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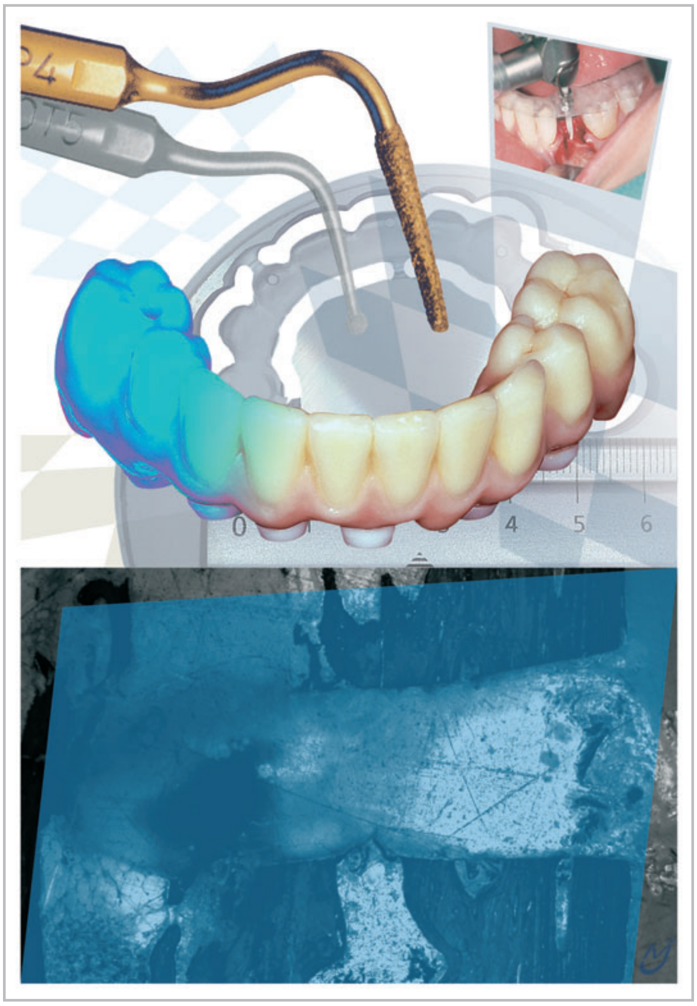

SPECIAL REPRINT

Xawex Zirconia – A New Framework Material for CAD/CAM All-Ceramic Dental Restorations

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A new dental alliance: Xawex, i-mes and WIELAND Dental + Technik

The materials described in and used for the following article “Xawex Zirconia – A New Framework Material for CAD/CAM All-Ceramic Dental Restorations” are now available from a different manufacturer.

The entire system is being marketed by WIELAND Dental + Technik GmbH & Co. KG in Pforzheim, Germany, under the name of “ZENO™ Tec System.”

WIELAND is the manufacturer of the Xawex G 100 blanks, distributing them under the name of “ZENO™ Zr Disc.”

The newly founded company, WIELAND i-mes, is the manufacturer of the ZENO™ Premium 4820, ZENO™ Premium 3020, and ZENO™ 4030 milling units.

Nothing has changed regarding the production parameters for the zirconia blanks, and the milling parameters have remained unchanged as well. The following article is therefore fully applicable to the ZENO™ Tec System.

Urs Brodbeck, Dr. med. dent.
Zürich, Switzerland, September 21, 2005

Xawex Zirconia – A New Framework Material for CAD/CAM All-Ceramic Dental Restorations

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Key Words Xawex method, zirconia, CAD/CAM systems, framework material, ceramics

Summary Ceramics have yielded good results as intraoral restorative materials for many years. Unfortunately, the step toward all-ceramic dental restorations was not a simple one, as many concepts and products were characterized by excessive clinical failures due to fracture. Of all ceramic materials, zirconia has the most advantageous material properties; it has been used in many medical fields and elsewhere. It is only the fact that zirconia requires costly CAD/CAM system for processing that has kept this excellent material from becoming more common in clinical dentistry. However, the current CAD/CAM systems allow zirconia frameworks to be fabricated at acceptable cost and with an excellent fit, so that they are now potentially interesting to any practicing dentist. For the first time, an all-ceramic framework material is available which in all probability will be able to replace the tried and tested metal-ceramic system for many indications. This report presents Xawex zirconia. This material allows the fabrication of well-fitting frameworks for single crowns as well as for multi-unit bridges of any shape and length.

Introduction

The term "CAD/CAM" (computer-assisted design/computer-assisted manufacturing) was first introduced in dentistry by *Duret*[6] in 1985. CAD/CAM aims at simplifying (or actually facilitating) certain process steps in the fabrication of dental restorations for the dentist (chairside) and the dental technician (in the laboratory). As recently as ten years ago, a review article described eleven different dental CAD/CAM systems.[33] Meanwhile, no one is any longer in a position to count the systems for the fabrication of dental restorations. Many of them have been consistently improved and optimized; others have disappeared from the market. Table 1 shows the currently best-known suppliers of CAD/CAM solutions in Germany.

