DENTAL CERAMICS-A LITERATURE REVIEW

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ABSTRACT

The improvement of the basic properties of dental restorative materials, such as their mechanical, physical, aesthetic, and bonding properties, has been dramatic and the current materials on the market show excellent clinical performance. This review article compiles the characteristics of ceramic dentures materials and the efforts made in order to improve the main features and to point out future perspectives.

Key words: *ceramic material, all ceramic, dental materials.*

INTRODUCTION

In dentistry, ceramics represents one of the four major classes of materials used for the reconstruction of decayed, damaged or missing teeth [1,2]. This article reviews the current literature regarding the all-ceramic materials,

The word Ceramic is derived from the Greek word "keramos", which literally means 'burnt stuff'. The American Ceramic Society had defined ceramics as inorganic, non-metallic materials, which are typically crystalline in nature, and are compounds formed between metallic and nonmetallic elements such as aluminum & oxygen (alumina - Al_2O_3), calcium & oxygen (calcia - CaO), silicon & nitrogen (nitride- Si_3N_4) [3].

Current dental ceramics are far from the early ceramics that started being used over 200 years ago. Early records of the first ceramics used as dental materials date back to 1774, when French apothecary Alexis Duchateau and Parisian dentist Nicholas Dubois de Chemant manufactured the first ceramic denture.

In dentistry, ceramics are widely used for making artificial denture, teeth, crowns, bridges, ceramic posts, abutments, and implants and veneers over metal substructures.

During the last 40 years, research has focused on improving metalfree systems and developing superior materials regarding esthetics and clinical performance to offer patients several alternatives to restore missing or damaged teeth.

Dental ceramics are usually referred to as nonmetallic, inorganic structures primarily containing compounds of oxygen with one or more metallic or semi-metallic elements like aluminum, calcium, lithium, magnesium, phosphorus, potassium, silicon, sodium, zirconium & titaniu..

Ceramics can appear as either crystalline or amorphous solids [1,10] (also called glasses). Thus, ceramics can be broadly classified as non crystalline (Amorphous Solids or glasses) and crystalline ceramics. The mechanical and optical properties of dental ceramics mainly depend on the nature and the amount of crystalline phase present. More the glassy phase more the translucency of ceramics; however, it weakens the structure by decreasing the resistance to crack propagation.

On the other hand, more the crystalline phase better will be the mechanical properties which in turn would alter the aesthetics [3,4,5]. Conventional or feldspathic porcelains are usually non crystalline ceramics. These conventional porcelains are very weak and brittle in nature leading to fracture even under low stresses.

Recent developments in the processing technology of dental ceramics have led to the development of crystalline porcelains with suitable fillers such as alumina, zirconia and hydroxy apatite [6]

Metal- ceramic restorations have been used since 1950's when Brecker described a method of baking porcelain onto gold. The original metal-ceramic crowns have undergone several refinements to develop crowns with adequate strength and reasonable aesthetics. The extent of tooth preparation and considerations of aesthetic and of allergy to nickel has led to the emergence of a variety of metal-free restorations (Barnfather and Brunton 2007)[8].

According to Hickel and Manhart (2001) ceramic materials such as spinel, alumina, and glass- ceramic reinforced with lithium disilicate have been used for the construction of metal-free restorations. The introduction of new restorative treatment patterns, materials and techniques has improved the longevity and aesthetics of fixed dental prostheses.

Metal- ceramic restorations in many studies exhibited good longevity however Sailer, Pjetursson et al. argued that there was some difficulty in the imitation of natural aesthetics especially in areas where there was limited space for veneering material [5,8]

Manicone, Rossi Iommetti et al. (2007) added that the metal-free crowns allowed preservation of soft tissue color similar to the natural gingiva compared to porcelain fused to metal. The advantage of all- ceramic restorations is the ability of the material to achieve optimal aesthetics however the lack of mechanical stability historically deemed them suitable only for single crowns (Hickel and Manhart 2001; Olsson, Fürst et al. 2003) [5,6].

All-ceramic restorations combining aesthetic veneering porcelains and strong ceramic cores were able to resist fracture during function as well as parafuction in both anterior as well as posterior areas (Conrad, Seong et al. 2007) [5,6,11,12].

