Glass-Ceramics

Ketij Mehulić

Department of Prosthodontics
School of Dental Medicine
University of Zagreb

Acta Stomat Croat
2005; 483-486

REVIEW
Received: November 16, 2005.

Address for correspondence:

Department of Prosthodontics
School of Dental Medicine
Gundulićeva 5, 10000 Zagreb
Croatia
Phone: +385 1 4802135
E-mail: mehulic@sfzg.hr

Summary

Glass ceramics is a polycrystal material which is obtained by controlled crystallisation of glass. During the controlled crystallisation of glass a two-phase material emerges: crystals and an amorphous glass matrix. The development of crystals, several micrometers in size, takes place during the procedure of heating the total volume of glass, formation of germs and growth of crystals. The germs are either latently present in the glass or are added as an insoluble material in the finely dispersed distribution of the mixture (glass amorphous mass). Glass ceramic systems exist for laboratory fabrication and machine milling of finished ceramic blocks. By the method of casting and heat pressing glass ceramics materials are obtained with excellent mechanical and aesthetic properties for fabrication single crowns, inlays and onlays and also of three-unit bridges.

Key words: *glass ceramics, properties, indications.*

Introduction

Glass ceramics is one more system in the aesthetic treatment of prosthetic patients, without the use of a metal construction, which was essential as support for brittle ceramics. A particular problem was the treatment of the lateral segment of the dental arch, where stress is intense. Glass ceramics emerged with the development of silicate chemistry, development of glass and its technology. Glass is a hard smelted mass of alkaline silicates, rich in cremic acid, which contains one other base, and according to this base can be subdivided into: natrium-calcium, potassium-calcium, alumina, and with the introduction of various oxides into the mineral glass, zinc, barite, borosilicate and other glasses are obtained. In order to obtain glass that suits the specific requirements of certain components the glass mixtures must be in a determined quantitative relation. The integral parts of the mixture are smelted, mutually chemically react and dissolve. The primary process of each controlled crystallisation in glass is the separation of microphases. After smelting the smelted mass is stained by adding small amounts of metal oxide, and occasionally (for use in dental medicine) clouding is necessary, and tin oxides, zirconium etc are added, which become discharged in the glass mass in the form of fine crystallised particles. Different types of glass ceramics are formed by such controlled crystallisation, some of which are used in medicine, such as: apatite-mullite (1), fluorapatite (2), lithium glass ceramic (3), bioactive glass (4,5) and others. It was first discovered by McCullock (1968.), and Stookey, (1974.) first attempted to apply it as a dental constructive material. However, twenty years of intensive development of the technology of the material passed before the appearance of sufficiently strong systems for biological application. Today, glass ceramics is one of the most frequently used systems of for all-ceramics. It creates excellent aesthetics, good strength, ensures durability of restorations, particularly in the case of those in the frontal region of the dental arch. However, application of these materials in the lateral segment showed certain limitations. For their elimination it was necessary to determine the cause of cracking of the ceramic material under greater loading, such as that which occurs in the masticatory centre. Investigations over the last four decades have concentrated on improving strength, toughness and modul of elasticity. Evaluation of clinical failure shows that 90% of the faults occur because of stress (6, 7). Stress occurs because of differences in the coefficients of thermal elongation of the crystal and amorphous matrixes on the one hand and stress which occurs because of differences in the coefficients of thermal elongation between the core and veneer material in two-layered systems. Stress occurs beneath and on the bond itself of the two materials, leading to cracking, which in turn leads to fracture of the ceramic if it spreads to the surface. Thus the critical strain is on the bonding and not the functioning surface of the restoration (8). Another significant problem is porosity, which can also be the initial site of cracks, and under loading and its propagation can eventually lead to fracture of the restoration. Strengthening of the glass ceramic is achieved by the specific crystal phase, controlled growth and distribution of crystals, preventing the occurrence (by additional heating or pression), and diversion or bridging the cracks, and finally by reducing the amount of porosity (vacuum firing). It is equally important to emphasise the importance of precise control of the technological method in the dentotechnical laboratory, both during fabrication and construction of the restoration. The final treatment of the restoration surface is of immense importance for the functional durability of the same, particularly in the case of tribological properties. Daily control of all the apparatures is also essential (8).

