Current technological processing and uses of silicate ceramics

Question

What are the clinical indication spectra and processing forms of silicate ceramics?

Background

In dentistry, silicate ceramics with varying amounts of glass are distinguished from oxide ceramics with little or no glass content. In an ideal glass, there are no crystalline structural elements like in ceramics. The higher and finer the arrangement of the crystalline structure, the less light can pass through the ceramic (Fig. 1); the opaquer it appears. Owing to the presence of a certain proportion of amorphous structures in a silicate ceramic, the transmission of light is less impaired. However, the higher translucency of the ceramic comes at the expense of lower strength [7] (Fig. 2, Fig. 3).

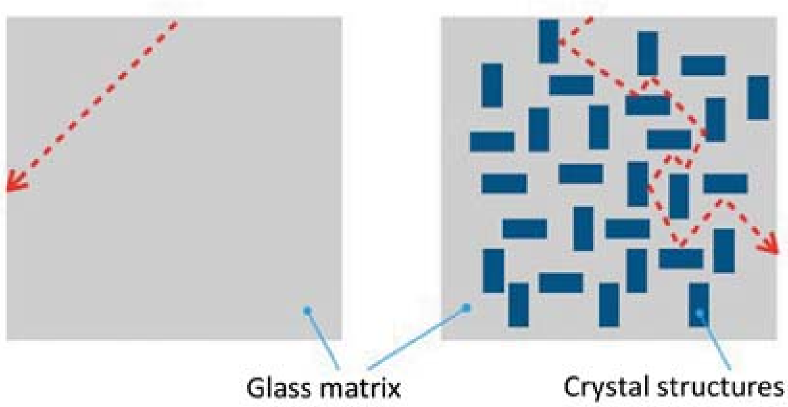

Figure 1 Differences in light refraction. Left: amorphous ideal glass; right: silicate ceramic with a high proportion of semicrystalline structure.

In principle, silicate ceramics are produced from blanks of a molten glass in which crystal formation is stimulated in a succeeding thermal process. The properties of a silicate ceramic are determined by the nucleation, subsequent grain formation as well as the size of the newly formed crystals. Currently, the following types of silicate ceramics can be distinguished [7, 10]:

- Feldspathic ceramic which is indicated for classical veneering, veneers or partial crowns (e.g. Vitablocs Mark II, Vita Zahnfabrik, Bad Säckingen, D)
- Leucite-reinforced glass-ceramic which is indicated for single crowns, veneers, partial crowns (e.g. Empress 1, Empress CAD, Ivoclar, Schaan, FL)
- Lithium disilicate ceramic which is indicated for crowns, three-unit bridges (anterior teeth, premolars), veneers, partial crowns (e.g. e.max CAD, Ivoclar, Schaan, FL)
- Zirconium oxide-reinforced lithium silicate which is indicated for crowns, small 3-unit bridges (anterior teeth, premolars), veneers, partial crowns (e.g. Celtra Duo, Dentsply-Sirona, Bensheim, D; Suprinity, Vita Zahnfabrik, Bad Säckingen, D).
- Fluorapatite ceramic which is indicated for overpressing of lithium disilicate frameworks (e.g. e.max Ceram), abutments (e.g. Straumann Anatomic IPS e. max, Ivoclar, Schaan, FL) or overpressing of zirconium dioxide frameworks (e.g. e.max ZirPress, Ivoclar, Schaan, FL), as well as veneers.

Processing methods

Nowadays, the following processing methods are distinguished for silicate ceramics (Tab. 1):

Slip casting method

The classical veneering ceramics made of feldspar are applied onto the restorations by slip casting. Veneering ceramics for metal frameworks have a relatively high leucite content because leucite increases the coefficient of thermal expansion (CTE) and matches the CTE of the metal alloy. In contrast, veneering ceramics for frameworks made of zirconium

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dioxide, for example, have a low leucite content (e.g. Vita VM9, Vita Zahnfabrik, Bad Säckingen, D). The dental technician's individual know-how in handling veneering ceramics determines variables such as the anatomical and color design, air inclusions, pores, duration and the number of firing cycles during slip casting.

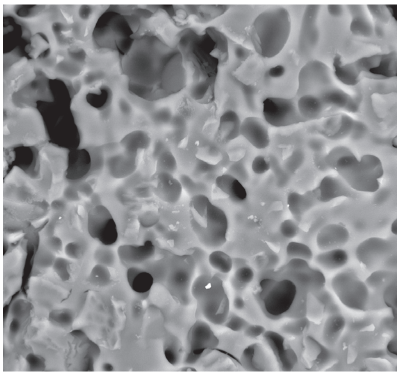


Figure 2 Scanning electron micrograph of a feldspar ceramic (Vitablocs Mark II, VITA Zahnfabrik, D). Condition after 60 s of etching with 5 % hydrofluoric acid. After etching, the sharp-edged shapes of the feldspar crystals emerge from the glass matrix which now appears porous (magnification 5000×).

