The Bonding of Zirconium Oxide Restorations
– *finally a solution that works!*

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Zirconium oxide restorations have many advantages, however, the fact that they are difficult to bond has left many dentists embarrassed by restorations that have fallen out or become loose. This article outlines a proven technique for "fusing" a thin layer of glass matrix to the inside of the zirconium oxide restoration ("Hotbond"). This glass layer can then be conventionally etched by HF acid to allow utilisation of conventional ceramic bonding techniques. The technique can be further improved by having the laboratory apply silane and bonding agent ("C-Link") under controlled conditions. This simplifies the bonding process for the dentist and eliminates the risk of contaminating the HF surface, an often overlooked source of bonding failures.

This article has been translated from German, and was originally published by Teamwork-Media.

Dentists and dental technicians are caught in a world where they are subjected to rapid development and aggressive marketing of the latest products, without the evidence of long term clinical studies. Pressure to move towards these developments cannot be underestimated. This is evident in the case of bonding with zirconium oxide. This article presents potential solutions to the issues.

Aesthetics

The argument which is put forward quite often that zirconium oxide cementation in the anterior region would give a very opaque look and conventional dental cements yield poor aesthetic results, cannot be confirmed by us. With an optimal preparation technique adapted to the given conditions (fig. 1), usage of digital images during and after the preparation (stump discolouration and metal cores), appropriately coloured frameworks as well as an adequate thickness of layering porcelain, and good staining technique, some excellent results can be achieved (Fig. 2 to 5). When the translucence of aluminum oxide is compared with that of zirconium oxide, it is often overlooked that aluminum oxide framework requires a minimum layer thickness of 0.6 to 0.7 mm in the anterior region whereas zirconium oxide framework only requires a 0.3mm thickness and hence there is very little difference in transparency.

Glass solder technique

Particularly in the case of minimal or non-invasive treatment methods such as 3/4 crowns, inlays or maryland bridges made from zirconium oxide, enamel bonding is preferred. For adhesive cementation of full crowns and bridges adequate conditioning of the ZrO2 surface is required. For good mechanical coupling and chemical bonding of silane, etchability of the adhesive surface is necessary. On conventional ceramics, a 40% hydrofluoric acid solution has the greatest effect (132). However, hydrofluoric acid does not have any effect on zirconium oxide. An interesting solution has been found with the glass solder technique for coating and fusion of zirconium oxide restorations (133-135). In the field of dental science, the term "solder" needs some getting used to for a glass-ceramic material but from material-technological point of view, it is correctly used. Zothner had the idea to develop silicate based glass particles which could help achieve complete wetting, gap-free depositing (adhesion) and diffusion into the zirconium oxide surface. This was proven through REM and recently in the Max Planck Institute in Berlin through STEM (Scanning Transmission Electron Microscope) on an atomic level [Fig 6].

The pioneering development with the products Hotbond, tizio connect and zirconnect (DCM, Rostock) [Fig 7] opens numerous new indications for zirconium oxide processing such as:

- material fusion or joining of bridge or bar segments (Hotbond),
- the joining of generic implant abutments with custom emergence profiles (Hotbond)
- soldering of custom zirconia abutments to titanium interfaces (Hotbond Tizio Connect)
- precoating and bonding of zirconium oxide framework (Zirconnect)

Fusion of bridge or bar segments

For the fusion of framework segments, the Hotbond operator kit is used. It consists of a main solder and two secondary solders in connection with an innovative and patented joining element (Fig. 8a and b).

Technique for atypical bonding between zirconium dioxide and titanium

Tizio connect enables the fusion of a pre-coated titanium part with contouring elements made of zirconium oxide for manufacturing custom abutments (fig. 9a to c).

Pre-coating and bonding of zirconium dioxide surfaces

The pre-coating of ZrO2 frameworks with Zirconnect, a glass ceramic layer, changes the surface of the zirconium dioxide to a chemically treatable surface versus the usual mechanical retention. The formation of a leucite phase leads to development of retentive structures after etching. This enables silanisation before bonding in the mouth, or also allows composite veneering in the dental laboratory. The microcrystalline structure formed during the firing process for veneering porcelain and conditioning of the adhesive surfaces improves the bonding to the ceramic structure (Fig. 10).

