Selected Properties of a Synthetic Quartz Glass-Ceramic

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The restoration of missing or compromised tooth structure requires dental materials that offer toothlike esthetics, functionality, biocompatibility, and longevity. Silica-based ceramics (eg, feldspathic porcelain) provide all of these necessities and are the materials of choice for esthetic all-ceramic restorations (eg, laminate veneers, ceramic inlays and onlays, and full-coverage jacket crowns) and for veneering of metal and high-strength ceramic copings and frameworks.[1–3]

Silica-based ceramics have dominated the esthetic dental material market for decades, and their esthetic properties cannot be matched by any other material. However, recent developments have led to a newer generation of silica-based ceramics to overcome some of the earlier shortcomings. This article reiterates some of the most significant properties of traditional silica-based ceramics and introduces some characteristics of a new synthetic quartz glass-ceramic.

TRADITIONAL SILICA-BASED CERAMICS

Traditional silica-based ceramics are, at least in part, glassy materials. Glasses are also considered supercooled liquids because of their noncrystalline structure.[3] An irregular network of silica formed by large alkali metal ions (eg, sodium, potassium, and lithium) shapes an amorphous structure. The large, irregular molecules limit the formation of an organized crystalline structure and

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have the tendency to form a glass when solidifying. The lack of a regular crystalline structure is responsible for favorable optical properties (ie, translucency) but also causes brittleness. The tensile strength of silica-based ceramics is low (20 to 60 MPa) since tensile stresses open small, propagating flaws. Compressive strength, however, is relatively high (350 to 550 MPa) because of the tendency of compressive stresses to close flaws.

The tendency of silica to form a glass rather than a crystalline solid also depends on the cooling rate. Rapid cooling of molten silica does not allow formation of organized crystalline structure and rather forms a fused quartz. This material has a melting point too high for general and efficient use. Therefore, metal oxides are typically used to reduce the melting temperature and to act as glass modifiers (eg, oxides of zinc, titanium, and aluminum). Instead of being made from crystalline silica, traditional dental ceramics are typically made from natural minerals (eg, feldspar) that have already undergone the vitrification process and exhibit a glassy structure. Traditional dental ceramics contain about 65% feldspar and 25% quartz. The feldspathic glass is dispersed by the quartz, which acts as a fine, crystalline strengthening agent. Some of the newly developed ceramics contain synthetic glasses, which ensure better control over quality as well as physical and optical properties.

Commercial ceramic powders are not just a mix of the various chemical components. The ingredients are previously fired and quenched by the manufacturers. Binders and water allow layering and packing, after which the particles are sintered to a coherent solid by being melted at a temperature higher than that for the specific glass transition. Metal oxides are added to the powder as colored pigments to obtain different shades and optical effects. Dental porcelains are often classified by their fusing temperature in high-fusing (1,300°C to 1,400°C) and low-fusing (850°C to 1,100°C) materials. Low-fusing ceramics are preferred especially for veneering of high-noble alloys with low melting temperatures.

The initial stage of the ceramic firing process slowly evaporates water and burns out binders. Fusion of the particles during sintering causes a nonporous material and is accompanied by significant contraction of about 20%. A slow cooling rate prevents cracking and crazing.

The coefficient of thermal expansion (CTE) of a ceramic material must fulfill the requirements for veneering of a given metal or high-strength ceramic core material. Certain ingredients (eg, soda and potash) and the crystalline (tetragonal leucite) content may influence the CTE. Unorganized crystallization, which may be caused by multiple firings or "overfiring" of traditional ceramics, induces stresses and cracks, which ultimately lead to fracture. Thermally induced stresses occur also in the event of a great mismatch of the CTEs of the veneering ceramic and the supporting core material.

