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CERAMIC MATERIALS IN IMPLANTOLOGY

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Abstract: In addition to restoring function, after restoring a lost tooth, it is essential to plan the return of aesthetics to the patient. The development of ceramic materials for use in dentistry, both on remaining dental structure and on implants, has enabled improvements in aesthetic results, since ceramics allow greater mimicry of the nuances of a natural tooth. The objective of this study was to present concepts and applications of ceramic materials in implantology, based on a literature review through electronic research. Ceramics can be classified as vitreous and non-vitreous, which is directly linked to the physical and chemical characteristics of each material, and these properties will determine the resistance to fracture and its aesthetic characteristics. Therefore, knowing the nature of each type of ceramic will affect the correct selection of the material to be used in rehabilitation. Ceramics can be used in implantology in all its elements, including: implant, abutment and crown. The research conducted concluded that vitreous crowns stand out for their aesthetic results, but they are very brittle, which limits their use in areas of high stress. Non-vitreous crowns, on the other hand, have excellent mechanical properties but leave something to be desired in terms of aesthetic qualities. Therefore, the combination of the two types of ceramics can provide resistance and aesthetics at the same time. Ceramic abutments have emerged as a viable alternative for the rehabilitation of patients with thin gingival profiles, and zirconia implants have favorable biocompatibility and osseointegration for their clinical use.

Keywords: Ceramic crown, zirconia, ceramic implant, implantology.

INTRODUCTION

The loss of a tooth leads to changes in masticatory function and social and psychological disorders. Advances in dentistry have enabled the development of techniques that offer mutilated patients the option of total or partial rehabilitation through implant-supported prostheses (ISPs), which have been increasingly used to replace the old removable prostheses (AZEVEDO et al., 2008).

In addition to restoring function, after rehabilitating a lost tooth, it is essential to plan how to restore the patient's aesthetics. The development of ceramic materials for use in dentistry, both on remaining dental structure and on implants, has enabled improvements in aesthetic results, since ceramics allow greater mimicry of the nuances of a natural tooth (MARQUES, 2017). Currently, to achieve the ideal aesthetic in the anterior region, a combination of ceramic crowns with ceramic abutments can be used, obtaining better translucency (BORGES, 2013). In addition to the crown and abutments, implants themselves can be made of ceramic materials, and have emerged as an alternative to metal implants, mainly due to their aesthetic characteristics and integration with peri-implant tissues (HOCHSCHEIDT et al., 2014).

Due to the large number of types of dental ceramics available on the market, it is important for professionals to know the characteristics, composition and indications of each one, in order to use them with greater safety (GARCIA et al., 2011).

By knowing the importance of understanding the progress of materials technology in dentistry and analyzing its viability as a promising technique, the aim of this study was to present concepts and applications of ceramic materials in implantology, based on a literature review through electronic research.

LITERATURE REVIEW

CONCEPTS AND BRIEF HISTORY

Achieving the aesthetic ideal in the anterior region is a major challenge for implantology (BORGES, 2013). In this sense, dentistry throughout its history has developed a wide range of restorative and rehabilitative materials, and within this context, ceramics have emerged as an excellent alternative and applicability in rehabilitations, and their clinical use has been established due to the numerous properties necessary for the artificial replacement of a lost natural tooth (GARCIA et al., 2011).

The initial record of the use of ceramics as a dental material dates back to 1774, in the manufacture of teeth for a complete denture, developed by the French apothecary Alexis Duchateau and the dentist Nicholas Dubois Chémant. In England, Chémant refined its formulation in collaboration with Josiah Wedgewood to improve translucency using a formula rich in feldspar (KELLY; BENETTI, 2011). Subsequently, new ways of handling ceramics emerged and were patented. The invention of the electric furnace in 1894 and of low-fusion porcelain in 1898 made it possible to create a porcelain crown over a platinum matrix. Thus, in 1903, Charles Land introduced a resistant porcelain crown with aesthetic properties to the market, effectively introducing ceramics into restorative dentistry (CHIARADIA, 2013).

Several advantages make ceramics a widely used material in dentistry, such as wear resistance, excellent aesthetics, low density, high hardness and chemical stability (DELLA BONA; MECHOLSKY JR; ANUSAVICE, 2004; GARCIA et al., 2011). Ceramics are inorganic materials and can be composed of metallic particles and non-metallic substances and characterized by two phases: a crystalline phase and a vitreous phase (CHIARÁDIA, 2013; MARQUES, 2017). The glass matrix consists of a basic chain of silicon oxide (SiO_4), and is closely related to viscosity and thermal expansion, while the amount and nature of the crystalline phase determine the mechanical and optical properties of the ceramic (RAPOSO et al., 2014).

