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Review Article

Polymer-Infiltrated-Ceramic-Network the Evolution of CAD/CAM Materials

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Abstract

The development of dental materials during the last few years is related to many factors, such as patient aesthetics requirements and also the increase in usage of CAD/CAM technology. The literature review shows the most used classes of indirect restorative materials and it demonstrates how the evolution of metal-free materials has reached a new level. Research combined with manufacturing technology is focusing in creating a material with similarities to a natural tooth. However, some clinical aspects must be considered such as patient requirements, clinical cost, clinical performance, manufacturing process, developing procedure, and disposal concerns. It is clear that progress has been made in this field, with fracture load rate of different materials similar to each other. Nevertheless, the survival rate achieved is not yet enough to say that polymer-infiltrated-ceramic-networks are compatible with all-ceramic crowns.

Keywords: *Ceramic; CAD/CAM; Hybrid Materials; Composite Resin; Polymers; PICN*

Review of Literature

Currently, four classes of indirect placement restorative materials have been extensive studied/documented: metal, porcelain-fused-to-metal (PFM), all-ceramic, and indirect composite. Metal and PFM are a great class of materials; however, the increase of aesthetics requirement has attenuated the usage by clinicians [1]. Each of these materials has their advantages and disadvantages. In order to obtain the best clinical performance from each one, clinicians must be inward with clinical techniques, knowledge of mechanical properties, and microstructural characterization [2]. This knowledge will lead to an ideal choice of materials regardless of the treatment, as well as better understanding of the behavior of the materials employed in restorative dentistry.

The beginning of ceramic usage in dentistry is dated from 1889, and it was known as "jacket" crown [3]. After some improvements, this material was extensively used until the 50s. However, some major concerns still remain, such as internal microcracks related with the cooling phase of the fabrication, which has resulted in a decline of its usage. Thus, to reduce the risk of internal cracks, the porcelain fused to metal (PFM) was created, so the metal infrastructure reinforces the internal part of the crown preventing the occurrence of microcracks. Yet, ceramic brittleness is still a challenge today, and it has inherent characteristics that require high handle abilities from the laboratory process to the clinical trial and cementing process.

Clinical investigations made in the past show that pure ceramic crowns have excellent aesthetic properties, such as great color stability, high biocompatibility, and high strength [4,5]. Furthermore, during the last decade the development of dental technology has contributed to the development of new techniques and new materials [1,6]. The great increase in use of computer-aided-design/computer-aided-manufacturing (CAD/CAM), has created new possibilities in dental treatments. CAD/CAM technology has shortened some ceramic fabrication process time by up to 90% [4]. So, as a result of the collaboration between researchers and manufacturing companies, the development of novel dental esthetic materials for indirect placement has occurred, named polymer-infiltrated-ceramic-network (hybrid or PICN).

Direct composite resin consists of monomers and co-monomers like Bis-GMA, UDMA, UTMA, TEGDMA, and Bis-EMA, which are responsible for dimensional changes like shrinkage. Nevertheless, they are necessary to allow incorporation of the inorganic filler [7]. Composite resin materials have their mechanical properties increased by the filler particles [8]. Inorganic filler components reinforce the structure and are related with composite hardness as well as some optical characteristics, and are almost silica-based particles in all [2]. However, low mechanical properties and inadequate wear resistance compromise them [1]. The first composite block for CAD/CAM application was launched around the year 2000, and it was first polymerized by light activation using manufacturing processes. This was the first step in the development of the hybrid CAD/CAM materials, similar to lab indirect composites. Furthermore, the hybrid has a dominant ceramic network and a minor polymer phase interconnected. One of its great advantages is that all the polymerization process occurs outside the mouth. These processes make it possible to eliminate all the major problems related with composite resin degree of conversion, besides improving all mechanical properties of polymer-infiltrated-ceramic-network materials.

Discussion

What should an ideal indirect restorative material be like, in terms of clinical characteristics? Fracture resistance, ease of clinical use, great clinical performance are clinical aspects that must be considered. However, before being ready to use, a new material should have more relevant characteristics, such as patient requirements, clinical cost, clinical performance, manufacturing process, developing procedure, and disposal concerns [9]. The CAD/CAM technology demands a huge initial investment from dentists; however, it is an investment that pays off in the long run. New technology that enhances dental procedures should be capable to incorporate these relevant details.