Glass ceramics can be classified into those for:

- laboratory fabrication (e.g. Dicor, Dentsply International, York, IPS Empress, Ivoclar Schaan Liechtenstein) and
- machine fabrication (e.g. Dicor MGC).

Glass ceramics for laboratory production can be subdivided into:

- casting, using the technique of heating wax and centrifugal casting of the restoration (Dicor) and
- pressing, using the method of heat pressing, IPS Empress 1, IPS Empress 2, and experimental.

Cast glass ceramics

First described by Grossman in 1970 (Nicor glass) and applied in a fixed prosthetic by Stookey in 1974. It consists of crystals of tetra silicate fluor (mica crystals) ($K_2Kg_5Si_8O_{20}F_4$) and amorphous glass matrixes. The crystals are flexible, similar to plates (thus Dicor is resistant to cracks), and react to diffraction because of which they absorb colour from their surroundings, which creates a cameleon effect. In laboratory investigations marginal gap amounts to 10-65 μm. However, these values are difficult to achieve in vivo (36-85 μm) (9). Denry in 2005. (10) compared laboratory (Dicor) with machine fabricated crowns (Dicor MGC) and obtained greater values of toughness (1.96 Mpa) for laboratory fabricated crowns. Tinschert in 2005. (11) states that machine glass ceramics shows less variation and deviation of the values of strenght than those fabricated in the laboratory. Industrially obtained blocks for the milling technique are structurally more durable, although during the production technique itself cracks can occur, which can compromise the material and restoration itself.

Pressed glass ceramics

Almost at the same time as the casting method a method of heat pressed glass-ceramics was also accepted, which in cooperation with the company “Ivoclar”, has been developed up to clinical application. It was first described by Wohlwend. IPS Empress 1 (E1) - leucite ($KA1Si_2O_6$) strengthened glass-ceramics, share of crystals (1.7 μm in size) is around 35% of the volume. Strengthening is achieved due to differences in coefficients of thermal elongation of leucites and glass matrixes. In the crystals compressive strain (slightly more) is present, and within the matrix tensile strain, thus leading to the transformation of high cubic leucites into tetragonal leucites, and mild compression is present in all the material.

IPS Empress 2 (E2) has a lithium disilicate core ($Li_2Si_2O_5$). On the periphery of the main crystal phase are crystals of lithium phosphate. The total share of crystals is around 60% of the volume. Apatite glass ceramics is used for layering. The crystal phase is present from the beginning, unlike Dicor, where it forms in the additional process of ceramming. After the compression procedure lithium disilicate crystals are elongated, 5.2 μm in length. The increase in the share of crystal components creates closely packed, dense, interlocked microstructural appearance, which significantly contributes to strength and toughness, and does not essentially effect the opacity of the material (12). E1 and E2 are two different materials. E1 has the same values of toughness prior to and after compression. E2 has different values of toughness, associated with the changed position of lithium disilicate during compression. Catell in 2005. (13) tested the amount of porosity after basic and subsequent compression of both Empress materials, and concluded that in the subsequent compression lithium disilicate crystals grew intensively (Empress 2) and the number and magnitude of the pores in both materials decreased.

Two techniques for both Empress materials have been developed; the technique of layering for fabrication of crowns in the frontal segment of the dental arch, and for E2 and for three-unit bridges distally up to the second premolar. The technique of staining, for fabrication of crowns in the post-lateral segment, veneers, onlays and inlays. E2 has better mechanical properties than E1, greater homogenous structure, thermal and tribological characteristics similar to enamel and better marginal gap (16 μm) (3). The technique of layering E2 core material has flexure strength of 440 MP. Pagniano in 2005 (14) states that E2 is 75% stronger in practice. The toughness is 3.1MP. Material for the technique of staining E2 has flexure strenght 120MP. Experimental Empress has a similar structure to E2, flexure strength 352-600 MP (and consequently is close to In Ceram, which to date is the strongest all-ceramic), toughness 2.7-4.49 MP. The lengths of the grains of these ceramics are different; medium 3.4um, small grains 1-4 μm, spherical grains 1um and the most important elongated grains 10-12 long and 2.5-4 μm wide. Isgro in 2005 (15) compared the contraction of E1, E2 and experimental E3 after multiple firing and found E2 and E3 to be more stable than E1. Luo in 2005 (16) concluded that the marked strength of E2 and E3 was achieved by the presence of fine lithium disilicate crystals, interlocked microstructure and diversion of cracks.