Today's ceramic materials used in the dental field comprise a large and diverse group of materials that offers patients a number of alternatives when dealing with prosthetic treatments. [15].

These ceramic systems have been developed over time seeking highlyesthetic but also functional materials. Current dental ceramic systems (leucite or lithium disilicate-reinforced glassceramics, highalumina or zirconia ceramics) offer better physical and mechanical properties than those of older, more traditional systems.

Feldspar-based and leucite-reinforced ceramics according to their low flexural strength (154MPa and 160MPa respectively) are indicated for single tooth restorations such as veneers, inlays, onlays, partial crowns, and anterior and posterior crowns. Beside the listed, zirconia-reinforced lithium silicate (420 MPa) can also be used for the fabrication of implant-supported crowns [16].

Having the high crystalline content, specific microstructure and flexural strength of 360–400 MPa, lithium disilicate ceramic can be used not only for single tooth restorations but the fabrication of hybrid abutments, hybrid abutment crowns and three-unit bridges as well (up to the second premolar as the terminal abutment) [17].

Due to the polymer content, low flexural strength (150–240 MPa) and high resilience, hybrid ceramics can be used only for single tooth restorations such as veneers, inlays and on lays (Lava Ultimate), as well as for anterior and posterior crowns and implant supported crowns [17,18].

Densely sintered, high–purity alumina can be used for primary elements of conical and telescopic crowns, crowns in the anterior and posterior area, as well as for bridges only in the anterior area with no more than 1 pontic (due to the average high flexural strength of 500 MPa).

Yttria-stabilized zirconia (with high flexural strength of more than 900 MPa) is indicated for fabrication of anterior and posterior crowns, implant abutments, implant abutments crowns, primary telescope crowns, 3-unit inlay and onlay bridges, cantilever bridges with minimum two abutment teeth and maximum of one pontic of no more than one premolar width, anterior adhesive bridges, as well as multi-unit long-span (up to 14 units) and curved bridges with a maximum of four pontics next to one another in the anterior area, and a maximum of three pontics (DC-Zircon) next to one another between abutment teeth in the posterior area. [18,19].

Some of them (Lava™ Plus High Translucency Zirconia, 3M ESPE) are indicated for clinical situations with limited interocclusal space, as well as when the toothpreserving preparation is needed (minimum 0.5 mm occlusal wall thickness). [20,21].

Esthetic advantages are real when the completely light-blocking metal is replaced, even by an opaque ceramic. All-ceramic systems can provide a better esthetic result for a wider range of patients than can metal-ceramics because a wide range of translucency-opacity (or ‘‘value’’ in the Munsell color system) can be achieved with commercially available ceramic systems. Other advantages relate as much to soft tissue health as to esthetics. Lesser amounts of plaque and adherence molecules are recovered from ceramic surfaces than from gold alloys or amalgam, and intra-oral plaque of a qualitatively healthier composition can form on ceramic surfaces [19–21].

It often is acceptable to leave the margin of all-ceramic prostheses supragingival or at the gingival margin, with the added benefit of more predictable and less traumatic impression making. Emergence profiles are less likely to be over-contoured, as is often the result with metal-ceramic prostheses due to efforts to provide a thicker layer of porcelain to mask the opaque-metal surface.[22]

Advantages of metal-ceramic systems lie in their predictable structural performance, their versatility, and that fact that less knowledge is required for choosing an appropriate system. The structural performance of metalceramic systems remains far better than for any all-ceramic system. As is discussed in more detail below, bulk failure and porcelain cracking affect approximately 5% to 10% of single-unit prostheses by around 6 years. Success rates are generally higher for anterior than for posterior single-unit prostheses.

Less clinical data are available for three-unit prostheses, and not all systems have been well studied. Conversely, structural problems related to the porcelain can be as low as ~3% to 4% at 10 years for metal-ceramic prostheses (nontitanium), and ~74% can still be in service at 15 years with the majority of problems being biologic (secondary caries, periodontal disease, and endodontic failures) [22–24].