The first ceramics for dental use were composed of feldspar, which, when associated with platinum sheets, gave rise to metal-ceramic crowns. Pure feldspathic porcelain crowns were used for a long time; however, their hardness and low tensile and flexural strength limited their indication for regions of low occlusal stress (AMOROSO et al., 2012). In order to expand the use of pure porcelain, alternatives for strengthening conventional ceramic structures have been researched through the inclusion of elements and substances, especially some oxides, whose purpose is to reduce the risk of fractures and minimize other failures, without the need for the use of metal substructures (KINA, 2005 apud CHIARÁDIA, 2013).

The correct choice of a ceramic system for each type of clinical case will directly influence the greater longevity and success of the treatment. Although all systems can provide good results, for rehabilitation in anterior regions some ceramics are more indicated than others due to the requirement for greater translucency and aesthetic gain (GARCIA et al., 2011).

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COMPOSITION

GLAZED CERAMICS

Feldspar ceramics, also known as conventional or traditional ceramics, were pioneers in dentistry and are obtained fundamentally by combining potassium or sodium feldspar and quartz, heated to high temperatures (around 1200 - 1250°C), decomposing the feldspar into an amorphous glassy phase and a crystalline phase composed of leucite. Alumina and other metal oxides, such as iron or nickel oxide (brown), copper oxide (green), titanium oxide (amber), manganese oxide (lavender), cobalt oxide (blue) and zirconium or tin oxide (opaque) are added to pigment and mimic the different shades of natural teeth. Although this material presents excellent aesthetic quality, it shows low fracture resistance (CHIARÁDIA, 2013). In order to improve the strength of feldspathic ceramics, the ceramics were reinforced with leucite, but they still presented a flexural strength of 90 to 180 MPa, which does not greatly expand their indications (AMOROSO et al., 2012).

Feldspathic ceramics reinforced with leucite consist of approximately 40 to 50% leucite crystals, inserted in the feldspathic glass matrix, to prevent the proliferation of microfractures and reduce friability (ROMÃO; OLIVEIRA, 2007). The incorporation of lithium disilicate particles into feldspathic ceramics benefited the mechanical properties while ensuring the optical properties, presenting approximately 400 MPa of flexural strength (AMOROSO et al, 2012). Lithium disilicate ceramics, in addition to being indicated for inlays, onlays, single crowns and veneers, are now recommended for fixed prostheses of up to three elements (RAPOSO et al., 2014).

NON-VITREOUS CERAMICS

Aluminized ceramics were created to provide twice the fracture resistance when compared to conventional feldspathic ceramics. It is composed of 50% alumina oxide, which on the one hand improved flexural strength, but lost translucency, since the alumina crystals restrict the passage of light. This gain in resistance due to the incorporation of alumina was not yet sufficient to indicate this ceramic for all rehabilitation processes, restricting its application to three-element prostheses in the anterior region and the manufacture of ceramic cores (AMOROSO et al., 2012).

Oxide-reinforced ceramics have high resistance, however, due to their high opacity, the aesthetic aspects are compromised, and for this reason they are indicated for the manufacture of infrastructure and copings, darkened substrates or over metal cores. To overcome the opacity, the external covering can be made of vitreous porcelain (FARIAS; VASCONCELOS; VASCONCELOS, 2022).

Alumina-based ceramics consist of an 85% alumina crystalline phase, which gives them high density with good flexural strength values (LAZAR et al., 2004). Alumina has a fracture resistance > 500 MPa, 4 MPa/m0.5 of toughness (degree of deformation without rupture) and 380 GPa of Young's modulus (elasticity) (PICONI; MACCAURO, 1999).

Zirconia is a biocompatible non-vitreous ceramic that allows the gingival tissues to adapt to the crown in a more natural way, and does not produce hypersensitivity reactions (LAZAR et al., 2004; BISPO, 2017). Zirconia has a fracture resistance: 900-1200 MPa, 7-10 $MPa/m^{0,5}$ of tenacity (degree of deformation without rupture) and 210 GPa of Young's modulus (elasticity) (PICONI; MACCAURO, 1999). It is considered one of the best options for prosthetic reconstructions (BISPO, 2017).