When it comes to metal-free restorations, CAD/CAM is primarily suited for the fabrication of dental restorations made of the high-performance ceramic material, zirconia. Right now, no other ceramic material can compete with zirconia on strength (Table 2). As early as 1970, *Helmer*[15] described biomedical applications for zirconia. Since that time, the material has proven its value in several medial fields, e.g. in balls of hip joint prostheses, in implant abutments, or as endodontic posts.[4,13,20,29] Zirconia is therefore also recommended as framework material for crown and bridge restorations. Single crowns with zirconia frameworks have already successfully rivaled metal-ceramic crowns in strength.[32] In long-term clinical studies at different universities, three-unit to four-unit bridges with zirconia frameworks have been clinically successfully for several years.[31,35,41]

System	Company	URL
Cercon smart ceramics	DeguDent, Hanau	www.degudent.com
Cerec,	Sirona Dental Systems, Bensheim, Germany	www.sirona.de
DCS Precident	DCS Dental, Allschwil, Switzerland	www.dcs-dental.com
DigiDent	Girrbach Dental, Pforzheim, Germany	www.girrbach.de
Etkon	Etkon, Gräfelfing, Germany	www.etkon.de
Everest	KaVo, Leutkirch, Germany	www.kavo-everest.com
i-mes dental	i-mes, Eiterfeld, Germany	www.i-mes.de
Lava	3M Espe Dental, Seefeld, Germany	www.3m.com/espe
Procera	Procera, Gothenburg, Sweden	www.nobel-biocare.de
Wol-Ceram	Wol-Dent, Ludwigshafen, Seefeld, Germany	www.wolceram.de
Xawex	Xawex, Ebmatingen/Zürich, Switzerland	www.xawex.com

Table 1 Dental CAD/CAM system manufacturers

Material	Flexural strength (MPa)	Fracture resistance ($MPa \cdot m^{1/2}$)
Zirconia	900[34]	9,00[34]
Industrial alumina	547[25]	3,55[25]
Slip-cast alumina	419[25]	2,48[12]
Dicor MGC	220[25]	2,02[25]
IPS Empress	182[25]	1,77[25]
Omega sintered ceramics	85[25]	0,99[25]

Table 2 Material properties of dental ceramics according to *Geis-Gersdorfer* et al.[12], *Lüthy*[25] and *Rieger*[34]

For many dentists, metal-ceramic systems are still their first choice for crowns and bridges. However, the point that their fracture risk is lower can no longer be defended today for certain indications. There are also various reasons weighing in on the side of all-ceramic dental restorations. Their high degree of oxidation makes for an optimum of biocompatibility, a point that is no longer seriously contended.[1,11,16] Tooth-like optical properties allow the complex light pattern of the natural tooth to be imitated more readily. In addition, there are no esthetically objectionable gray discolorations of the gingiva or the peri-implant soft tissue by a dark framework or visible metal margins. And, finally, crowns and bridges with zirconia frameworks no longer need to be retained adhesively, but can be cemented in place conventionally using glass-ionomer or zinc oxide/phosphate cement.[38]

Zirconia as a Material for Restorative Frameworks

In the English-speaking world, the common term “zirconia” has come to be preferred over “zirconium oxide“; the more precise “zirconium dioxide” (ZrO_2) is encountered even more rarely. Zirconia is a polycrystalline ceramic material. It may be present in one of three different phases (monocline, tetragonal, cubic), each of which gives the material different properties. Zirconia is usually blended with a small amount of other oxides (MgO, CaO, Yt_2O_2) which stabilized the various phases. Tetragonal zirconia partially stabilized with yttrium oxide (Yt_2O_2) has proven its value for medical use.

This type of zirconia is the only ceramic material that features a so-called “self-healing mechanism.” By adding 2 to 3 mol per cent of Yt_2O_3 to pure ZrO_2 as a partially stabilizing oxide, a multi-phase crystalline structure is created that is called partially stabilized zirconia (PSZ). Microstructurally, PSZ consists predominantly of cubic zirconia with homogenously with a minor percentage of finely distributed monoclines and tetragonal crystals. Thanks to a phase change of the ZrO_2-Yt_2O_3-Systems from the tetragonal to the more voluminous monocline shape, the tip of a progressive crack is placed under pressure, preventing its propagation. Phase change also occurs spontaneously at the surface of PSZ, resulting in an annealing-like effect by building up pressure to a depth of several micrometers.[30]

