www.zmk-aktuell.de

ZMK

ZAHNHEILKUNDE | MANAGEMENT | KULTUR

5
May 2020
Year 36
ISSN 1862-0914
E12169

8,- Euro

Reprint

A universal adhesive cementation and core build-up material

spitta

A universal adhesive cementation and core build-up material

Range of indications and case studies

If one were to reach into the dental toolbox and hybridize a very good adhesive core build-up material such as Visalys Core with a premium adhesive luting composite such as Panavia V5, the result would be an adhesive cementation material for all indirect restorations that can be used both for producing adhesive core build-ups and adhesive cementation of root posts. This innovative and practical new product, which can be applied universally, was presented at IDS 2019 by Kettenbach under the name Visalys CemCore. In this article, Professor Dr. Claus-Peter Ernst describes the broad range of uses for this new product, which can be used for all dual-curing and dark-curing adhesive indications in routine dental practice, with the exception of direct restoratives.

There are outstanding adhesive cementation systems that have been clinically well-established for many years as well as their equivalent adhesive core build-up systems. These latter can even be used in cementing an adhesive glass fiber post in one step. Both product groups have a similar viscosity and would therefore be difficult to distinguish from one another in a blinded test. Nevertheless, they differ in a number of physical and chemical details. An adhesive cementation material requires a certain degree of hydrophilicity for the adhesive (preferably self-conditioning) to bond to the dentin as well as an appropriate wettability, color stability, and good polishing properties. Conversely, the core build-up composite benefits from hydrophobic properties that counteract the hygroscopic expansion of the considerably larger volume needed, compared to the adhesive cementation material, and from better flexural and compressive strength values [9]. Adding all these properties to a wish list has, to date, been unproductive because of the chemical and physical limits. Consequently, adhesive cementation systems and the predominantly self-adhesive cements for use as core build-up composites are contraindicated because their increased water sorption can even lead to fracture of lithium disilicate crowns, as was demonstrated in an in-vitro study conducted in Berlin [91]. This found that 50% of lithium disilicate crowns luted onto a core build-up using a self-adhesive cement showed detectable cracks after 9 months of storage in water.

After conducting an intense research program, Kettenbach has now been able to manage this balancing act. The new development comprises a hydrophilic, self-conditioning boundary reaction and hydrophobic core properties to satisfy all requirements for large-volume composite cores. Accordingly, Visalys CemCore contains special hydrophobic monomers that prevent swelling and absorption of stains. The Active-Connect-Technology (ACT) developed by Kettenbach achieves high adhesion despite hydrophobicity. This is due to special phase transfer catalysts that are responsible for the transition between hydrophilic tooth substance and hydrophobic luting composites.

Hydrophilicity is only required at the actual interface to the tooth substance, while the bulk of the material is actually a rather hydrophobic dual-curing restoration material. This means that other benefits, including esthetic ones, immediately become apparent, such as the hope that with adhesive cementation of esthetic all-ceramic restorations, adhesive joints will not discolor so rapidly.

Selection of adhesive with dual-curing or dark-curing luting composites

In general, adhesive cementation of indirect restorations places great demands on not only the materials but also the expertise of the user as soon as dark-curing or dual-curing comes into play – especially when it comes to the combination of adhesive and luting composite. While (luting) composite and adhesive from different manufacturers can be combined without any problems for exclusively light-curing materials [90,95], this is not the case when combining self-curing or dual-curing materials [5]. In such instances, the curing-system of the composite must be taken into account, which mostly is an amine/peroxide based system. Amines are acid sensitive, that is, they are protonated by acids and thus deactivated as co-initiators of the self-curing system. This is the case when self-conditioning all-in-one adhesives are used, and also with some self-conditioning two-step systems and most universal adhesives. If such products are not used according to the manufacturer's compatibility recommendations, the self-curing mechanism of the dual-curing or self-curing composite will no longer work. A complete adhesive failure would be a regrettable outcome. Only adhesives with a manufacturer's guarantee of compatibility with the corresponding luting composites should be used with dark-curing or dual-curing composites.

Sometimes a dark-curing activator must be added 1:1 – this does not render a light-curing adhesive a self-curing one, however. It only indicates compatibility with a dark-curing or dual-curing luting composite and it still must be light cured. For this reason, names such as "Self-Cure Activator" are misleading. On the other hand, there are individual product combinations from separate manufacturers in which certain combinations do not require addition of a dark-curing activator when using products from the same manufacturer. The instructions for use should be studied very closely in these cases. As has been described, there are indeed many pitfalls lurking in the form of unforeseeable incompatibilities, and it is therefore recommended that adhesive cementation, which as a rule incorporates one dark-curing component, should adhere strictly to the manufacturer's recommended combinations.