Patient case

In the case of an 18 year old patient with congenitally missing lateral incisors, it is shown how the application of Zirconnect to the single wing Maryland bridge zirconium oxide frameworks provides a non-invasive option of bonding to the enamel only of the unprepared tooth (Fig. 11 to 19). The patient was actually referred to us for implantation. The implant treatment of young patients with missing lateral incisors is difficult, if not contraindicated. Problems include infraocclusion due to incomplete development, buccal bone loss and the development of dehiscences in the adjacent teeth [136]. In many cases, an adhesive bridge is a more reasonable option than a risky and involved implant placement in young patients [137]. As in the case of this young patient, narrow gaps or unfavourable axial inclinations of the upper incisors pose a limitation to implantation technique despite long term orthodontic treatments. (fig. 11a and b.)

One option for treatment is the use of metal based adhesive bridges (metal based Maryland bridge). However, these exhibit a high failure rate in case of minimal invasive preparation (30% after ten years) [138]. Using retentive tooth preparation, the failure rate drops to 4 percent [139]. In terms of conservative dentistry, we wanted to avoid causing any damage to intact tooth structure. Zirconium oxide could offer a real solution for non-invasive cementation on basis of its strength(1200-1400MPa). Conventional dental bridges were contraindicated due to the intact tooth structure and the young pulp (Fig. 11c and d). The interocclusal clearance was 2 mm and hence we took a non-invasive approach with single wing and glass solder coated zirconium oxide adhesive bridges into consideration. The whole treatment procedure was explained to the patient. He decided in favour of it and against implant therapy and any other form of orthodontic treatment. Impressions of the unprepared teeth were taken. The articulated models

Fig 1 Preparation of teeth 42 & 43 for a full ceramic bridge. "Metal free" thinking means getting rid of friction and sharp edges. (Practioner: Dr T. O. Bloecker)

Fig 2 Anterior crown made of zirconium oxide, individually layered and stained. (Dental Laboratory: Martin Groeschel, Labor Moss)

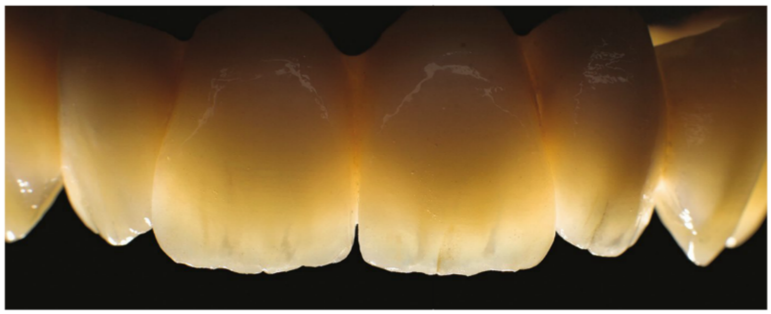

Fig 3 Backlit, the zirconium oxide crowns exhibit beautiful transparency.

Fig 4a Treatment with conventionally cemented (zinc oxide phosphate cement) zirconium oxide crowns 13 to 22. (Practitioner: Dr T. O. Bloecker, Dental Laboratory: Labor Moss)

Fig 4b The same patient three years later: In the lower arch, veneers were needed on teeth 32 to 42.

Fig 4c The individually layered veneers on 32 to 42. Situation after bonding.

Fig 4d The conventionally cemented upper anterior crowns do not exhibit an aesthetic drawback in contrast to the bonded veneers in the lower arch. (Practitioner: Dr T. O. Bloecker)

Fig 5a Difficult circumstances. Veneer preparation on tooth 11. Gold post on tooth 21 and a veneered ceramic crown already existing on tooth 22.