LABORATORY MANUFACTURING PROCEDURES

Ceramics can also be classified according to the processing method used to obtain them: stratified (conventional), pressed, cast, CAD/CAM (Computer Assisted Design/ Computer Assisted Machine) and infiltrated ceramics. Regarding the presentation form, they can be found in the form of powder, tablet or block (PAGANI; MIRANDA; BOTTINO, 2003). Conventional ceramics are presented in the form of powder, which is added to an appropriate vehicle and sculpted. Cast ceramics consist of solid bars, which employ the lost wax and centrifugal casting technique to make crowns. Pressed ceramics are presented in the form of solid blocks, are cast at high temperatures and pressed into molds. Computerized ceramics are made from the machining of ceramic blocks using a computerized system (CAD-CAM). Infiltrated ceramics are composed of two components: a porous substrate, and a glass, which is infiltrated into the substrate at high temperature (PAGANI; MIRANDA; BOTTINO, 2003).

USE OF CERAMICS IN IMPLANT DENTISTRY

CERAMIC ABUTMENTS

Prosthetic pillars, also known as abutments, are usually made of titanium and other metals, and their use is well-established in the literature. However, the grayish color of the metals can cause an unsightly appearance, since in thin gingival biotypes and/or in cases of peri-implant recession, part of the pillar may be exposed, causing an unpleasant effect. Within this context, ceramic abutments emerged, usually made of zirconia or alumina, isolated or combined, which provide biocompatibility with peri-implant tissues, adequate optical properties, and aesthetic longevity (FIG. 1) (SALLENAVE; VICARI; BORBA, 2016). One of the main indications for the use of ceramic pillars is their use in patients with thin gingival biotypes (<2 mm thick), thus achieving a good mucogingival aesthetic result (KOHAL et al., 2008).

Figure 1: Zirconia abutment

Source: Adapted from Google Images, 2022.

Ceramic abutments can be prefabricated or customized. Polycrystalline alumina ceramic abutments are materials that are practically inert under physiological conditions and are resistant; they present favorable characteristics such as hardness, flexural strength, excellent surface finish, good optical properties and low thermal conductivity. When performing the individualization of alumina abutments, caution is required during wear to correct the angulation, since excessive reduction can weaken the axial walls and cause fracture (SALLENAVE; VICARI; BORBA, 2016). The possibility of customizing customizable alumina abutments allows for modification of the color and contour in the cervical region, through the application of sintered coatings, establishing a harmonious and more natural emergence profile (PRESTIPINO; INGBER, 1996).

Polycrystalline zirconia abutments are more resistant to fracture when compared to alumina abutments, which favors the individualization of the abutment through reduction (wear). On the other hand, the aesthetics are inferior (SALLENAVE; VICARI; BORBA, 2016). Due to its radiopacity, the zirconia abutment allows good visualization in radiographic examinations, whereas alumina already presents this characteristic in a reduced form, which makes it difficult to check the positioning of the abutment. Despite the inherent advantages of zirconia abutments, they have a higher cost and unfavorable optical attributes (BORGES, 2013).

CERAMIC IMPLANTS

Osseointegration has been confirmed in several studies through the detection of mature bone formed on the surface of ceramic implants (HAFEZEQORAN; KOODARYAN, 2017), remembering that osseointegration is understood as the fixation of the implant to the bone with intimate contact between living bone tissue and the surface of the implant without interposition of connective tissue (BRÅNEMARK et al., 1983).

The physical properties of alumina comprise an alumina particle density of approximately: 4 g/cm^3, Vickers hardness of 2300, compressive strength of 4400 MPa, flexural strength > 500MPa, and a toughness of 4 MPam ^{0,5}. Alumina is a friable material, and this is due to its high hardness and modulus of elasticity, combined with its relatively low flexural strength and toughness, and as a consequence, this material is prone to fracture when unfavorably loaded. The risk of fracture probably discouraged the market in relation to alumina implants, causing them to fall into disuse (ANDREIOTELLI; WENZ; KOHAL, 2009).

Recently, the material of choice for ceramic implants is zirconia y-TZP, which compared to alumina, has a flexural strength of 900 - 1200 MPa), an elastic modulus of around 200 GPa and greater fracture toughness. (7–10 MPam^{0,5}). Experiments testing the osseointegration and biocompatibility of y-TZP implants have shown promising results (ANDREIOTELLI; WENZ; KOHAL, 2009).

As a chemically inert material, y-TZP has low affinity for biofilm, good cell adhesion, excellent tissue response and biocompatibility with bone and soft tissues (CALVO, 2018). Nowadays, the most widely used ceramic material in endosseous implants is zirconia, as its physical and chemical characteristics make it attractive for Implantology (FIG. 2) (LANÇA, 2011).

