Slip-casting alumina ceramics for crown and bridge restorations

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The In-Ceram technique uses alumina ceramics and glass in a two-step firing procedure to create a high-strength core material for single-tooth restorations as well as small fixed partial dentures. Fine-grain alumina particles are sintered to form a porous substructure, which is infiltrated with molten glass. The combination of these two processes gives the material its outstanding properties. The sintering process is almost without shrinkage, providing an excellent fit, while the glass infiltration leaves practically no porosities, resulting in high strength. (Quintessence Int *1992;23:25–31.*)

Introduction

Ceramics have been used for dental restorations for a long time. Single jacket crowns were the first all-ceramic restorations, developed by Land in the last century. Although conventional jacket crowns have been improved so that they give excellent clinical results,[1] their strength remains fairly low, and it is difficult to obtain a reproducible, precise marginal fit. The main field of ceramic application, however, became ceramic veneers on cast metal substructures.[1] In the past, the construction of fixed partial dentures with a good prognosis was only possible with the porcelain-fused-to-metal technique.

The desire for better esthetics and improved biocompatibility led to the development of metal-free ceramic restoration systems. New materials, such as Cerestore (Johnson & Johnson Dental Care Co), Dicor (Dentsply International), Hi-Ceram (Vident) or Optec (Jeneric/Pentron Inc), nourished hopes that the construction of all-ceramic fixed partial dentures would be possible. These expectations of benefiting from the advantages of biocompatibility and improved esthetics for the treatment of partially edentulous patients were not fulfilled, however.[2–5] The major problem with ceramic substances is their brittleness and lack of resistance against tensile forces and crack propagation.[1,6]

The new In-Ceram technique (Vita Zahnfabrik), which was developed by Sadoun[7] in France, uses alumina in a slip-casting procedure as a core material.[7–12] A *slip* is a suspension of fine insoluble particles in a liquid. For instance, slip-casting procedures are used for the fabrication of ceramic tableware. The slip-casting alumina is first sintered in a furnace and then infiltrated with glass in a second firing process. The combination of these two procedures gives the material its outstanding properties. The densely packed alumina particles limit crack propagation. The infiltration with glass eliminates practically all porosities. Both procedures contribute to the high bending strength of the material.

This article describes the clinical and technical procedures of the In-Ceram system as well as the clinical and material science results achieved with this material.

Clinical and technical procedures

A clinical case will be used to demonstrate the procedures (Fig 1). All-ceramic crowns require an overall tooth reduction of at least 1 mm. Because thin, beveled margins cannot be reproduced with ceramics, a circular shoulder or deep chamfer preparation is required (Fig 2). Internal line and point angles should be rounded. This preparation results in a substantial loss of dental hard tissues with an increased risk of damage to the pulp. For this reason, all-ceramic crowns should

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be considered mainly for older patients, in whom pulp chambers are smaller and dentinal tubules narrower. Impressions are taken with any precision impression material suitable for crown and bridge technique. As there are no long-term experiences concerning the minimal thickness of the In-Ceram core, we try to establish a reduction of 1.0 to 1.5 mm to achieve a substructure thickness of at least 0.5 mm. Because of the matching color and the translucency of the core material, esthetic problems, especially in the cervical area, are reduced.

After preparation and mounting of the master casts, defects and undercuts are blocked out. The dies are coated with a die spacer to achieve a film thickness of approximately 45 μm (Fig 2). The preparation margin must not be covered with spacer. The master stone dies are duplicated with addition silicone in a special plaster to create working dies (Fig 3). The special die plaster's expansion is adjusted to the later contraction of the slip-casting material in the sintering process.[8] The duplicate dies must be trimmed dry, because wet trimming would alter their dimensions.

For single crowns, simple copings are manufactured. The slip is liquid, so pontics of fixed partial dentures cannot be cast free standing. Thus a "rest," or prop, for the pontic has to be created before the dies of the fixed partial denture are reproduced. For bridge construction, the whole segment, ie, abutments and rests, are duplicated in special plaster (Fig 4). The duplicate cast is glued to an alumina baseplate and the abutments are separated with saw cuts (Fig 4). The separation is necessary to compensate for the shrinkage of the plaster during the sintering process. After the duplicate die preparation is accomplished, the borders of the preparation may be marked with pencil, and a sealer is applied. The sealer regulates the absorption effect of the dry plaster die onto the liquid slip.

A special ultrasonic device is used for the preparation of the slip. Liquid, alumina powder, and an additive are combined and stirred under ultrasonic agitation until a homogenous mass with so-called rheopex properties is achieved. *Rheopexy* is when a liquid mass stiffens under sudden pressure. Thus, working with the slip is different from working with conventional ceramics and requires some practice and experience.