Exclusively light-curing adhesive cementation

When combining exclusively light-curing materials the situation is different. Adhesives and composites from different manufacturers can be combined without any problems [90]. Exclusively light-curing cementation is most definitely an option and is also recommended by renowned universities and research institutes [78] – with the assumption of sufficient light curing. For exclusively light-curing cementation of lithium disilicate partial crowns, the above paper recommends polymerization of 2 × 20 sec from 4 directions; this results in a total polymerization time of more than 2.5 minutes, which would probably result in the death of living pulp without additional cooling. For this reason, such recommendations for exclusively light-curing cementation must be treated with caution. This is because even the thinnest of coatings of translucent ceramic significantly reduce the light transmittance. In a simple radiometer experimental set-up [16], the light output was reduced by 30% from 1065 mW/cm^2 to 778 mW/cm^2 using a 0.4 mm thick e.max LT A2 ceramic disk placed between the light emission window and the radiometer sensor. A disk 0.7 mm thick led to a reduction of 45% to 616 mW/cm^2 and a 1.5 mm thick e.max LT disk in light shade A2 caused a reduction of 67% to 388 mW/cm^2. Keeping in mind that 1.5 mm thickness is still the minimum required thickness of most glass ceramics, it can be assumed that a high percentage of indirect ceramic restorations, particularly in the lateral tooth area, exceed this minimum thickness, which is good for the mechanical stability of the restoration but bad for the light-curing. This issue illustrates how exclusively light-curing adhesive cementation remains an exceptional situation and remains restricted to indications such as anterior tooth veneers, inlays, and occlusal veneers.

Requirements for the use of dual-curing and dark-curing luting composites and their differentiated application

The conclusion remains that we will still be working with dual-curing and dark- or self-curing for many years to come. But even here it is worth looking at the dark-curing potential of a "dual"-curing cementation material. A dual-curing system is based on self-curing and light-curing; a self-curing system dispenses completely from VLC – the same applies for self-curing systems with a light-curing option. The light curing is optional in such a case, which means that, the same final hardness can be achieved with or without additional light curing. A light-curing option may be useful to enable, for example, immediate surface finishing. "Dual" curing therefore does not mean that the cementation material dispenses entirely from light; it is also better in this case if additional light curing is at least carried out over the easily accessible interfaces following the completion of cementation and removal of excess material.

When using traditional dual-curing systems, sufficient light curing must be assured to achieve optimal adhesive bonds, final hardness, and degree of conversion [63,64]. Because this cannot be guaranteed, for example, in the root canal and beneath opaque ceramics such as zirconium oxide or even a porcelain fused to metal crown, traditional dual-curing luting composites can only be recommended for these indications to a limited degree. A study in 2017 [21] illustrated this issue using RelyX Ultimate. Without light curing there was a degree of conversion of 27% while additional light curing for 20 sec using an Elipar S10 VLC device increased this to 62%. This clearly illustrates that conventional dual-curing composite cementation systems must be applied in such a way that adequate secondary light access to the adhesive interface is assured, which may possibly be the case with most glass ceramic inlay, onlay, and partial crown restorations. Since 2016 Ivoclar no longer recommends Variolink Esthetic DC for use with glass fiber posts in the root canal*. The self-curing adhesive composite with light-curing option, Multilink Automix, is preferred by the manufacturer in such cases. The authors of a similar older document from 2013 were more daring with Variolink II, indicating the use of Variolink II as suitable for the cementation of glass fiber posts**. This clearly shows that in some cases successor products may have restrictions of indications. Careful study of the instructions prevents misuse in this highly sensitive area of adhesive cementation. Consequently, it remains the responsibility of the interested user to ask the manufacturer for verifiable data on the adhesive bond and the degree of conversion even after loading that demonstrates an approximately equivalent performance for dual-curing and self-curing.

* https://www.ivoclarvivadent.com/zoolu-website/media/document/887/Indications+Reference+Card+Cements

** https://www.ivoclarvivadent.com/zoolu-website/media/document/29952/Combination+Card*
https://www.ivoclarvivadent.com/zoolu-website/media/document/887/Indications+Reference+Card+Cements

The following quality criteria should apply to the luting composite:
- adequate self-curing
- light curing only as an additional option
- high degree of conversion even for exclusively self-curing applications
- optimal adhesive bonding potential in combination with a suitable, preferably self-curing adhesive
- low polymerization shrinkage stress; this prevents disintegration of the root dentin into the cavities with C-factors that are extremely unfavorable because they are very high
- adequate working time
- tack-curing option
- adequate radiopacity
- color stability

According to the data available to date from the manufacturer and external research centers, Visalys CemCore meets all the necessary requirements for an adhesive cementation system. The very good self-curing potential even without additional light curing must be emphasized here. There is thus nothing to stand in the way of clinical application, which will be illustrated using the following case reports.