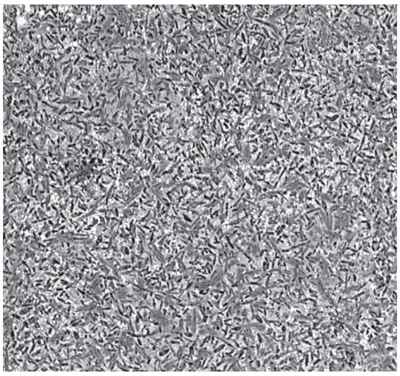


Figure 3 Scanning electron micrograph of a lithium (di)silicate ceramic (e.max CAD, Ivoclar, Schaan, FL). Condition after 20 s of etching with 5 % hydrofluoric acid. The darker lithium (di)silicate crystals emerge from the brightly depicted glass matrix (magnification 4000×).

Pressing method

Since glasses represent „frozen liquids“, silicate ceramic masses such as feldspar or fluorapatite ceramics can be hot pressed (Fig. 4). The advantage of this method is that processing errors such as pores and defects can be minimized [7]. The shape of the veneering is designed on the framework material with the help of castable wax or resins. The framework and burnout form are embedded in investment material and the ceramic mass is pressed into the cavity under vacuum. In the so-called „cut-back technique“, individual requirements in terms of shape and color can be achieved. In this procedure, a part of the pressed material is removed. It is supplemented with color-optimizing dentin or enamel masses. For each type of framework material, special masses are available. For example, Vita PM9 (Vita Zahnfabrik, Bad Säckingen, D) is suitable for overpressing metal alloys, e.max Ceram (Ivoclar) for overpressing lithium (di)silicate and e.max ZirPress (Ivoclar, Schaan, FL) for veneering zirconium dioxide frameworks.

Monolithic restorations can be produced using the pressing technique as well. Veneers, partial crowns (Fig. 5), crowns (Fig. 6) and small three-unit bridges can be fabricated in this way. Pressed restorations generally exhibit a higher level of strength [1] and better interface quality than restorations which are fabricated using the slip casting method [7].

Milling method

CAD/CAM milled veneers and restorations made of silicate ceramics are on the rise. Advantages of industrially produced blocks for milling in-