The slip is applied with an acrylic brush (Fig 5). The work has to be done quickly, so that previously applied masses do not dry. The dry die absorbs the fluid out of the slip, and this fluid flow leads to a condensation of the alumina particles. The mass can be cut with a scalpel, so that the framework is shaped roughly before the first firing. After the die has dried (30 minutes), a stabilizer is applied to the framework, which is then sintered on the duplicate plaster dies in a 10-hour firing cycle with temperatures reaching 1120°C. Sintering and the infiltrating process require a special furnace, the Inceramat (Vita Zahnfabrik). The plaster shrinks during sintering, so that the sintered frameworks are easily removed from the dies. A blue testing liquid is used for the detection of eventual cracks. Cracks, which occur very rarely, would make the fabrication of a new substructure necessary. The final shaping of the framework is accomplished with hard polishers, smooth grinding stones, or fine-grit diamond instruments (Fig 6).

Glass powder of a color matching the desired tooth color is mixed with distilled water. The finished frameworks are set on a platinum-gold foil (Pt 95; Au 5), and the glass-water slurry is applied amply (Fig 7a). Air impactions must not occur, and the framework must not be covered completely with the glass-water mix, so that the air in the porous framework may escape. The infiltration firing takes from 4 to 6 hours at 1100°C, depending on the size of the object. Single-tooth restorations are fired for 4 hours, while fixed partial dentures take 6 hours. In this time the once-porous alumina ceramic is completely infiltrated with molten glass, leaving practically no porosities (Fig 7b).

After the infiltrated frameworks are removed from the platinum foil, the bulk of excess glass is removed with a diamond in a turbine. The rest of the excess glass is blasted away with corundum (35- to 50-μm corundum at 3 to 6 bars) (Fig 8). Another firing (10 minutes at 960°C) is necessary to check for excess glass, which would have to be removed by blasting. The functional and esthetic reconstruction is then accomplished with conventional dental ceramics (Figs 9 and 10).

Material science

Structure

Scanning electron microscopic analysis of the sintered and infiltrated material shows the ultrastructure. In the sintered stage, the alumina particles are connected by only small joints (Fig 11). If there is a delay in the application of the slip, the previously applied portion dries. This results in an "onion shell" layered structure, which may reduce the strength of the material (Fig 12).

Fig 1a Intraoral frontal view of a patient before placement of restorations.

Fig 1b Occlusal view of the maxillary arch. A fixed partial denture is to be constructed to replace a central incisor.

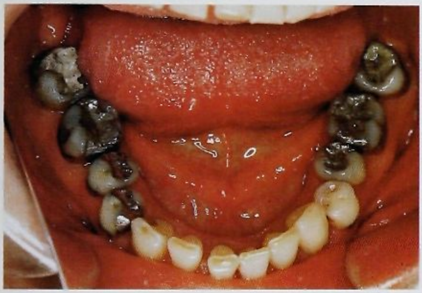

Fig 1c Occlusal view of the mandibular arch. Complete-coverage crowns are planned for all premolars and molars.

Fig 2 For all-ceramic crowns, a circular shoulder or chamfer preparation is necessary. The dies are coated with a die spacer, but care is taken not to coat the preparation margin.

Fig 3 With an addition silicone impression material, the original dies are duplicated in a special plaster.

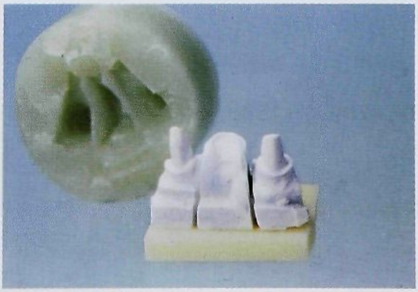

Fig 4 For the construction of fixed partial dentures, the duplicate die is glued with cyanoacrylate to an alumina-ceramic baseplate. To avoid tensions during sintering, the die is separated with vertical saw cuts. For the pontic, a "rest" must be created before the duplicating process.

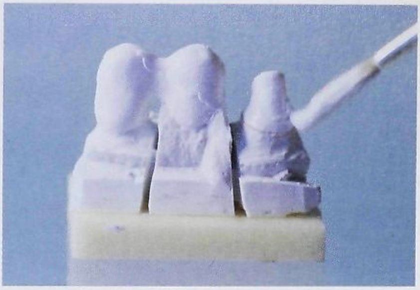

Fig 5 The slip is applied with an acrylic brush. This has to be done quickly, to avoid premature drying of the previously applied slip, which would result in an inhomogenous framework.