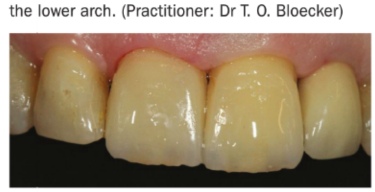

Fig 5b The outcome: veneer on tooth 11 (layering technique) directly after cementation (Variolink). Zirconium oxide crown on tooth 21 after cementation (Harvard Cement). (Practitioner: Dr T. O. Bloecker, Dental Laboratory: Ante Lopar, Labor Moss)

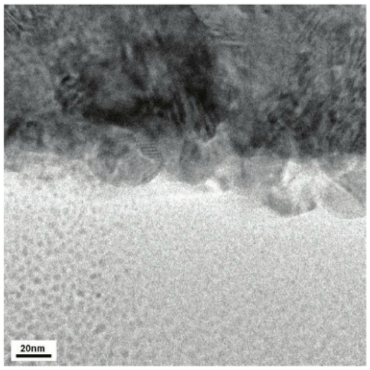

Fig 6 Image taken with a transmisson electron microscope: Transition zone of ZrO2-Zirconnect in a thin section. Silicate based glass particles make the complete wetting, gap free deposition and diffusion into the zirconium oxide surface possible. (with kind permission of Dr M Hopp, Berlin)

Fig 7 The Hotbond System with the components: Hotbond, Hotbond Tizio Connect and Zirconnect (DCM) in conjunction with the C-Link System (Deltamed)

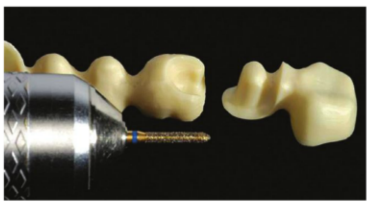

Fig 8a The joining of framework segments: Primary and secondary part of the special joining element.

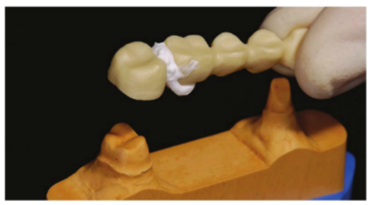

Fig 8b The framework joined with Hotbond, before firing, only dried with hot air.

Fig 9a Hotbond Tizio connection between custom zirconia abutment and titanium interface.

Fig 9b Example of titanium zirconia abutments after soldering.

Fig 9c Individual titanium ZrO2 abutment with beautifully designed emergence profile and perfect fit.

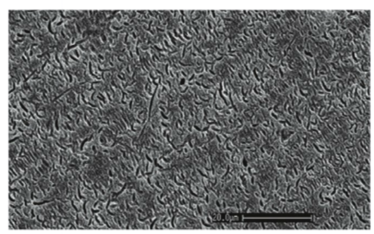

Fig 10 Retentive Zirconnect surface after sandblasting and etching. The adhesive bonding to the ceramic structure is significantly improved (REM, 1000 x magnification)

and the waxup was scanned and sent to an external milling centre for frame production (Fig 12). To ensure a precise fit of the restoration, particularly as no preparation has been carried out, it is important that the Zirconnect material is applied using the airbrush spray on technique. Zirconnect is applied to the zirconia wings in a thin and even layer, then fired at 1000°C (Fig 13 & 14). After the layering porcelain has been applied and the restoration has been glazed and finished (Fig 15), the wing is sandblasted very carefully with 50 µm aluminium oxide at a maximum of 5 bar pressure, only for cleaning, not roughening the surface. The surface is then etched with C-Link Ceramic Etching (5% HF/8% H_2SO_4 solution) for one minute (C-Link, Australian Dental Solutions). An innovative product, the C-Link Set simplifies the bonding process in the Dental Practice. The complete framework conditioning process is now the responsibility of the Dental Laboratory and is carried out under magnification in laboratory conditions. This eliminates the risk of etching problems such as spillage on the labial surfaces or external margins. Next the surface is silanated and coated with a micro film bonder (C Link connector) and light cured with a laboratory light curing unit. The bonder does not negatively affect the fitting of the restoration due to its micro thinness. The surface is now resistant to contamination during try in procedures and does not age.[139] (Fig. 16a to 18).

The restoration can be tried in the mouth without causing contamination to the silane layer. After the try in, the surface is cleaned with 37% phosphoric acid solution for 30 seconds. This step significantly improves the end result and is good practice. The restorations are bonded with an enamel bonder, whereby the connector forms the bonding layer for the composite which is used. The tooth surface is conditioned with phosphoric acid for 30 seconds and the frameworks are cemented with Variolink and A.R.T bond. The A.R.T bond shall not be cured until the placement of the restoration, as this could affect the fit. Excess composite is removed carefully and the restoration margins are finely polished, followed by renewed inspection of the occlusion (fig. 19a and b).