In the production of zirconia, a powdery mixture is first condensed to form a so-called green body. Zirconia is still porous in this green phase and relatively soft. Its terminal strength is achieved by a sintering process at temperatures of up to 1,600 °C. This dense sintering of the green bodies causes a linear contraction of the material of approximately 20%. A subsequent high isostatic pressure (HIP) treatment additionally reduces the level of imperfections in the crystal lattice, further optimizing strength. However, it has not been shown whether HIP zirconia is significantly stronger than conventional fully sintered zirconia after the milling process required for the fabrication of a dental restoration. It is probable that the traces left behind by the instruments after the milling process and the microcracks on the ceramic surface are more significant for reducing the strength of the material.[23,42] Thanks to its excellent strength, zirconia is now capturing an ever greater market share as a material for crowns and bridge frameworks, at the expense of dental alloy frameworks. Zirconia has also consistently demonstrated its superiority over other dental ceramics in terms of material reliability (resistance to cracking, Weibull module), which emphasizes the homogeneity of the crystalline structure.[9]

Zirconia, which by nature has a whitish color, is amenable to dyeing. Whether and how the accompanying changes in the crystalline structure affect its strength is a question that is currently being studied. Preliminary results, however, indicate that this is not associated with any deterioration in material properties.

Processing Zirconia

For dental restorations, zirconia can be processed either in its densely sintered form or in its green phase.

Due to the high strength of the densely sintered zirconia, working on this places a very heavy burden on the cutting tools and spindles of the milling unit. Fabricating zirconia frameworks fabricated in this way takes a lot of time and is therefore costly.[24] Even if all milling parameters are optimally adjusted, the milling time for each framework unit made from densely sintered blanks is approximately one to two hours. Alternatively, zirconia can also be processed in the green phase.[8] The crucial advantage is that the material will still be relatively soft, shortening the milling step drastically. The time the work piece has to spend in the milling unit is shortened, and there is less wear and tear on the tools, which moreover do not need to be as expensive. All this gives this option a significant economic edge over processing the densely sintered zirconia. Processing the material in its green phase is also recommended by *Luthardt*, as milling the sintered material destroys its microstructure, resulting in microcracks.[23] Microcracks often lead to clinical failure, especially if they occur on the internal occlusal surface of all-ceramic crowns.[18]

Figure 1 The Xawex G 100 blank is disk-shaped and as a diameter of 100 mm. It consists of zirconia in its green phase. Depending on their size, up to 30 units may be milled from the same blank. Several thicknesses are available to meet different needs

As the work pieces undergo a contraction processes during the final sintering phase, they will have to be milled to an enlarged size. This contraction compared to the green phase has its advantages, especially regarding the finishing of the internal crown surfaces: On one hand, larger cutters can be used for gross cutting; on the other hand, cutters with small diameters are able to finish these internal surfaces to greater detail, improving their internal fit and thereby supporting the anti-rotation features of the framework.

The Xawex Method

The Xawex method uses a large round blank 100 mm in diameter (Figure 1). CAM processing is performed in the partially sintered state (green phase). The exact designation of the blanks is Xawex G 100. A patent claim has been filed for the disc shape. Thanks to a demanding fabrication process, the crystalline structure is optimized as early in the partially sintered state, homogenously throughout the blank. This is why the contraction behavior of each blank is amenable to exact calculation; the requisite parameters can be fed into the CAD program's calculations by read in using a specific code. This ensures precision in the contraction behavior of frameworks of all sizes and shapes during the final sintering step. Xawex (Ebmatingen/Zürich, Switzerland) also supplies the corresponding sintering furnace, where the blanks are fully sintered over a period of approximately twelve hours using a high-precision firing program. The dental technician benefits from the large size

Figure 2 The i-mes Premium milling machine was developed from a proven industrial milling machine to accommodate the special needs of dentistry. In addition to Xawex zirconia, it will work with many other materials such as titanium, non-precious metals, or acrylic resin. i-mes also offers systems that are suitable only for Xawex (and that carry a lower price tag)

of the blank mainly in two ways. On one hand, up to 30 units (depending on their size) can be produced from a single blank, which is highly economical. The milling time is 15 to 20 minutes per object on average. On the other hand, even larger bridge frameworks with up to 16 units can be cut from the disk and fully sintered without any distortion.

The milling units by i-mes dental (Eiterfeld, Germany) were not developed specifically for the dental field. They have been proven in other industries for e.g. die or electrode construction. There are several materials suitable for CAD/CAM processing in dental technology. In addition to zirconia in its green phase, various alumina ceramics, non-precious alloys, titanium, and acrylic resin can be shaped. The i-mes machines are configured individually depending on their intended use. The most extensive machine is the i-mes Premium (Figure 2), which allows dry or wet processing of all the materials mentioned using two separate basins. All machines feature a industry-standard interface (STL) and therefore ready for future innovations and upgrades. A large milling center in the Munich, Germany region (etkon, Gräfelfing) started including Xawex G 100 zirconia in its comprehensive offering during the fall of 2003; by the end of 2004, approximately 15,000 units had been delivered successfully.