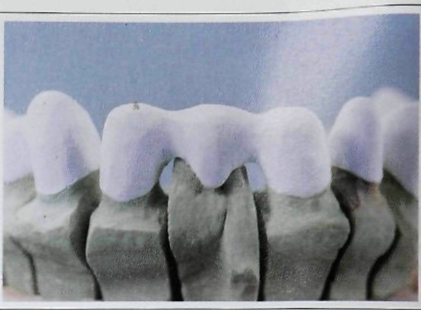

Fig 6 The final shaping of the sintered frameworks is best accomplished with hard, white silicone polishers or pink stones. The finished sintered frameworks are shown on the master die. Note the excellent marginal fit.

Fig 7a For the infiltration firing, the frameworks are placed on a platinum-gold foil. Each restoration sits on amply applied glass-water slurry.

Fig 7b During firing, the frameworks soak up molten glass. Every restoration lies in excess glass.

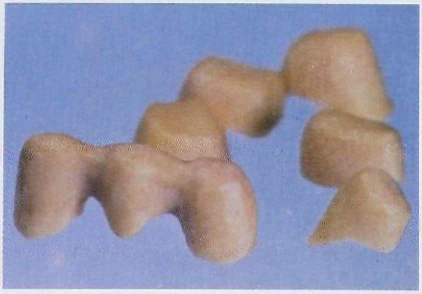

Fig 8 The excess glass is removed with diamonds and blasted away with corundum. The glass-infiltrated frameworks are shown after finishing.

Fig 9 The esthetic and functional reconstruction is performed with conventional dental ceramics.

Fig 10a Frontal view of the finished reconstruction in the patient's mouth.

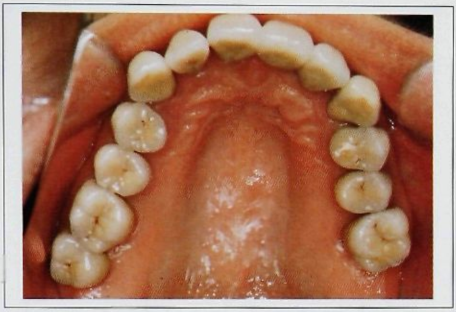

Fig 10b Occlusal view of the cemented restorations in the maxillary arch.

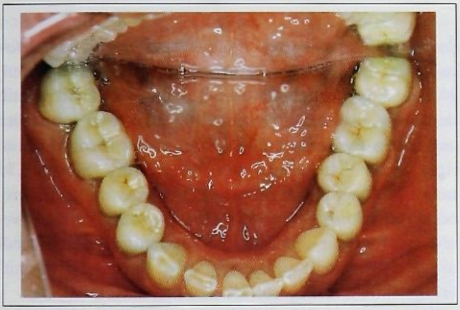

Fig 10c Occlusal view of the restorations in the mandibular arch.

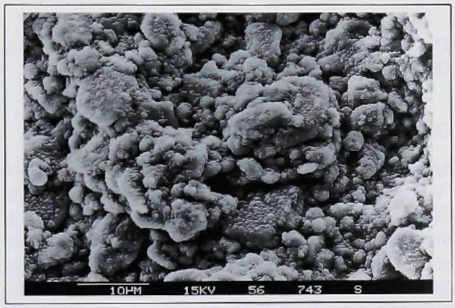

Fig 11 Sintered alumina particles. The particles are densely packed.

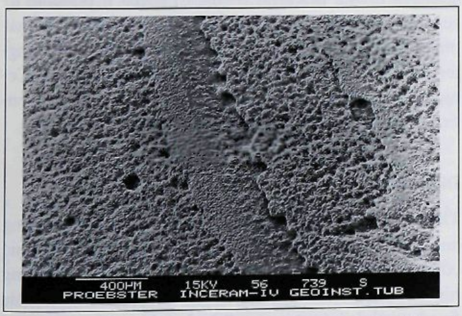

Fig 12 If there is a delay in the application of the different portions of the slip, onion shell-like layers appear, which may decrease the strength of the material (a cross section of sintered material).

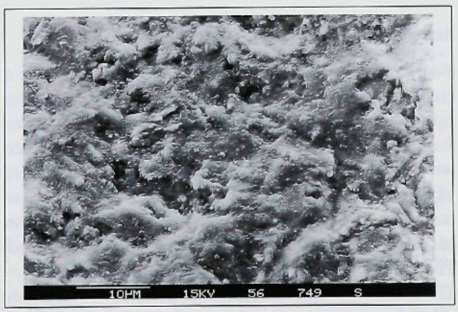

Fig 13 In the glass-infiltrated material, the alumina particles are embedded in a nonporous matrix.