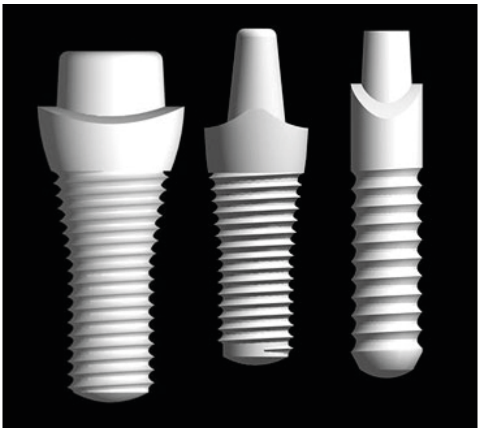

Figure 2: Zirconia implant.

Source: Adapted from Google Images, 2022.

CERAMIC CROWN

Crowns used in implant-supported prostheses can be screwed or cemented, and each of them has intrinsic advantages and disadvantages. A possible disadvantage of screwed crowns is linked to the discontinuity of the ceramic in the region of the screw hole, making it more friable (VILAS BOAS, 2013).

The definitive crown of an implant-supported prosthesis can be made of various materials, such as lithium disilicate, metal-ceramic, zirconia, etc. (FIG. 3). Metal-ceramic crowns remain popular in oral rehabilitation, and one of their indications is in implant-supported prostheses. Research indicates high success rates for metal-ceramic crowns (ARAMBURU, 2017).

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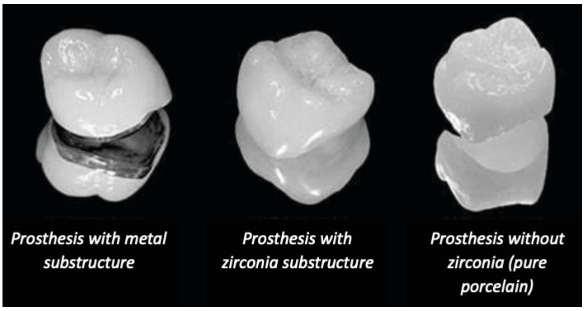

Figure 3: Metal-ceramic crowns, with zirconia substructure, and metal free.

Source: Adapted from Google Images, 2022.

The metals that make up metal alloys can be basic (Ni, Cu, Zn, Sn) or noble (Pd, Au, Pt). The physical properties depend heavily on the design of the substructure that supports the ceramic coating. The flexural strength of single implants with metal-ceramic crowns is greater than that of metal-free crowns. Implants with metal-ceramic crowns can achieve success rates of over 96% in 5-year periods (ARAMBURU, 2017).

One of the indications for lithium disilicate-reinforced ceramics machined by the CAD/CAM system is the production of implant-supported restorations. (CARVALHO, 2014).

Zirconium crowns are used in implantology, but their indication has some limitations. For implant-supported zirconia crowns, monolithic crowns are recommended, as they have greater fracture resistance. However, they are very rigid and have high wear resistance, which induces wear on the opposing teeth. Another disadvantage of the zirconia crown is the low quality of important essential optical effects, color and translucency. Zirconia crowns are commonly coated with vitreous porcelain, and chipping of the coating porcelain often occurs (HAN; ZHAO; SHEN, 2017).

DISCUSSION

The CHO et al. (2002) studied the resistance of milled ceramic abutments and metal-free crowns. The authors compared five crown-abutment combinations in relation to their load-bearing capabilities.

The following combinations, loaded at angles of 0 and 45° to the long axis, were tested: a) metal-ceramic crowns on titanium abutments, b) non-glass ceramic crowns on titanium abutments, c) feldspathic crowns on titanium abutments, d) non-glass ceramic crowns on ceramic abutments, and e) feldspathic crowns on ceramic abutments.

The fracture resistance under vertical loading was higher than under obliquely applied load. Metal-ceramic crowns on titanium abutments obtained higher fracture resistance than metal-free crowns on ceramic abutments. There was no significant difference in the fracture resistance of ceramic crowns in relation to the two types of abutments under oblique loading. The authors concluded that metal-free crowns on milled ceramic abutments were less resistant when compared to metal-ceramic crowns on titanium abutments under oblique loading.

Sallenave, Vicari and Borba (2016) compared, through a systematic review of the literature, the survival rates of ceramic and titanium abutments. After searching databases, 16 clinical research journals and case studies were selected. According to the studies, there was no significant difference in biological and radiographic indices, in addition, no significant bone loss was noted for both abutments (titanium and ceramic). Alumina abutments showed a survival rate of 94.7 to 100%, zirconia abutments showed a survival rate of 97.6 to 100%, and titanium abutments, 100%. The failures detected for the abutments were: screw loosening and fracture. The authors concluded that the similarity in biomechanical behavior between titanium and ceramics makes ceramic abutments a suitable alternative.