Designing the Zirconia Frameworks

The zirconia frameworks have a whitish basic hue prior to veneering (cf. Figure 12); contrary to what one would expect, their opacity is low. Light conductivity is approximately on the same order as densely sintered alumina.[7] If desired, the framework can be dyed prior to final sintering. The zirconia framework can be given different margin designs, depending on the clinical situation. The same options exist as for metal frameworks. Zirconia is the only ceramic material that can be configured for a feather-edge preparation. (That is why this material can be used for making ceramic knives for domestic use.) If a shoulder preparation is present, the framework can be partially or circularly reduced and then rebuilt in veneering ceramics. Moreover, the framework can be ground very thin all the way to the outer preparation margin and veneered with sintered ceramics (Figure 3). If esthetic considerations are secondary, a white zirconia margin may be left in place. This is recommended for less invasive preparation types (shallow chamfers or tapering preparations). If required, the frameworks may be tried in intraorally (cf. Figure 12).

By analogy with the bridge framework design in metal-ceramic, zirconia frameworks must have a minimum cross-section at the pontic connection sites. As these minimum cross-sections have not been finally established, it is recommended to design all frameworks as massively as possible. An in-vitro study evaluating the connection sites of zirconia frameworks has shown that the following cross-sections should prevent fatigue-related fracture for a period of 30 years: 6 mm^2 for three-unit bridges with one pontic, 8 mm^2 for four-unit bridges with two pontics, and 11 mm^2 for five-unit bridges with three pontics. This study had been performed using round connectors and water storage; the bridges were loaded with simulated masticatory forces of up to 880 N.[39]

Veneering the Frameworks

Various manufacturers of ceramic veneering materials offer sintered ceramics whose coefficient of thermal expansion (CTE) matches that of zirconia. The veneering ceramics used in the clinical cases shown here are experimental products by Ivoclar (Schaan, Liechtenstein). By contrast with metal frameworks, zirconia frameworks exhibit no distortion even after multiple firing cycles, as the temperatures during veneer firings never even come close to the temperature critical for zirconia (above 1,500 °C). As with any new technique, dental technicians are expected to learn new things to add to their stock of experiences.

Inserting the Restorations

The greatly improved adhesive techniques of recent years offer the clinician many new therapeutic options. Different types of surface treatments and the use of composite resins ensure a durable bond between the remaining hard tissues of the tooth and the dental restoration. As early as 1955, *Buonocore* had introduced the principle of enamel etching, which allows a strong micromechanical bond with the dental enamel. Dentin adhesives made immense progress, offering the dentists advantages in many different ways. If dentine adhesives are used properly, postoperative complications are uncommon. Dentin adhesives improve the marginal seal and reduce the incidence of microcracks, resulting in less discoloration in the marginal region and therefore in superior esthetic results. If only little natural tooth substance is left or if its retentive shape is suboptimal, the use of a dentin adhesive and a composite cement is recommended to optimize retention. In adhesive cementing, the cement should not adhere only to the dental hard tissues, but also to the restoration itself.

The rules for creating a durable bond to zirconia are different from those for conventional silicon-based ceramics. If silicon-based ceramics are etched with hydrofluoric acid, this will create a retention pattern at the surface that allows mechanical microretention between ceramics and composite. Applying a silane coupling agent adds a chemical bond and increases overall bond strength. Using the Panavia composite adhesive (Kuraray Dental, Düsseldorf, Germany) after air-abrading the surface with alumina (50 to 110 Nm, 2.5 bar) yields bond values that fully meet clinical requirements.[5,19,22] This composite adhesive contains the adhesive phosphate monomer MDP, which forms a chemical bond with the zirconia surface. That this adhesive bond is durable and stable was confirmed in a long-term trial where test speciments were stored in water for two years and subjected to a cyclical mechanical load.[43] Interestingly, it is much more difficult to create an adhesive bond to alumina using relatively simple means.[3]

Discussion

All-ceramic single crowns (Figures 3 and 4) have proven their value in everyday clinical practice during the past ten years as important progress was made by a variety of products. Procera AllCeram, InCeram, and Empress 2 are all systems that have performed well in long-term clinical studies.[10,28,37,40] Zirconia has significantly better material properties and will therefore exhibit even lower fracture rates. The question the dentist is faced with is therefore as follows: Looking at the intraoral life of the restoration, does it still make any difference whether a metal-ceramic or a zirconia crown is inserted? This question will most probably have to be answered in the negative. Those who want to be absolutely certain will of course have to await the results of the first long-term clinical studies. However, those who have confidence in the laboratory results may even now rely on the fact that zirconia and metal-ceramic systems are

Figure 3 For these four single crowns, the Xawex zirconia frameworks taper off toward the preparation margin. This framework design offers optimum stability in the marginal region

Figure 4 The four maxillary left single crowns were conventionally cemented with glass-ionomer cement

Figure 5 By contrast with all-ceramic systems with lower strength, crown and bridge restorations with zirconia framework allow less invasive modes of preparation. This is especially important in teeth that have not been treated endodontically, to maintain their vitality

Figure 6 Three-unit bridges with zirconia frameworks have already proven their value in clinical studies over many years

Figure 7 The three-unit Xawex zirconia bridge, restoring the second premolar, in situ. Despite minimal buccal preparation and a framework design that allows a white zirconia margin to reach all the way to the surface of the tooth, light conduction in the region of the gingiva is not affected

equivalent with regard to their fracture rates.[32] One might add to this the observation that many metal-ceramic crowns are not replaced, after many years in situ, because of fracture but because an ugly metal margin with a dark root becomes visible. This esthetically undesirable aspect can be eliminated or at least reduced by inserting an all-ceramic crown.

