterior restorations. In vitro studies comparing the mechanical properties of micro- and nano-hybrid composites to those of hybrids and midifills concluded that, as general categories, and because of the great variations among different commercial brands, there is no difference between micro- and nano-hybrid materials (Kaizer, De Oliveira-Ogliari, Cenci, Opdam, Moraes, 2014: 30). However, in terms of polishability and long-term gloss retention, micro and nano-hybrids have demonstrated far superior performance both in vitro (Kakaboura, Fragouli, Rahiotis, Silikas, 2007: 155-163) and in clinical studies (Rode, De Freitas, Lloret, Powell, Turbino, 2009: 87-92) compared to their predecessors. In general, their clinical performance is excellent with some examples of up to 10-year follow-up studies showing failure rates of less than 3% (Beun, Glorieux, Devaux, Vreven, Leloup, 2007: 51-59). It is noteworthy that the differences between micro and nano-hybrid materials are in fact very subtle. Because of the size distribution of particles, as shown in Table 1, the overall particle size is very similar for the two categories.

True nanofill composites contain filler particles with the smallest size available to date, ranging from 5-100 nm. These materials do not contain additional glass particles that exceed the nanoscale i.e. greater than 100 nm. Their obvious advantage is the excellent esthetic made possible by the fact that the dentist can obtain highly polished surfaces, which can retain their gloss even after long-term use. Different manufacturers rely on different strategies to decrease the filler size and still keep the overall filler loading high, such as the clustering of nanoparticles via water dispersion and spray drying (Filtek Supreme, 3M-ESPE). Other nanohybrids have used different approaches to achieve low overall average particle size but high filler fraction, such as the use of pre-polymerized composite particles re-dispersed in the matrix (such as in Tetric Evo-Ceram – Ivoclar-Vivadent), or the solvent-driven dispersion of particles in the matrix, followed by atomization and pre-polymerization (CeramX, Dentsply-Sirona). One study has indeed demonstrated color stability and gloss retention for several nano-hybrid and nanofill materials after simulated clinical conditions (Hamid, Esawi, Sami, Elsalawy: 2008). A comprehensive literature review of in vitro studies, however, concluded that nanofill composites were no better than microhybrids in terms of surface smoothness and/or gloss, before and after surface challenges (Cetin, Unlu, Cobanoglu, 2013: 38). Nanofills have also been demonstrated to behave very similarly in vitro to nano and micro-hybrids, both in terms of mechanical properties and depth of cure (Boaro, Gonalves, Guimarães, Ferracane, Versluis, Braga, 2010: 26). Clinical studies with follow up times of up to 5 years have demonstrated an annual failure rate for nano filled composites of less than 3%, deeming these materials clinically acceptable and within the range of survival of micro and nano-hybrid materials.

While the evolution of fillers improved the wear and fracture characteristics of dental composites, most of the development in the organic matrix in the last 10–20 years has been dedicated to producing low-shrinking materials. It has long been demonstrated that the composite polymerization shrinkage that takes place, when confined by the adhesion to the relatively rigid cavity walls, leads to stress development at the tooth-restoration interface.

With that in mind, manufacturers developed new products based on a few different shrinkage and/or stress reduction strategies. Some products rely on the use of monomers of higher molecular weight compared to the conventional BisGMA/TEGDMA mixtures. Larger monomers lead to less shrinkage because of the lower concentration of reactive functional groups (C=C) per unit volume. This is the same rationale for why the inclusion of pre-polymerized additives reduce shrinkage and stress, as has been recently demonstrated with nanogels in experimental dental composites.

This is because the stress, apart from the shrinkage, also depends on the final degree of conversion and elastic modulus of the composite, so comparisons among commercial brands is often difficult. In general terms, the stress increases for higher shrinkage, higher conversion and higher stiffness materials. When experimental materials are used, under controlled conditions (geometry, photoactivation protocol) and known composition, those relationships are usually straightforward. However, for commercial materials, it is impossible to control all the variables simultaneously, because of the differences in type and concentration of initiators, type and concentrations of monomer species, filler type, etc. For example, one study demonstrated that the ring-opening-based material produced the lowest shrinkage while showing one of the highest elastic moduli among the materials tested, including the conventional control. Interestingly, the stress values for that material were actually higher than the conventional control, likely due to the high modulus, and in spite of the lower shrinkage. Other composites showed lower stress than the control in that study, with comparable modulus, which is an encouraging result. This demonstrates the complexity of the polymerization stress issue in commercial materials, even in controlled, in vitro studies, where biological factors such as the biofilm and complex occlusal loading do not come into play.

Still, the subject of polymerization stress continues to be investigated. More recently, materials capable of directly reducing stress have been introduced. Examples range from thiol-ene-methacrylate formulations to covalent adaptable networks. In the case of thiolene methacrylates, the presence of thiols leads to delay at the point in conversion when gelation and vitrification take place, i.e the point where the liquid resin polymerizes sufficiently to form a network with substantial rigidity. By delaying gelation, the impact of stresses is reduced, because they do not reach a high level until the network is mostly formed, and therefore, the overall stress is drastically reduced. There are currently no commercial materials based on this technology, though it has been licensed by dental companies.

Conclusion

Until such time in the future when regenerative therapies have completely evolved to the point that damaged dental tissues or the entire tooth can be regenerated, direct and indirect restorations will to continue to be a very important part of the clinician's armamentarium to repair the damage resulting from dental caries. Among direct restorative materials, dental composites will continue to replace amalgams, due to esthetic demands. The past couple of decades have seen an enormous amount of progress in terms of enhancing filler and organic matrix composition, with the result being that the average life span of a composite restoration has increased significantly compared to what was expected when they were first introduced. However, as clinicians improve their techniques and researchers fine tune the composition of materials, more and more focus will likely be placed on the interaction of the material itself with its surroundings, including the mineralized tooth and soft periodontal tissues and the environment as a whole, including bacteria and components of the saliva. In other words, producing materials that can not only generate less interfacial stress and withstand the occlusal loading, but also that can resist chemical and biological degradation, will be the focus of future dental composite research. Significant efforts are currently underway to produce materials that are better able to resist enzymatic degradation, focusing on the elimination of ester-containing methacrylate monomers. In addition, materials with self-healing capabilities are also being studied. On the more biological side, re-mineralizing and antibacterial composites have been investigated for several years, and are getting closer to being commercially viable. Ultimately, the goal is to produce materials that are easier to use, and therefore are less technique-sensitive, and that will produce robust, long-lasting restorations. This will reduce costly replacements and will significantly advance oral health.

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