Agustín-Panadero et al. (2019) investigated the fracture resistance and failure mode of zirconium oxide (zirconia) abutments placed on dental implants in the anterior region with crowns made of different esthetic materials: zirconia, lithium disilicate, and nanoceramic resin. The sample was divided into four groups: Control group (metal-ceramic crowns on titanium abutments);

Group ZZ: (zirconia crowns and abutment); Group Z-LD (lithium disilicate crowns on zirconia abutments); and Group Z-NCR (nanoceramic resin crowns on zirconia abutments). The evaluation of fracture resistance and the failure mode produced resulted in the following data: In the control group, fracture of the prosthesis fixation screw occurred in 100% of the specimens. In Group ZZ, 80% of the fractures occurred in the fixation screw, 15% in the abutment and 5% in the abutment and crown. In Group Z-LD, 60% of the fractures occurred in the fixation screw and 40% in the abutment. In Group Z-NCR, 70% of the fractures occurred in the fixation screw and 30% in the abutment. The authors concluded that the abutments and crowns evaluated have the potential to withstand physiological occlusal forces. Andreiotelli, Wenz and Kohal (2009) conducted a systematic review to collect data on bone-implant contact (BIC), survival and clinical success rate to indicate whether ceramic implants are a viable alternative to titanium implants.

The sample included 25 screened articles. The review identified histological studies in animals with similar BIC rates for titanium, zirconia and alumina implants. Clinical studies of alumina implants (follow-up up to 10 years) showed survival and success rates ranging from 23 to 98%, while zirconia implants showed a survival rate of 84% after 21 months. There was no statistically significant difference in the osseointegration rate between the implants (titanium, alumina and zirconia) in histological analysis of experiments with animals, however, in cohort studies questionable scientific values were found. The researchers concluded that alumina implants did not perform well and for this reason (according to the study cited), they are not viable when compared to titanium implants. Zirconia implants have an encouraging potential according to the research; however, more clinical investigations are needed before ceramic implants can be recommended as a clinical routine.

Hafezeqoran and Koodaryan (2017), in a systematic review and meta-analysis, compared the BIC of titanium and zirconia implants with different surface topographies. The authors did not detect a significant difference in BIC values between titanium and machined zirconia implants; however, significantly higher BIC values were observed for acid-etched zirconia implants. These results allowed the authors to conclude that, in relation to osseointegration, acid-etched zirconia implants can replace titanium implants.

Pjetursson et al. (2018) conducted a systematic review to analyze the survival and complication rates of implant-supported zirconia and metal-ceramic single crowns. The study included 35 studies, and the meta-analysis indicated an estimated survival rate at five years of 98.3% for metal-ceramic crowns compared with 97.6% for zirconia. Regarding complications, metal-ceramics presented rates of 13.3% and zirconia crowns presented 16.2%. Other results found include: similarity in biological performance for both crowns; fewer aesthetic complications were found in zirconia crowns; the incidence of chipping of the veneering ceramic (in 5 years) was similar for both; failures related to material fracture were more frequent in zirconia crowns, although in small numbers. The authors confirmed that implant-supported zirconia ceramic crowns are a viable alternative to metal-ceramic crowns, with a similar incidence of biological complications and fewer esthetic problems.

Biscaro et al. (2013) evaluated the adaptation of single-tooth ceramic crowns based on zirconium oxide, generated by CAD/CAM, in comparison to metal-ceramic crowns. The authors admitted that ceramic crowns based on zirconium oxide showed a similar and acceptable marginal adjustment when compared to metal-ceramic crowns.

CONCLUSION

The aesthetic appeal of rehabilitation has driven research into the development and improvement of ceramic materials. A wide range of ceramic options are available for use in implantology, including crowns, abutments and implants themselves.

Vitreous crowns stand out for their aesthetic results, but they are very brittle, which limits their use in areas of high stress. On the other hand, non-vitreous crowns have excellent mechanical properties but leave something to be desired in terms of the most refined aesthetic qualities. The combination of the two types of ceramics favors clinical results, since the non-vitreous ceramic substructure covered by vitreous ceramic can provide resistance and aesthetics.

Ceramic abutments have emerged as a viable alternative for the rehabilitation of patients with thin gingival profiles, avoiding the grayish appearance of the mucosa often seen with metal abutments. And for ceramic implants made of zirconia, they present biocompatibility and osseointegration favorable to their clinical indication. Within the limitations of this study, I emphasize that ceramics remain consolidated in implantology, but more studies and long-term monitoring need to be carried out to confirm the advantages of this material over other available materials.

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