Different rules apply to all-ceramic bridges. Occlusal forces of up to 880 N can be measured especially in the posterior region.[17] Bridges with InCeram Alumina or Empress 2 frameworks would have to feature excessively large, overcontoured connectors, which would greatly limit their range of clinical indications. These materials can be recommended for anterior three-unit bridges in selected cases, but are not recommended for the posterior region. Given the superior material properties of zirconia, more and more researchers are interested to see how this material performs in the posterior region. Zirconia bridges are currently being clinically tested at three universities (Aachen and Homburg, Germany; Zürich, Switzerland).[31,35,41] To date, no framework fractures have occurred in any of these three studies. Proof is thus beginning to accumulate that with zirconia, for the first time in dental history, an all-ceramic dental material is now available for use in bridge frameworks for the anterior and posterior region.

Figures 5 to 7 show a typical posterior three-unit bridge. The Xawex system can also be used to produce four-unit and multi-unit bridges of any width. Figures 8 to 16 show the fabrication of a ten-unit maxillary bridge with up to three adjacent pontics. Figures 17 to 24 show a total maxillary and mandibular reconstruction with two five-unit bridges, one six-unit bridge, and one seven-unit bridge. A ten-unit, strictly implant-supported bridge with a zirconia framework is presented in Figures 25 to 31. It is true that these multi-unit bridges must at this point still be considered experimental, as there are still insufficient data extant on bridges for four or more units. If the frameworks are sufficiently massive, however, the risk appears to be limited in selected cases.[39]

In the absence of sufficient clinical experience, the following practical guideline applies: Ceramic framework should always be designed as massive as possible. Of course, the fundamentals of prosthodontics (no interference with speech, mastication, esthetics) and periodontology (no impingement on papillae, attention to biological width, oral hygiene) may never be disregarded. With regard to the design of the framework on the lingual/palatal side, the question may be asked whether the zirconia, for reasons of stability, should not go all the way to the surface or be covered with a minimum of dye and glaze to achieve a tooth-like color. The natural appearance of the teeth may be optimized on the buccal/labial side using a ceramic veneer. On the lingual/palatal side,

Figure 8 Baseline situation. An esthetically unsatisfactory nine-unit metal-ceramic maxillary bridge. The patient requested a new, esthetically optimized and metal-free bridge with an additional premolar extension on the left side

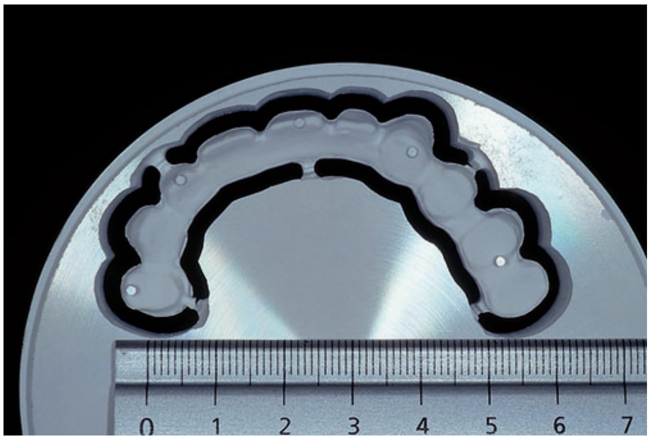

Figure 9 The ten-unit zirconia framework before removal from the Xawex blank in the green phase. During the subsequent sintering process, the framework will shrink by approximately 20% to attain its definitive form and strength

Figure 10 In the green phase, the framework can be worked on simply and efficiently using suitable cutting tools

Figure 11 Occlusal view of the maxilla with augmented alveolar ridges and prepared abutments

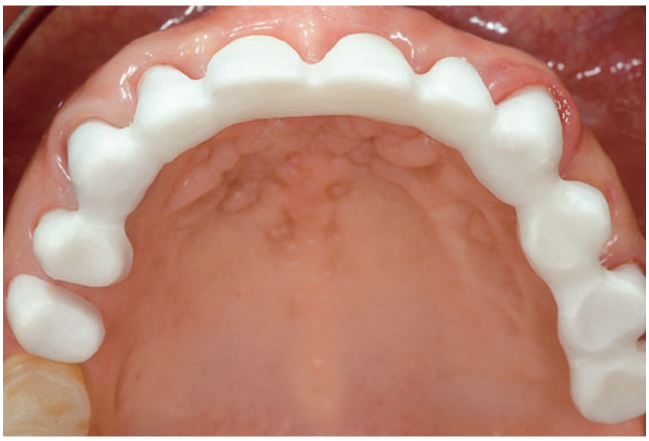

Figure 12 The Xawex zirconia framework for a ten-unit bridge with a distal extension on the left and the framework (primary coping) for a single crown on the right second premolar during clinical try-in