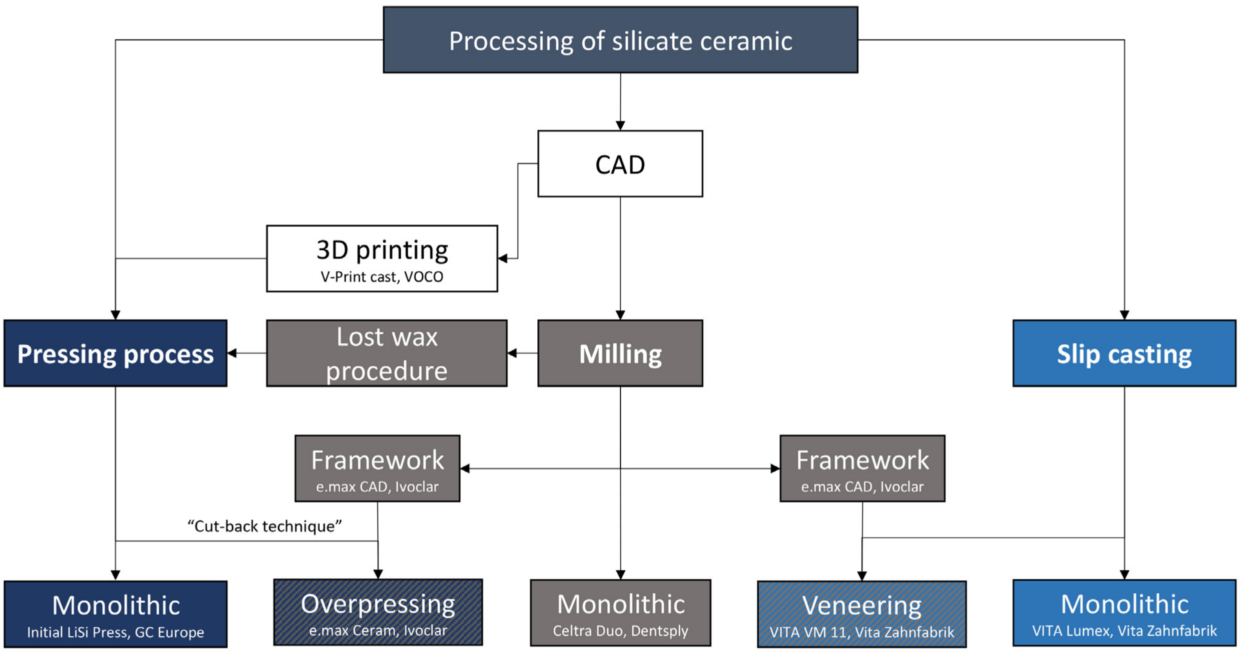


Table 1 Overview of the various processing methods of silicate ceramics. (see text for details)

Figure 4 Removed and cleaned hot pressed restorations. Processing method: e.max Press (Ivoclar, Schaan, FL).

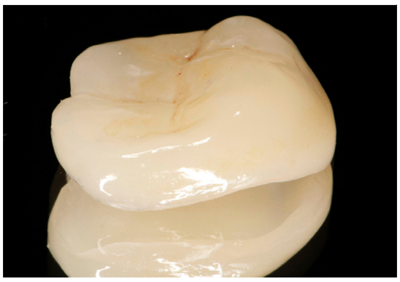


Figure 5 A so-called "tabletop" made of lithium (di)silicate.

clude better control of structural defects and composition. Moreover, the assessment of effective layer thickness of the veneer is easier to perform on the PC in CAD mode, which as a rule of thumb, should never be thicker (stronger) than 1.5 mm; otherwise, the chipping rate increases. The bonding together of the framework and the milled veneering is made in the furnace using a „glass solder“ (Ivoclar, Schaan, FL) or with an adhesive luting composite using the „rapid layer“ technique (Vita Zahnfabrik, Bad Säckingen, D) [7]. Silicate ceramics have the advantage that they can be etched with hydrofluoric acid for the latter technique, thus creating a reliable bond. In contrast, zirconium dioxide cannot be etched. The bond to zirconium dioxide is considered as being partially problematic [3].

Due to their hardness, pressable crystalline lithium (di)silicate blocks are not suitable for milling processes. Hence, special milling blocks have been developed for this purpose. The blocks of lithium metasilicates are „presintered“ at low temperatures. As a result, they have a light blue, shimmering appearance. These presintered blocks can be readily milled using the CAD/CAM process. The milled „blue" blocks are so stable that they can be tried in. After their clinical check and adjustment, they receive the desired color through staining and crystallization firing. The flexural strength is specified as > 350 MPa, so that, crowns made of lithium (di)silicate do not need to be cemented adhesively.

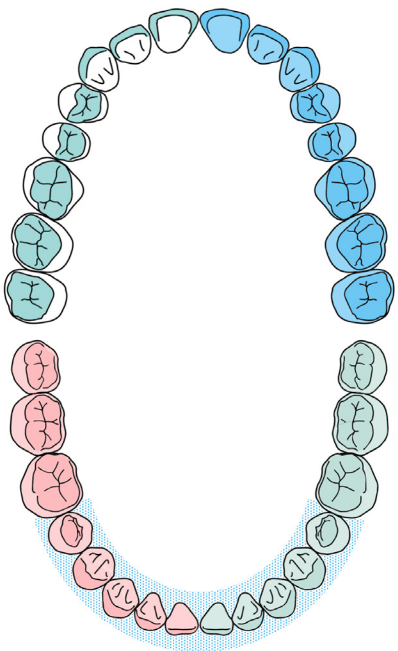
So-called „zirconium dioxide-reinforced“ lithium silicates follow a comparable strategy [5]. Since the zirconium dioxide is only dissolved in the glass, the extent to which the zirconium dioxide causes reinforcement in the ceramic is controversial [4]. Lithium silicates such as Celtra Duo (Dentsply) or Suprinity (Vita) are fully crystallized. They can be milled and polished subsequently. However, the flexural strength reduces to around 210 MPa. This means that crowns with a flexural strength of less than 350 MPa must be adhesively cemented. An additional glaze firing increases the flexural strength to approximately 370 MPa, so that, crowns could then be conventionally cemented as well. In the case of den-

Feldspathic ceramic

Subgroups	Amorphous, reinforced
Indication	V, PCr
Flexural strength	< 150 MPa
Cementation	adhesive

Leucite ceramic

Subgroups	-
Indication	V, PCr, AntCr, PstCr
Flexural strength	< 200 MPa
Cementation	adhesive