The replacement of a natural tooth by any type of restorative materials is still time limited, that is, it must be replaced sometime in the future [10]. The development of a material with similar mechanical behavior to enamel and dentin has always been the goal for dental restorative material scientists. Different laboratory equipment has been used to study the new features of dental ceramics and hybrid materials; these tools are useful to determine topography information and microstructural characterization, such as particle size and shape [2]. Those parameters constitute the first step to understand the clinical behaviors of the materials that are used in restorative dentistry [2]. Since dental ceramics are brittle materials, some mechanical properties have been combined to better understand clinical performance with the aim of avoiding crack propagation and premature failure. The majority of dental ceramics are based on silicon, in the form of silica4; likewise, the filler particles of CAD/CAM hybrid materials are mostly silica.

Polymer-infiltrated-ceramic-network has similarities with a ceramic interpenetrating material, which was introduced in dentistry more than twenty years ago. The interpenetrating ceramics are based on a porous aluminum-oxide suspension with lanthanum glass powder specifically for this use [10,11]. The glass powder of fine particles is mixed with distilled water to obtain a mass of fluid consistency to be applied to the porous aluminum-oxide base previously sintered. The infiltration of the glass phase will occur by capillary action, throughout the interior of the pore structure [11]. Furthermore, the set must be put inside the oven to finish the cycle of glass infiltration. Some advantages of the aluminum-oxide ceramic are wear resistance, high temperature strength, and increase of fracture toughness [10].

The first researches started with interpenetrating phase composites (IPC) almost two decades ago. These materials had considerable attention for their potential for structural applications. IPC has a multiphase structure where each phase is topologically interconnected across the microstructure [12]. The challenge to manufacture IPC materials starts with processing two different materials. The second phase must penetrate the first phase, which is supposed to be a ceramic network. However, after both phases move across each other, they should not form a homogenous material matrix. In the beginning, only impure concentrations of a second phase could be incorporated. The development in increasing the volume fraction of the second phase has raised the chances of intentionally producing composite materials in which individual phases are continuous and go across the microstructure. The capability of manufacturing three-dimensional microstructure creates the possibility to make new materials with multifunctional characteristics [13]. Furthermore, the literature suggests that IPC have better mechanical properties [10,13,14].

In terms of mechanical behavior, the ideal restorative material would be similar to dental hard tissues, which include enamel and pulp-dentin complex. Enamel consists of approximately 96% hydroxyapatite, 3% water, and 1% protein content by weight [15]. Moreover, with highly anisotropic stiffness characteristics, it has a great wear resistance. However, it is weak and brittle without the presence of dentin. The enamel load path is directed into the dentin, and the loading follows the enamel prisms direction [16]. On the other hand, dentin, the major hard tissue of the tooth, is composed of approximately 45% inorganic, 35% organic, and 20% water content by volume [17]. Dentin has a completely different behavior and acts with considerably lower stiffness than enamel, absorbing the loading and dissipating it along the collagen.

When ceramics as well as polymer crowns are cemented onto the tooth structure, many factors contribute to the success of the procedure, such as crown preparation design, type of resin cement, material thickness, and dentin surface conditioning (i.e. bonding procedure). These aspects may enhance the retention and also the longevity of definitive metal-free restorations [18]. Due to the fact that all-ceramic crowns have an elevated cost, polymer crowns have been proposed with acceptable esthetics [19,20]; and clinical studies have been made, with great survival rate between 87 - 96% after 3 years [21,22]. The development around the mechanical properties of composite resin-based materials called now as polymer-infiltrated-ceramic-network, is due to advances made through manufacturing and CAD/CAM technology, allowing ceramic networks containing leucite as the primary oxide and zirconia as a minor phase interconnected with a polymer-based network. The volume varies between 70 - 75% and its weight is 85 - 92% of filler contents [2,19].

CAD/CAM enhances the process of manufacturing PICN restorations by eliminating the common internal defects (i.e. voids) from manual build-up technique, which results in decreased strength. Furthermore, hybrid composite crowns have shown similar fracture resistance to lithium disilicate crowns [19]. The fact that there are similar results between two different materials when under loading could be associated with the modulus of elasticity and Poisson's ratio. When in function, hybrid composite and the die material works as one single element, on the other hand, lithium disilicate has a higher modulus, so according to researchs [19,23,24] an elastic die could lower the fracture loading of all-ceramic crowns. It is definitely possible that the same occurs in natural teeth, since composite dies have similar modulus of elasticity and Poisson's ratio to healthy dentin [25].

Conclusions

Despite the fact that flexural properties of polymer-based materials are lower than lithium disilicate crowns, showing properties between ceramics and highly filled composites, the literature assures that PICN materials could be used in pre-molar and molar region with safety and fracture resistance similar to all-ceramic crowns.

Conflict of Interest

There is not conflict of interest among the authors included in this review article.

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