Dental silica-based ceramics provide unsurpassed biocompatibility, longevity, and resistance to chemical influences. Esthetic replication of natural tooth structures depends on the ability of the restorative material to mimic their optical characteristics. Besides individual shades and translucency patterns, natural teeth exhibit various degrees of fluorescence and opalescence.[4] The ability of a material to radiate light is termed *fluorescence*, while the ability to reflect light is called *opalescence*. Fluorescence of natural teeth is extremely difficult to mimic. Early ceramics contained uranium, which may have provided some fluorescence but also caused some radiation-related adverse effects. In modern dental ceramics, fluorescence is typically achieved by adding luminophores (eg, ytterbium, cerium, europium, terbium).[5] Opalescence is typically simulated by adding tinted pigments to a ceramic material. However, all added pigments diminish the optical properties of a ceramic material in respect to translucency, light reflection, and optical purity. Optical purity, chromatic stability, chromatic predictability, reactivity, and adaptability are important prerequisites for perfectly matching the appearance of natural teeth.[4]

Synthetic Low-Fusing Quartz Glass-Ceramic

A synthetic, low-fusing, quartz glass-ceramic (HeraCeram, Heraeus Kulzer, Armonk, NY, USA) was recently developed to overcome some of the disadvantages of traditional silica-based ceramics.[4–6] The synthetic phase is a prefabricated, optical, fiber-grade glass, which has a purer and more homogeneous consistency than natural quartz.[4,5] Natural quartz bears structural impurities that conventional firing cannot remove. The synthetic quartz glass contains quartz crystals that are superheated at 1,600°C to vaporize and remove all impurities typical for natural quartz.[4] This process creates a ceramic with optical purity as well as inherent fluorescence and opalescence as found in natural teeth.[4–6] The homogeneous glass phase and microfine leucite distribution creates a surface that is extremely smooth, exhibits superior polishability, and has a low wear resistance similar to that of natural enamel.[5]

Many traditional silica-based ceramics change color after multiple firing cycles. This color change is due to shade-defining metal oxides that are simply added to the ground raw material and tend to burn out after repeated firing.[4] With synthetic ceramic, colorants are added before the material is ground into small particles, and colored crystals are presintered at a temperature that is higher than the firing temperature of the ceramic powder, therefore, protecting the colorants from vaporization during firing.[4] This unique characteristic, called *intrinsic chromatic stability,* is defined as the ability of a material to maintain its color and chroma even after multiple firings.[4] The presintered ceramic also shrinks significantly less during firing and allows for faster firing cycles.[5]

Synthetic quartz glass-ceramic incorporates pre-matured leucite crystals, which prevent uncontrolled crystallization and provide a stable CTE. Therefore, unlike some traditional materials, this ceramic can be cooled at much faster rates and fired multiple times without the risk of cracks and fractures.[5] The maximum firing temperature of synthetic quartz glass-ceramic is very low (870°C) and allows the use of various coping materials, from nonprecious metal to high-gold alloys.

The technical and physical characteristics of synthetic quartz glass-ceramic complement the esthetic properties of the material, which provides optical purity, natural translucency, fluorescence, and opalescence, as well as chromatic stability, predictability, reactivity, and adaptability.[4] Two clinical applications of this new ceramic material are discussed and illustrated in the following cases.

CASE 1

A female patient presented with intrinsically stained and moderately misaligned teeth (Fig 1). After esthetic analysis and diagnosis, the comprehensive treatment plan included porcelain laminate veneers for 10 maxillary teeth. The diagnostic full-contour waxup was verified with an intraoral mockup to provide esthetic predictability. The teeth were prepared conservatively to ensure enamel support for the bonded restorations (Fig 2). Figure 3 shows the minimally invasive preparation design and the interproximal finish line. Note the interproximal separation of the prepared teeth for better space appropriation and for simplified impression and insertion techniques. The final impression was poured, and a sectioned master cast and a solid model were fabricated.

A platinum foil technique (Argen, San Diego, CA, USA) was selected. Cut foil pieces were applied individually on each master die. A glass instrument was used to fit marginal areas, and excess material was removed with a surgical scalpel blade. Synthetic quartz glass-ceramic (HeraCeram) was used with a segmental layering technique. The first thin layer contained dentin shades with approximately 35% clear in the cervical areas to obtain a "contact lens effect" to blend the restorative material with the natural tooth structure in the marginal areas. Body shades with a minimal value of 2 (according to the HeraCeram Matrix Shade system, Heraeus Kulzer) functioned as an active wavelength enhancer to block out

CASE 1 (Figs 1 to 9)

Fig 1 Intraoral preoperative situation reveals intrinsically stained and moderately misaligned teeth in a female patient. The definitive treatment plan comprised laminate ceramic veneers on 10 maxillary teeth.