Figure 13 The ten-unit Xawex zirconia framework and the single-crown framework at try-in. Compared to the baseline situation in Figure 8, the soft tissues have been harmonized by periodontal soft-tissue augmentation surgery and by covering areas of recession and lengthening clinical abutments

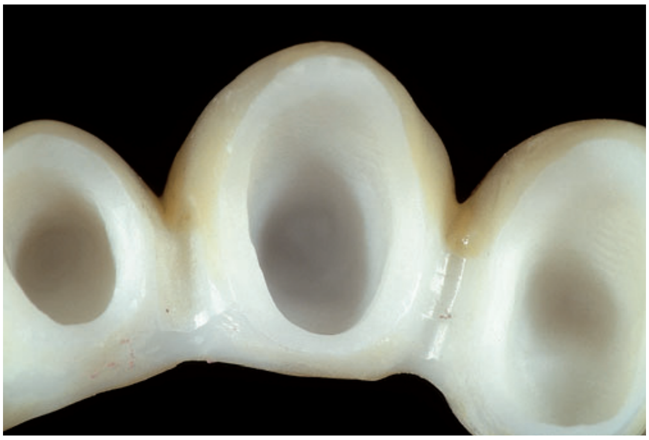

Figure 14 This detail of the completed restoration shows that, for reasons of stability, the zirconia has been veneered with sintered ceramics only on the buccal side; on the palatal side, the entire space available has been used for the zirconia framework. Interdental recessions were avoided almost completely on the palatal side, avoiding predictable fracture points

Figure 15 The maxillary reconstruction with its Xawex zirconia framework after one year in situ. Despite the challenging situation at baseline, an attractive treatment results was achieved

Figure 16 This maxillary detail shows how well the restoration is integrated, both esthetically and biologically

whitish-opaque bands are usually tolerated by the patient (cf. Figure 14).

When designing the zirconia framework, the cost of the material may safely be disregarded. In crown and bridge restorations using zirconia frameworks, the cost per unit counts, regardless of how massive the framework turns out to be and how much material is ultimately utilized. When working with metal-ceramic systems, the cost of the material does matter a lot, especially if a sophisticated technique and high-gold alloys are used.

An important advantage when fabricating wide-span bridges is that zirconia frameworks do not distort when the veneer is fired. Critical temperatures that might result in framework distortion are not achieved by a comfortable margin. In metal-ceramic systems, by contrast, one often observes that the metal framework exhibits a perfect fit at try-in, but that that fit is suddenly lost after veneering – the framework having become distorted after multiple firing cycles.

Composite cements may increase the clinical fracture rates of certain all-ceramic systems.[26] Thanks to the high intrinsic stability of the zirconia framework, however, it most probably does not need amplification by a composite cement. It has also been reported that the coefficients of elasticity of the dye materials affect the fracture resistance of various all-ceramic crown systems.[21,36] Whether that is also the case for crowns with zirconia frameworks remains to be investigated.

Figure 17 The original treatment provider had incorporated various maxillary and mandibular metal-ceramic restorations for this patient, who had multiple teeth congenitally missing. The gingiva surrounding the abutments is highly inflamed despite acceptable oral hygiene

Figure 18 An earlier version of the restorations (also metal-ceramic) had also caused continuously gingival inflammation, and the present set of restorations, which had been in situ for five years, did not achieve any improvement in this respect. The patient suspected an allergic reaction and requested completely new, metal-free restorations

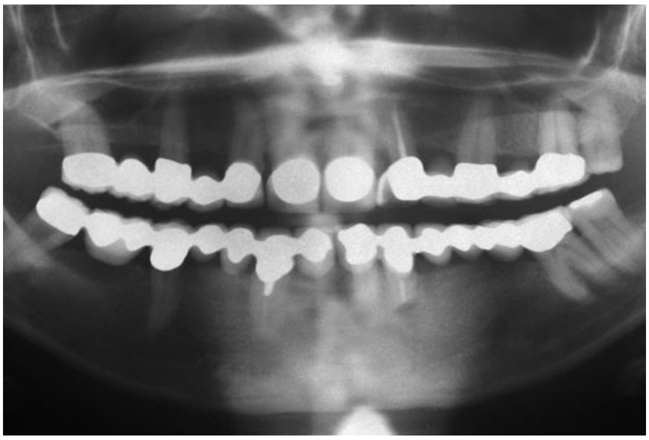

Figure 19 The preoperative radiograph shows that several teeth are missing. Metal-ceramic restorations present were two maxillary five-unit bridges and two maxillary single crowns as well as a six-unit and a seven-unit mandibular bridge