Bonding of restorations

Better bonding methods result in better aesthetics, the need for less grinding of the teeth, and ensure better marginal fit of the crown. By using better quality methods and materials, when cementing with conventional cements, the problem of retention and resistance is reduced. Materials and methods for cementing restorations can be passive so that they merely mechanically fill the space between the restoration and the supporting tooth or they can be active and form a mechanical and chemical bond between the supporting tooth and the crown (17). Because of such methods, grinding of all teeth surfaces can be avoided, and the duration of some restorations, such as inlay bridges, is prolonged. The correct course of the bonding procedure is of great importance for the success of the entire therapy. Etching creates a rough surface which enables sealing between the cement and the tooth. Nagai in 2005 (3) recommends etching of restorations fabricated from Empress ceramic with hydrofluor, and not phosphoric acid. Ammonium bifluoride can also be used. The majority of all-ceramic restorations must be etched and bonded onto the conditioned surface of the stump. Variolink II is produced simultaneously like Empress 2. These restorations are cemented adhesively, Variolink II by the system (Vivadent) or Cem Kit (Ivoclar). Only the E2 layering technique can be cemented by glass ionomer cements. Several investigations have been carried out on the influence of the type of cement chosen on the durability of glass-ceramic restorations. Conditioning improves the quality of the bond, as condensation occurs between SiO2 in the ceramic and trimethoxyl group in silan primer, and at the same time improves the moistening of the ceramic surface. Burke in 2005 (17) warns of the importance of the base which can cause cracks to appear. Malament in 2001 (18) compared the durability of Dicor crowns cemented with zincphosphate and glass ionomer cements, and demonstrated that the latter are durable. Rosenstiel in 1993, Shehab in

1995, Groten in 1997 and Fleming in 2003 reported increased value of flexure strength of crowns permanently fixed by composite bonding agents (19). Pagniano in 2005 (14) recommended the thickness of these bonding agents as 0.09-0.14um. Sobrinho in 1998 (20) excluded other cements apart from Variolink II for fixing restorations fabricated from E2. With which Bookhan in 2005 (21) agreed. However, because of the different data on the bonding of glass-ceramic restorations by using different bonding agents and different, non-uniformly performed investigations a certain reserve remains.

Durability of glass-ceramic restorations

Durability depends on the mechanical properties (determined by the composition and microstructure of the material), course of fabrication in the dentotechnical laboratory and the quality of treatment of the restoration surface, bonding agent and the procedure (care with regard to earlier storage - premature ageing of the material), level of hygiene and frequency of check-ups. Complications during therapy with glass-ceramic restorations can occur immediately (early) or after several years (late). Most frequently the following occurs: fracture of the restoration, inadequate marginal fit (van Dijken states that this depends more on the skill of technician than on the type of material), secondary caries, weakening of the bonding agent (22). Demirel in 2005 (23) examined the influence of topical fluoridation and citric acid (2%) on Empress restorations in laboratory simulated two-year use. He concluded that significant wear of the glazed surface of the restoration occurs. Zimmer in 2004 (24) studied the durability of E2 after three years and found that all crowns were satisfactory (100% success), bridges 72.4%. Chadwick in 2004 (12), carried out an investigation after 7 years and found 92% of crowns were in a clinically satisfactory condition, of which 99% in the period up to 3.5 years. Inlays, onlays 96% in 4.5 years and 91% in 7 years caused by fracture. Kramer in 2005 (25) carried out an investigation after 8 years and determined that 92% of inlays were successful.

Conclusion

Fixed restorations fabricated from glass-ceramics can be successfully used for treatment of single crowns, inlays, onlays and three-unit bridges. These materials show good mechanical properties and excellent aesthetics.