Fig 2 Frontal view of tooth preparations for laminate veneers in the maxilla. Note the conservative preparation design confined to enamel to ensure optimal resin-bonding prerequisites.

Fig 3 Occlusal view of the preparations.

Fig 4 Ceramic laminate veneers were fabricated with a synthetic quartz glass-ceramic (HeraCeram) and a segmental layering technique.

undesirable shade translucency of the prepared tooth (Fig 4).

After firing of the first layer (Fig 5), the veneers were gradually built up to full contour (Fig 6). Interproximal contacts were verified, and final facial anatomic sculpting was achieved by using rotary instruments (Brasseler, Savannah, GA, USA). Marginal areas were finished with a diamond disk (Cherry Hill, NJ, USA) at about 4,000 rpm. Platinum foils were removed and veneers cleaned after firing of the final glaze. The veneers were tried intraorally to verify all functional and esthetic parameters and then were adhesively cemented with a light-curing composite resin luting agent (Figs 7 and 8) following standard procedures for resin-bonding of silica-based ceramic restorations.[7–9]

Figure 9 depicts the newly established incisal edge position in respect to the lower lip. This incisal edge position was previously verified with an intraoral mockup and transferred to the laboratory with silicone indices and a full-contour waxup.

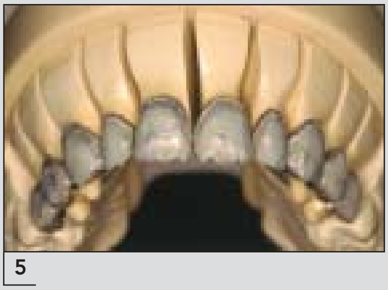
Fig 5 Situation on the master cast after firing of the first ceramic layer.

Fig 6 The veneers were successively built up to full contour.

Fig 7 Intraoral labial view of the completed restorations after adhesive cementation with a light-curing composite resin luting agent.

Fig 8 Labial view of the completed restorations.

Fig 9 Closeup buccal view of the newly established incisal edge position in respect to the lower lip.



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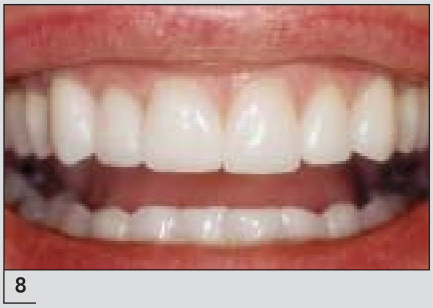

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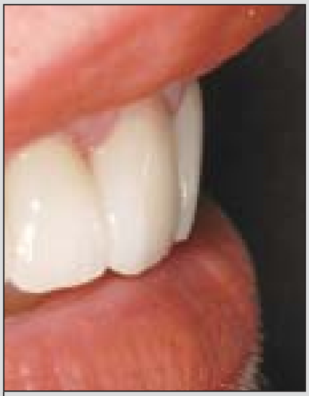

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CASE 2

Secondary carious lesions required multiple restorations in the maxillary left quadrant in a 65-year-old male patient. The left first premolar was severely broken down and was not restorable. The tooth was extracted (Fig 10), and a one-piece implant was placed immediately into the extraction socket. The existing crown was hollowed out and relined with acrylic resin to fit the supragingival aspect of the implant. The system required placement of a plastic tissue-protection sleeve as displayed in Fig 11. The provisional crown was cemented with temporary cement after all occlusal and functional contacts were carefully eliminated.

The maxillary left canine, second premolar, and first molar required buildups and full-coverage crowns. Figure 12 shows the prepared teeth and the customized, supragingival aspect of the implant.

After final impression making and master-cast fabrication, restorations were made with Captek (Precious Chemicals, Altamonte Springs, FL, USA) composite gold crowns with a 360-degree porcelain shoulder. Figure 13 shows the completed Captek copings, which were fabricated by applying a first layer of Captek P (platinum) on the die. A first ceramic oven bake matured the substrate capillary infrastructure. Second, Captek G (gold) was applied, followed by another oven bake. Investment was removed with super striper acid

CASE 2 (Figs 10 to 21)

Fig 10 Secondary carious lesions required full-coverage restorations for the maxillary left canine, second premolar, and first molar. The left first premolar was extracted, and a one-piece dental implant was immediately placed into the extraction socket. (Surgery by Michael Block, DMD, LSU School of Dentistry, New Orleans, LA, USA.)