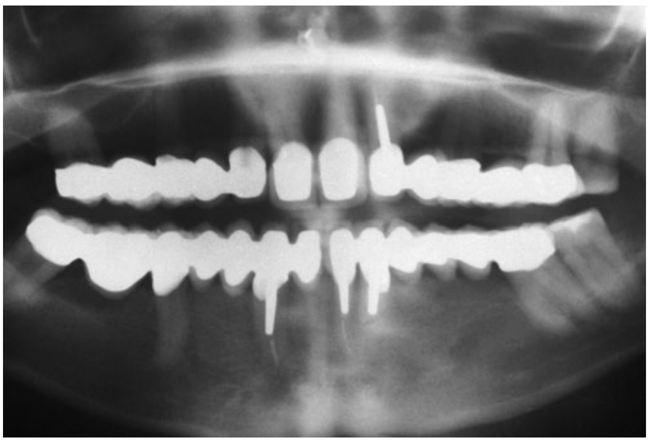

Figure 20 Radiograph of the overall restorative result after completion of the treatment. Zirconia is highly opaque to x-ray radiation and is clearly delimited both as a framework material and as a material for endodontic posts. The bridges have the same spans as their metal-ceramic predecessors

Figure 21 The Xawex zirconia framework at try-in. The fit is checked with a silicone material. At the same time, the bite and the pressure on the pontic are checked using a temporary resin

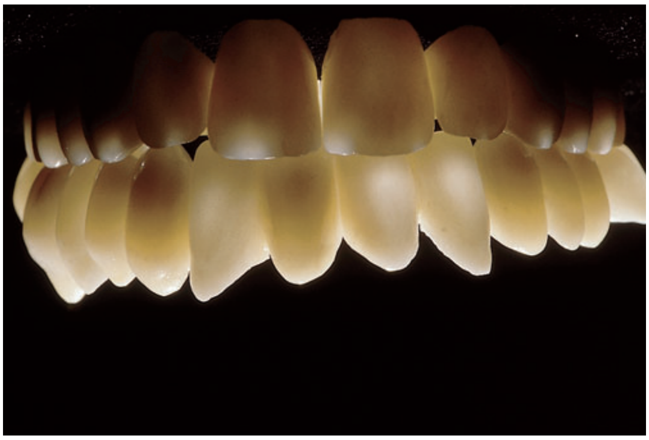

Figure 22 Complete all-ceramic maxillary and mandibular reconstruction using Xawex zirconia frameworks, shown in transillumination (25 units)

Figure 23 An aesthetically and functionally successful treatment result. The patient had desired the same bright shade already present in the previous restorations (cf. Figure 17)

Figure 24 With the new all-ceramic, the gingiva is practically free of inflammatory reactions; compared to baseline (cf. Figure 18) there is no reason for concern

Most dentists prefer a conventional (glass-ionomer or zinc oxide/phosphate cement) cement for their crowns and bridges. For Procera AllCeram crowns (with their alumina frameworks), conventional cementing using zinc oxide/phosphate cements has proven effective. Restorations with zirconia frameworks should behave in the same manner.[28,38]

Adhesive cementing is recommended especially in the following two clinical situations: If the tooth preparation is short or provides suboptimal retention, the use of a composite cement can lower the risk of retention loss. Where esthetics plays an important role, adhesive insertion of zirconia restorations is also recommended. The correct use of a composite cement complete with a matching dentin adhesive minimizes the probability of microcracks forming in the marginal region. Such microcracks may lead to gray discoloration near the margin of the all-ceramic crown, compromising overall esthetics. This is particularly true in cases where the die is tooth-colored and the restoration to be inserted is very thin and consequently highly transparent.

Air-abrading with alumina to optimize microretention does not seem to have any negative impact on fracture resistance either in adhesively or in conventionally inserted restorations. Zirconia appears to be one of the few ceramic materials where air-abrading does not induce microc-

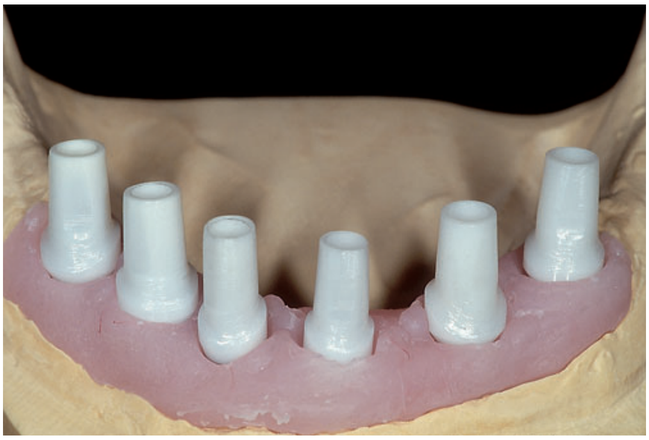

Figure 25 ZiReal abutments for a fixed mandibular reconstruction, made from zirconia (3i Implant Innovations, Karlsruhe, Germany) on six implants on the master cast. The abutments were parallelized by minor adjustments using abrasive instruments

Figure 26 The zirconia framework for the ten-unit complete bridge on the ZiReal abutments at clinical try-in