Four ceramic systems have received notable attention in peer-reviewed literature: (1) a leucite-reinforced glass (Empress, Ivoclar), (2) a glassinfiltrated alumina (In-Ceram Alumina, Vita), (3) a glass-infiltrated magnesium aluminate spinell (In-Ceram Spinell, Vita), and (4) a polycrystalline alumina (Procera, Nobel Biocare).

In most cases, fracture rates seem to be lower for anterior crowns than for molar crowns, with the lowest failure rates for posterior restorations being reported for the high fracture toughness/high strength alumina-like and alumina materials (In-Ceram Alumina and Procera)

Studies of crowns having substructures of the higher toughness/strength alumina-based ceramics (In-Ceram Alumina, Vita; Procera, Nobel Biocare) report generally similar results for both materials. No bulk fracture was reported for 28 anterior and 68 posterior In-Ceram crowns at 4 years

In a 4-year university trial of 80 InCeram crowns (73% anterior, 27% posterior), one molar crown fractured and the marginal ridge of one premolar crown chipped. Of 97 Procera alumina crowns followed for 5 years, three crowns experienced bulk fracture, and two had some loss of veneering porcelain [25].

The 5-and10-year survival rates reported in another study of Procera crowns were 98% and 92%, respectively [20,21]

Dental ceramics exhibit excellent biocompatibility with the oral soft tissues and are also chemically inert in oral cavity. They possess excellent aesthetics. The structure of porcelain restoration is probably the most important mechanical property [22]

The structure of porcelain depends upon its composition, surface integrity and presence of voids. The strength is also depends on the presence of surface ingredients. The nature, amount, particle size and coefficient of thermal expansion of crystalline phases influence the mechanical and optical properties of the materials

The major drawbacks of ceramics are brittleness, low fracture toughness and low tensile strength. Methods used to overcome the deficiencies of ceramics fall into two categories including methods of strengthening brittle materials and methods of designing components to minimize stress concentration and tensile stress.

It is apparent that ceramics as a material group would continue to play a vital role in dentistry owing to their natural aesthetics and sovereign biocompatibility with no known adverse reactions. However, there will always remain a compromise between aesthetics and biomechanical strength. In order to achieve adequate mechanical and optical properties in the final porcelain restoration, the amount of glassy phase and crystalline phase should be optimised [26,27].

CONCLUSIONS

Ceramics are widely used in dentistry due to their ability to mimic the optical characteristics of enamel and dentin and their biocompatibility and chemical durability. Most highly esthetic ceramics are filled glass composites based on aluminosilicate glasses derived from mined feldspathic minerals. One common crystalline filler is the mineral leucite, used in relatively low concentrations in porcelains for metal-ceramic systems and in higher concentrations as a strengthening filler in numerous all-ceramic systems.

In general, the higher the fraction of polycrystalline components, the higher is the strength and toughness of a ceramic. The development of substructure ceramics for fixed prosthodontics represents a transition toward fully polycrystalline materials. Although the strength of a dental ceramic can be a meaningful number, it is not an ‘‘inherent’’ property and varies due to testing parameters that are often not well controlled to optimize clinical relevance. Fracture toughness is a far more ‘‘inherent’’ measure of the structural potential of a ceramic and represents a more easily compared value.

Clinical data for all-ceramic systems are becoming available, and results exist for many commercial materials, providing guidance regarding clinical indications.