Both Maryland bridges have been in situ for more than 3.5 years now (fig. 20a to c). There is neither secondary decay, nor tooth mobility or debonding. To our knowledge, this is the longest reported retention period for single wing zirconium oxide adhesive bridges. The patient is highly satisfied with the outcome. He plays soccer at a performance level where

Fig 11a Portrait image of the 18 yo patient

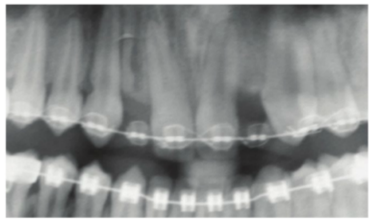

Fig 11b Condition after orthodontic treatment for a planned implantation in region 12 & 22. Extremely narrow gaps and unfavourable axial inclination of the incisors prevents risk free and aesthetic implant treatment.

Fig 11c The occlusal image shows the buccal bone loss in region 12 & 22.

Fig 11d Even with a 3.5mm implant, 1.5mm is lacking in width to conserve the papilla. The dark colour of tooth 11 makes the colour matching quite difficult. The patient refused bleaching.

Fig 12 Milled zirconium oxide Maryland bridges on the model. A precise framework fit can be seen.

the bridges had to "withstand quite a fair amount of stress" such as elbow strikes on the face and several falls.

Conclusion

While there have been some good clinical results for cementation of metal based restorations over the past 20 years [128,129], the historical data for zirconium oxide ceramic restoration with regard to clinical studies is still deficient [142]. This is true in particular for long term scientific studies. Calvacanti et al. are of the view that a recommendation for a certain cementing protocol cannot be given due to insufficient data availability [143]. There are numerous in-vitro studies for adhesive force measurement with different cements and surface treatments in connection with zirconium oxide. The clinicians are puzzled about the variety of results and the lack of conclusions that can be drawn for practical activity.

On the other hand, however, if one looks at the degree and speed with which the different zirconium oxide and CAD/CAM systems are brought into the market, there is high potential for error. Grumbling about the industry here would be shorted-sighted. Currently, we – practitioners and dental technicians – benefit largely from the developments. However it appears as if the development is in the fast lane rushing towards the finish line and the practitioners are left back on the starting line. We believe that a focus on basics, taking a low risk and conservative approach would be preferable. Hence, in consent with several authors, we cement zirconium oxide frameworks using the conventional methods.

Bonding is regularly challenged with inadequate retention or increased occlusal forces. Three main factors affect the

Fig 13 Uniform coating with Zirconnect.

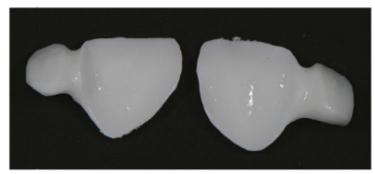

Fig 14 Flawless glass coating after firing.

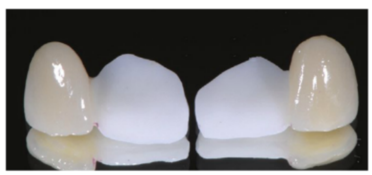

Fig 15 Finished bridges.

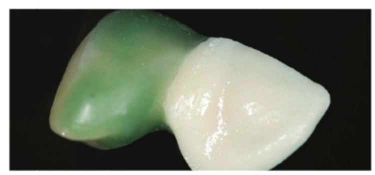

Fig 16a Protection of layering porcelain before sandblasting the wing.

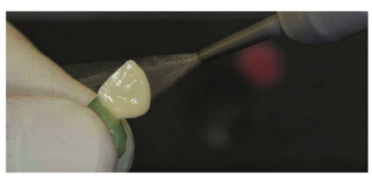

Fig 16b Fine sandblasting of the glass layer (at no more than 5 bar pressure).

Fig 17a Conditioning with ceramic etch (hydrofluoric acid – C-Link) ...

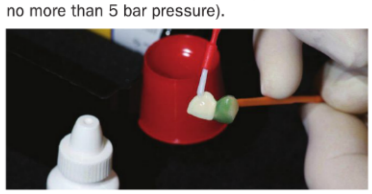

Fig 17b ... and silanisation (C-Link)

Fig 17c Sealing of the etched surface (C-Link Connector) ...