Zirconium oxide-reinforced lithium silicate Zr-LiSi

Subgroups	no glaze firing with glaze firing
Indication	V, PCr, AntCr, PstCr V, PCr, AntCr, PstCr, AntBr, PrBr
Flexural strength	ca. 210 MPa > 350 MPa
Cementation	adhesive adhesive and AntCr/PstCr also conventionally

Lithium disilicate $LiSiO_2$

Subgroups	-
Indication	V, PCr, AntCr, PstCr, AntBr, PrBr
Flexural strength	> 350 MPa
Cementation	adhesive (AntCr/PstCr also conventionally)

Table 2 Overview of silicate ceramics: Indication and cementation. V = veneer, PCr = partial crown/inlay, AntCr = anterior crown, PstCr = posterior crown, AntBr = three-unit anterior bridge, PrBr = three-unit premolar bridge

tal bridges that are made of zirconium dioxide-reinforced lithium silicate or lithium (di)silicate, the following applies for safety reasons: it is better to cement adhesively (Tab. 2).

Printing method

The first processes of purely additive manufacturing of dental restorations made from ceramics are still being tested [8]. Currently, 3D printing is already being applied for the pressing method [11] (Fig. 7). After the restoration design is made using CAD (e.g. a crown), it is first printed in a castable resin (e.g. Voco Cast, Voco, Cuxhaven, D). The stable resin restorations can be tried in and clinically adjusted. They are then embedded in an investment material, the (printed) resin form is burned out and the ceramic material is hot pressed into the remaining cavity. The final color is achieved using the above-mentioned cut-back technique or through staining and glaze firing.

Figure 6 Anterior crowns made of lithium (di)silicate.

Figure 7 Example of a 3D printing process (V-Print Cast, Voco, Cuxhaven, D) for the production of a pressed lithium (di)silicate crown. Left image: printed object in light-cured state after CAD production. Middle picture: fitted and finished resin crown before investment. Right image: finished ceramic crown.

(Fig. 1–7, Tab. 1 und 2: Behr et al.)

Cementation of silicate ceramic

Both in vitro as well as in vivo studies indicate that the adhesive bond appears to improve the stability of lithium (di)silicate restorations against masticatory forces more than conventional cementation with, for example, glass ionomer cement. In a clinical study, conventionally cemented crowns showed slightly higher rates of loss after 8 years, but these differences were not statistically significant [6]. Other clinical studies could not determine any difference in the survival rate of lithium (di)silicate restorations based on the cementation [12]. In vitro studies showed that adhesive cementation had slight advantages after mastication was simulated. In this context, it was interesting to observe that crowns cemented with self-adhesive composites only reached the fracture strength level of conventional cementation [9]. In order to attain the advantages of adhesive cementation, the classical adhesive procedure is apparently required. Especially in the case of adhesive cementation, silicate ceramics can reveal their great advantage over „translucent“ zirconium dioxides: in contrast to zirconium dioxide, silicate ceramics can be etched with 5 % hydrofluoric acid. After etching and the application of an adhesive silane, a reliable adhesive bond is formed. The indication spectrum of lithium (di)silicates and 3rd generation („translucent“) zirconium dioxides is largely identical [2].

Statement

The optical properties of silicate ceramics make them well-suited for the replication of enamel and dentin with a natural appearance. Various types of silicate ceramics are available for veneering frameworks and monolithic restorations.

In most cases, the veneering is made with classic feldspathic ceramic which is applied using the slip casting method. However, (over-)pressing methods have been developed which can optimize the work process and increase the quality of the veneering. In the pressing method, leucite-reinforced glass-ceramic (metal frameworks) or fluorapatite ceramic [mostly for zirconium dioxide and lithium (di)silicate frameworks] are used.

The development of lithium (di)silicates ($LiSiO_2$, Zr-LiSi) has significantly increased the strength of silicate ceramics and therefore expanded the range of indications for monolithic restorations. Their indications are largely identical to those of 3rd generation zirconium dioxides („translucent“ zirconium dioxides). Good optical properties, high strength, which permits the use of various luting concepts, the ability to be etched with hydrofluoric acid for a reliable adhesive bond if needed, enamel-like wear behavior, and various new processing options such as pressing, milling, and printing, distinguish the material group of silicate ceramics. They thus represent a significant enrichment of the clinical choice of dental materials.

Conflicts of interest

The authors declare that there is no conflict of interest as defined by the guidelines of the International Committee of Medical Journal Editors.

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(Photo: UKR)

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