REFERENCES

1. Heffernan MJ, Aquilino SA, Diaz-Arnold AM, Haselton DR, Stanford CM, Vargas MA. Relative translucency of six all-ceramic systems. Part I: core materials. J Prosthet Dent 2002;88:4–9.
2. Kawai K, Urano M. Adherence of plaque components to different restorative materials. Oper Dent 2001;26:396–400.
3. Anderson RJ, Janes GR, Sabella LR, Morris HF. Comparison of the performance on prosthodontic criteria of several alternative alloys used for fixed crown and partial denture restorations: Department of Veterans Affairs cooperative Studies Project 147. J Prosthet Dent 1993;69:1–8..
4. Pallesen U, van Dijken JWV. An 8-year evaluation of sintered ceramic and glass ceramic inlays processed by the CEREC CAD/CAM system. Eur J Oral Sci 2000;108:239–46.
5. Otto T, De Nisco S. Computer-aided direct ceramic restorations: a 10-year prospective clinical study of Cerec CAD/CAM inlays and onlays. Int J Prosthodont 2002;15:122–8.
6. Peumans M, Van Meerbeek B, Lambrechts P, Vanherle G. Porcelain veneers: a review of the literature. J Dent 2000;28:163–77.
7. Christensen GJ, Christensen RP. Clinical observations of porcelain veneers: a three year report. J Esthetic Dent 1991;3:174–9.
8. Fradeani M, Aquilano A. Clinical experience with Empress crowns. J Prosthodont 1997; 10:241–7.
9. Latta M, Barkmeier WW. Approaches for intraoral repair of ceramic restorations. Compend Contin Educ Dent 2000;21:635–9.
10. Zarone F, Russo S, Sorrentino R. From porcelain-fused-to-metal to zirconia: Clinical and experimental considerations. Dent Mater. 2011; 27(1):83-96
11. Gracis S, Thompson VP, Ferencz JL, Silva NRFA, Bonfante EA. A new classification system for all-ceramic and ceramic-like restorative materials. Int J Prosthodont. 2015; 28(3):227-35.
12. Oh S, Shin SM, Kim H-J, Paek J, Kim S-J, Yoon TH, Kim S-Y. Influence of glass-based dental ceramic type and thickness with identical shade on the light transmittance and the degree of conversion of resin cement. Int J Oral Sci. 2018; 10(5):1-6.
13. Borges GA, Sophr AM, de Goes MF, Sobrinho LC, Chan DC. Effect of etching and airborne particle abrasion on the microstructure of different dental ceramics. J Prosthet Dent. 2003; 89(5):479-88
14. Kruger S, Deubener J, Ritzberger C, Holand W. Nucleation kinetics of lithium metasilicate in ZrO2-bearing lithium disilicate glasses for dental application. Int J Appl Glass Sci. 2013; 4(1):9-19.
15. Denry I, Kelly R. State of the art of zirconia for dental applications. Dent Mater. 2008; 24(3):299-307
16. Chevalier J, Gremillard L, Virkar AV, Clarke DR. The tetragonal-monoclinic transformation in zirconia: lessons learned and future trends. J Am Ceram Soc. 2009; 92(9):1901-20.
17. Scherrer SS, Quinn GD, Quinn JB. Fractographic failure analysis of a Procera AllCeram crown using stereo and scanning electron microscopy. Dent Mater. 2008; 24(8):1107-13.
18. Guess PC, Schultheis S, Bonfante EA, Coelho PG, Ferencz JL, Silva NR. All-ceramic systems: Laboratory and clinical performance. Dent Clin North Am. 2011; 55(2):333-52.
19. . Garvie RC, Urbani C, Kennedy DR, McNeuer JC. Biocompatibility of magnesia-partially stabilized zirconia (Mg-PSZ) ceramics. J Mater Sci. 1984; 19(10):3224-8.
20. Kern M, Wegner SM. Bonding to zirconia ceramic: Ahesion methods and their durability. Dent Mater. 1998; 14(1):64-71
21. Hannink RHJ, Kelly PM, Muddle BC. Transformation toughening in zirconia-containing ceramics. J Am Ceram Soc. 2000; 83(3):461-87

22. Li RWK, Chow TW, Matinlinna JP. Ceramic dental biomaterials and CAD/CAM technology: State of the art. J Prosthodont Res. 2014; 58(4):208-16..
23. Lughi V, Sergo V. Low temperature degradation-aging-of zirconia: A critical review of the relevant aspects in dentistry. Dent Mater. 2010; 26(8):807-20.
24. Hjerppe J, Vallittu PK, Fröberg K, Lassila LVJ. Effect of sintering time on bi-axial strength of zirconium dioxide. Dent Mater. 2009; 25(2):166-71
25. Suresh A, Mayo MJ, Porter WD, Rawn CJ. Crystallite and grain-size-dependent phase transformations in yttria-doped zirconia. J Am Ceram Soc. 2003; 86(2):360-2.
26. Yoshimura M, Noma T, Kawabata K, Somiya S. Role of H2O on the degradation process of Y-TZP. J Mater Sci Lett. 1987; 6(4):465-7