Figure 27 The zirconia framework is veneered with sintered ceramics. The framework exhibits no distortions, even after multiple firing cycles

Figure 28 The screwed-on ZiReal abutments are intraorally connected with the completed zirconia bridge using a composite adhesive. This procedure allows the fabrication of a bridge supported by several implants that exhibits a perfectly passive fit

Figure 29 The fixed-removable, passively fitting, ten-unit all-ceramic bridge supported exclusively by six implants

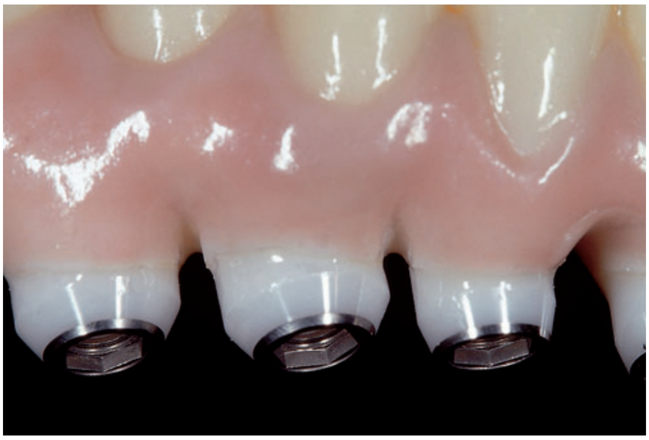

Figure 30 Detail of the ZiReal abutments adhesively connected with the zirconia bridge. At their apical ends they show integrated titanium inserts to optimize their connection with the implant heads

Figure 31 The complete all-ceramic mandibular bridge with its Xawex zirconia framework on six implants in situ. The access holes for the abutment screws are still closed with temporary material

racks.[30] A study on zirconia post-and-cores was even able to show that the air-abraded posts exhibited significantly higher fracture resistance than non-abraded posts.[27]

As with metal-ceramic restorations, restorations with a zirconia framework sometimes fail due to chipping of the ceramic veneer.[2,35] The surface of the fracture may in these cases be located inside the veneer, with the zirconia still being covered with a sintered veneer layer (cohesive failure). There are also cases, however, where the entire veneer is detached, partially exposing the underlying zirconia framework (adhesive failure). In many clinical cases, rather than redoing the entire restoration, an intraoral repair using a light-polymerizing composite may be attempted. In cohesive failure, it is possible to pre-treat the veneer surface by etching it with hydrofluoric acid and to silanize it. In adhesive failure, where the zirconia is exposed, the framework can first be air-abraded, whereupon the surrounding ceramic veneer is etched with hydrofluoric acid and silanized. The best composite to zirconia bond is achieved by applying a thin layer of Panavia as a so-called bonding agent.[43].

A frequent problem described for crowned teeth is pulp necrosis.[14] Pulp necroses continue to occur in all-ceramic crown systems, e.g. in 2% of the cases in the Procera AllCeram study.[28] The endodontic treatment that is necessary in these cases requires access through the crown. In the case of a zirconia framework, it is recommended to create the aperture using diamond disks and copious irrigation. Once the endodontic treatment is completed, the crown is sealed with a dental composite. A redeeming factor may be that even a perforated zirconia crown is much more probable than any other all-ceramic crown to remain functional for a long time, despite structural weakening.

In 2001, *Filser* et al.[9] posited that no low-cost all-ceramic bridges were able at the time. In their publication dated 1997[8], they had presented the DCM (direct ceramic machining) system, which was the first system to permit the processing of zirconia in a partially sintered state. The average milling times required to fabricate a framework could thus be reduced from 120 minutes (for fully sintered zirconia) to approximately 20 minutes (author's experience). The subsequent final sintering has no significant effect on the final price. What does have an effect is the time the dental technician requires to fit the framework to the master cast. With both modes of fabrication, this must be done in the fully sintered state, where the material is much more difficult to machine, which may take a lot of time and be quite expensive. There seems to be a growing trend toward processing in the green state, as this is faster and more cost-effective. The purchase price of the materials used is also important. Depending on their size, up to 30 units may be cut from a Xawex disk with a diameter of 100 mm in the green state.

In a prospective study directed by the author and conducted in his private practice, 234 Xawex units have been under observation since March of 2003. These include both single crowns and multi-unit bridges (the widest one being a ten-unit bridge). All the cases illustrated here are included in the study. Within the first two years, complications occured in two cases: One molar crown had to be perforated because endodontic treatment was required; one premolar crown exhibited veneer chipping on the palatal cusp (cohesive failure), which was repaired with composite. Both crowns continue to be in situ. Of course, there are as yet no long-term data on the clinical performance of this type of restoration.

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Editor's Remark

Medical progress is closely linked to the improvement of methods, materials and devices. The Innovations section offers up-to-date information about new developments in dentistry. The products and procedures described here will not necessarily have a positive long-term record yet. This section also welcomes ideas and working hypotheses, giving creative authors the opportunity to subject their thinking to the scientific scrutiny of their peers.