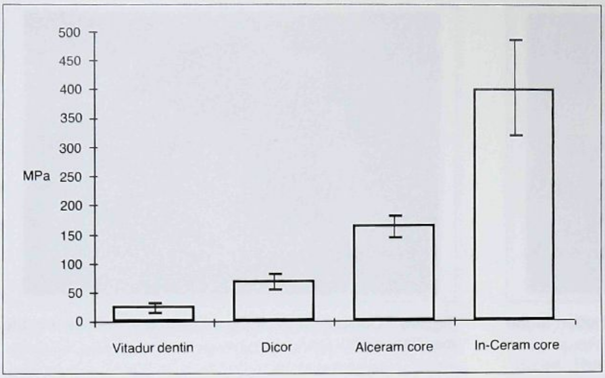

Fig 14 Three-point bending strength of selected dental ceramic materials.

The interconnecting porosities are then completely filled with glass in the second firing (Fig 13).

Three-point bending strength

Specimens (25 × 5 × 2 mm) were prepared of Vitadur, (Vita Zahnfabrik) Dicor, Alceram (Innotek), and In-Ceram ceramics. Testing was performed in a Zwick No. 1554 universal testing machine at a crosshead speed of 0.5 mm/min. The results indicated that the In-Ceram core material had approximately ten times higher bending strength than did conventional dental ceramics and four times higher strength than did glass ceramics, which have been used for the construction of fixed partial dentures[8,11,13,14] (Fig 14).

Marginal integrity

Four extracted human molars were prepared with a circular shoulder and In-Ceram crowns were manufactured. All clinical and technical procedures were performed as described above. The crowns were cemented with fast-setting phosphate cement. The margins were examined in a scanning electron microscope (Stereoscan 250, Cambridge Instruments) at a magnification of × 100. A total of 599 measuring points was examined. The resulting mean marginal opening of 39 μm (SD = 17) is in the range of cement film thickness and considered as excellent for all-ceramic crowns (Fig 15).

Clinical experiences

Eighty-two In-Ceram restoration were inserted in 19 patients. Fifty-seven restorations were single, complete-coverage crowns, 11 were inlays or partial crowns, and 14 were fixed partial dentures. The group of fixed partial dentures consisted of nine three-unit, two four-unit, and three five-unit bridges. The mean incorporation time of all restorations was 7.8 months (SD = 5.7; range of 0.5 to 21.0 months). No fracture or failure occurred within the observation period. The positive results with three-unit fixed partial dentures encouraged us to fabricate larger prostheses, like the five-unit bridge shown in Fig 16.

The construction of inlays, onlays, and partial crowns is also possible. Because beveling is not compatible with ceramics, care must be taken to create blunt angles of approximately 90 degrees. The high strength of the material seems to make it possible to cement these all-ceramic restorations with conventional phosphate or glass-ionomer cements (Fig 17). No long-term clinical data support this procedure, however. Cementing of partial In-Ceram restorations with conventional cements must be considered experimental.

Discussion

The innovative In-Ceram technique combines a sintering and infiltrating process to obtain a nonporous ceramic core material for dental restorations. The resulting high bending strength[11–14] seems to make all-ceramic fixed partial dentures possible for the replacement of not only anterior teeth, but also posterior teeth.[9] The achievable marginal gaps[11,15] are within the range of the cement film thickness and are considered excellent, especially for a ceramic material. In a clinical observa-

Fig 15 Marginal area of a cemented In-Ceram crown on a natural tooth. The marginal opening is in the range of 20 to 40 μm.

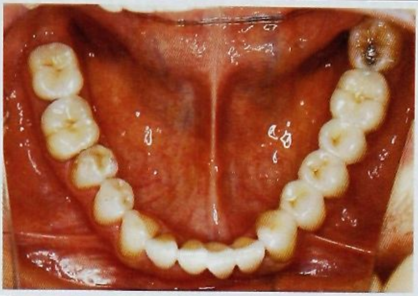

Fig 16 Mandibular arch of a patient with multiple In-Ceram restorations, including a five-unit fixed partial denture spanning teeth 33 to 37.

tion period of almost 2 years, no failure occurred. Although this is a promising result compared to experiences with other all-ceramic restorations,[4] a longer observation period (at least 5 years) with a larger number of restorations is necessary before the suitability of the In-Ceram material for fixed partial dentures can be judged.

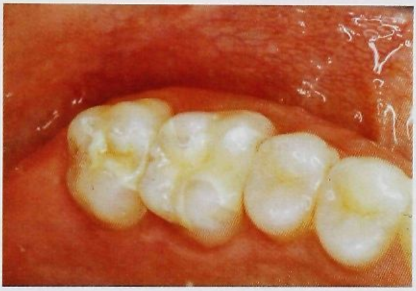

Fig 17 In-Ceram inlays cemented with glass-ionomer cement. The restorations have been in function for 10 months.

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