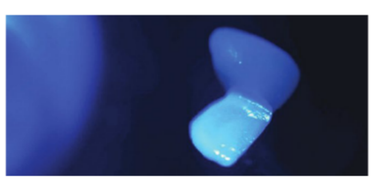

Fig 18 ... and finally, light curing of the connector.

Fig 19a Inserted Maryland bridges after bonding from the anterior and palatal.

Fig 19b Inserted Maryland bridges after bonding from the anterior and palatal.

retention significantly: retention surface area (such as short stumps or unfavourable length to base ratio of teeth), angle of convergence and type of luting cement used [143, 85]. According to treatment guidelines, zirconia restorations should be avoided in these cases. This prompts the question as to why adhesive cementation would be required? High occlusal forces,

Fig 20a to c - Condition after 3 years, from anterior and palatal views, as well as full face. Bleaching was not carried out as per patient's request.

such as bruxers may lead to problems in the medium term, due to framework wearing, with up to a 50 percent decrease in strength. The bonding technique also requires a lot of time and materials and is hence costly. Why should the cost of the zirconium oxide treatment method be made even more expensive?

The so often postulated better aesthetics provided through composite cement appears overestimated to us after eight years of clinical experience with zirconium oxide crowns and bridges. Good communication between the Dental Practice and Laboratory, with consideration of patient requirements, profound material knowledge, good preparation and layering technique are all more important in our eyes, despite being aware of the difficulties that are associated with these.

In our view, the cementation of zirconium oxide ceramic restorations with unfavorable stump geometry and very high occlusal forces without sufficiently conditioned ZrO2 surface would involve a high risk. Glass-ceramic precoating [135] seems to be the right solution. Zirconnect not only improves the bonding of the structural ceramic frameworks for veneering ceramics but also facilitates the adhesive technique for zirconium oxide frameworks as well as composite veneers, adhesive bridges (Maryland), retainers, full crowns and bridges. Sintered glass layers with a thickness of 20 µm can be prepared in a conventional way through sandblasting and etching for silanisation. Leucite, a very retentive composite structure is the result after etching (Fig 10). Through simultaneous surface conditioning, silanisation and sealing of the bonding surfaces with C-link in the laboratory, the procedure is simplified and the safety level is enhanced for the patient.

The Hotbond operator kit and tizio connect expand the handling possibilities of zirconium oxide significantly. With tizio connect, we now have a new bonding system for joining titanium and zirconium oxide. The advantage with it is the use of inexpensive titanium bases with their ductile properties in connection with a custom abutment which not only offers improved aesthetics through its individual design but also optimizes the emergence profile. The glass-chemical bond improves the biocompatibility and long-term stability of the subgingival bonded areas [133].

Studies or case reports about Maryland zirconium oxide adhesive bridges are rare and appear to cover relatively short time spans. Most of the restorations in these studies were sandblasted and resin bonded. Zhou et al. report of a study over 22 months of bridges in situ under stress with a 90% success rate and the loss of only two single wing and one double wing bridge.[144]. Komine and Tomic report of a 2.6 years long complication-free use of a single one wing adhesive bridge [145]. Foitzik et al. describes the successful use of a single-retainer bridge after 2.5 years as replacement for a maxilla canine tooth [146]. Kern found a 5 year survival rate for double wing bridges to be 73.9 percent and 92.3 percent for single sided adhesive bridges, made from In-Ceram [147].

The significant difference between tooth preparation carried out to increase the retention and our technique is that we use a non- invasive approach. The high strength of zirconium oxide allows for a lesser or no tooth preparation, as space for adequately dimensioned connectors is not needed. In relation to aesthetics and biocompatibility, full ceramic bridges are superior to metal based bridges. However to carry out this technique satisfactorily, adequate clinical experience and training in bonding techniques is desirable. The question to use rubber dam or not in a situation like this, is left up to the practitioner. Hajto [148] reports about the adhesive cementation of anterior veneers without the use of a rubber dam. Many clinical results show that even without the use of a rubber dam, great long term results can be achieved through a well thought out work area preparation. As a result of the "real" adhesive bonding of both the Maryland bridges presented in this article, the patient has experienced no complications in the 3.5 years thus far. ◆

Literature from the author on request or in internet at www.teamwork-media.de in the left navigation section under "Journale Online".