Fig 11 Buccal view of the intraoral situation during placement of an immediate provisional restoration on the immediately placed implant in the first premolar area. The existing crown was hollowed out and relined with acrylic resin.

Fig 12 Intraoral buccal view of the prepared teeth and the customized, supragingival aspect of the implant.

(ADS, Easton, PA, USA). All margins were finished, and passive internal fit on master dies was verified. Next, Capbond (bonder; Precious Chemicals) was placed on the external surface of the copings to increase the metal-ceramic bond strength (Fig 14).

The veneering porcelain was added subsequently (Fig 15) using the HeraCeram synthetic quartz glass-ceramic with the Matrix shades expansion kit addition of opalescent range. A first layer of opaque (0A2/0A3 and Gold intensive) was applied and fired, followed by a second layer of the same opaque with a slightly thicker consistency to create a polychromatic environment of fluorescent value ranges. Margin material (HM2 and HM3) was mixed over a wet tray, placed at the 360-degree peripheral shoulder, and fired.

Final shade selection of the body and incisal area was based on three zones: the gingival third (hues and chroma), the midsection (blend of higher value with incisal interaction), and the incisal third (opal incisal combination of higher value blended with translucency). A first body skin technique was applied starting from the cervical base of each crown (gingival third) to the midsection. Values were laid over the gingival two thirds and covered by the opalescent range of incisal, followed by the first body bake. Incisal corrections were made for final anatomic form and function (Fig 15).

Figure 16 illustrates the ceramic layering of the first molar before a second body bake. Buccal and occlusal aspects of the first molar crown at an advanced stage are depicted in Figs 17 and 18. Final fit, occlusion, and esthetics were verified and the restorations finalized (Figs 19 and 20). The crowns were inserted in the patient's mouth. The clinical situation 12 months after insertion demonstrated excellent tissue integration of all restorations including the implant-supported crown on the first premolar (Fig 21).


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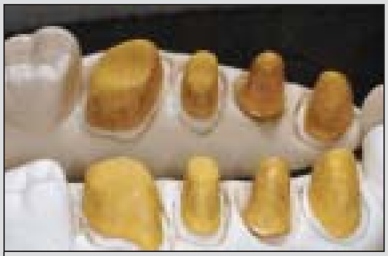
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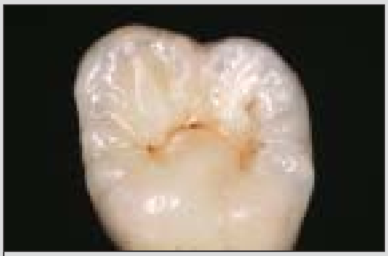
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Fig 13 Gold copings for the porcelain-fused-to-metal (PFM) restorations for the canine, second premolar, and first molar, as well as for the first premolar implant, were fabricated with the Captek system.

Fig 14 Captek copings were placed on the master cast to verify precision of fit. A bonder (Capbond) was applied to enhance the metal-ceramic bond.

Fig 15 The veneering porcelain (HeraCeram) was successively applied to full anatomic contour.

Fig 16 Interproximal view of the ceramic layering of the first molar before a second body bake.

Fig 17 Buccal aspect of the first molar crown before finalization.

Fig 18 Occlusal view of the first molar crown details anatomic and morphologic features.

Fig 19 PFM restorations for the canine, first and second premolars, and first molar.

Fig 20 Occlusal view of finalized PFM restorations.

Fig 21 Intraoral buccal view of PFM restorations after 12 months in function demonstrates esthetic integration and favorable soft tissue response around the first premolar implant.

SUMMARY

Silica-based ceramics are the materials of choice for superior and long-lasting esthetics and function. Their inherent brittleness, however, requires strengthening through metal or high-strength ceramic substructures (PFM or all-ceramic full-coverage restorations) or resin bonding for final cementation (laminate veneers or inlays and onlays). A new synthetic quartz glass-ceramic was developed in the attempt to overcome some of the disadvantages of traditional silica-based ceramics. It provides excellent optical characteristics and offers some physical properties that allow easier handling and improved function.

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