Patient case-reports

Case 1: Cementation of 2 lithium disilicate partial crowns

A 42-year-old medical colleague required replacement of inadequate, larger composite restorations with partial cusp restorations on her lower right molars. For esthetic reasons, a lithium disilicate ceramic (IPS e.max Press, Ivoclar Vivadent) was selected. The shade was chosen chairside by the senior dental technician of the dental clinic. **Figure 1** shows the completed laboratory work on the working model. The critical pre-treatment of the ceramic is its cleaning with Ivoclean or phosphoric acid gel [10] and subsequent hydrofluoric acid conditioning after the try-in. 5% hydrofluoric acid is still the most accepted pre-treatment method for glass-based ceramics [1,12,14,36,51,61,73]. This is confirmed in a 2015 meta-analysis [69].

Fig. 1: IPS e.max Press partial crowns for lower right molars on the laboratory model.

Buffered 9% to 9.6% yellow hydrofluoric acid is definitely an interesting and less dangerous alternative to red hydrofluoric acid [38,39,60,97]. With respect to the etching time and the type of hydrofluoric acid on lithium disilicate ceramic, there are unfortunately contradictions between Ivoclar Vivadent's of 20 sec (5% hydrofluoric acid only) and, for example, the recommendation for Ultradent hydrofluoric acid of 90 sec (9% buffered hydrofluoric acid gel). For this reason, it is unfortunately not possible to give evidence-based recommendations for a suitable etching time with a buffered 9% to 9.6% yellow hydrofluoric acid on lithium disilicate ceramic, as one must follow **either** the ceramic manufacturer's recommendation (20 sec, 5% hydrofluoric acid) **or** those of the etching gel manufacturer (90 sec). Many colleagues have reached their own compromise of 60 seconds in this case. Particularly for IPS e.max, we persist with the red 5% hydrofluoric acid [24,25,69] for this reason and thus follow the recommendations of the ceramic manufacturer. The alternative conditioning agent based on ammonium polyfluoride (Monobond Etch & Prime, Ivoclar Vivadent) is certainly a highly interesting alternative to the traditional hydrofluoric acid/silane combination [27,28] but does not quite approach the gold standard [29,30].

It is quite clear from the literature already cited that silane application after hydrofluoric acid conditioning achieves significantly higher bond strengths than hydrofluoric acid conditioning alone. Thus, silanization of a glass-based ceramic surface conditioned with hydrofluoric acid can similarly be designated as state of the art, as was demonstrated by a meta-analysis of this topic [29,94]. The traditional silane application (Monobond S, Espe-Sil, etc.) works but is no longer useful in the present day due to standardization of stocks held and the risk of mix-ups with other ceramic primers: glass ceramic requires a silane, zirconium oxide MDP, and metal certain sulfur compounds. Mixing up the specialized individual primers leads to disintegration of the adhesive bond. Therefore, universal primers in which all three components, or at least silane + MDP, are included have become usual and reliable. Mix-ups are no longer possible and the correct primer is always used.

The best-known products are Monobond Plus (Ivoclar Vivadent) and Clearfil Ceramic Primer Plus (Kuraray). The Visalys Restorative Primer that belongs with Visalys CemCore has an identical structure. The name alone precludes all ambiguity: it is part of restoration, regardless of whether glass ceramic or zirconium oxide. The Visalys Restorative Primer from Kettenbach was applied to the two IPS e.max partial crowns for a working time of 60 sec. Subsequent evaporation of solvent completed the pre-treatment of the glass ceramic. Universal adhesives containing silane [22] should, on the other hand, not be used on glass ceramic etched with hydrofluoric acid because the silane present is no longer stable in the acid environment of the universal adhesive [29]. If they then even work at all, the adhesives exhibit significantly reduced bond strengths [19,45,51,54,74,83,100,101].

And then, the tooth. A sufficient contamination control is crucial with adhesive cementation [84]. The simplest tool – particularly for adhesive partial crowns – is rubber dam isolation. **Figure 2** shows the isolated working area after removing all temporary restorations, cleaning of the adhesive surfaces with ultrasound and prophy paste (Zircate, Dentsply Sirona), and blasting of the composite surface on ower right 1st molar with 50 µm aluminum oxide (Rondoflex, KaVo). The short, wingless molar rubber dam clamps facilitate access to the proximal space when cleaning with dental floss. Because this involves adhesive cavity floor elevation with composite [66] prior to the preparation and not an adhesive core build-up, adequate pre-treatment of this adhesive surface is also of critical importance to ensure an adhesive bond between the composite and the adhesive cementation system.
Cavity floor elevation was published for the first time in 1993 by Krejci and Lutz [56] with the procedure then repeatedly published in case studies [18,79,80] and, following the publication of many in-vitro studies on this issue since [35,46,68,81, 82,96,102], can be considered a treatment option for establishing a secure adhesive bond to an indirect restoration with deep proximal lesions. Because direct adhesive restorations, unlike indirect inlay and partial crown restorations, can also very frequently and easily be placed free of contamination without rubber dam isolation using sectional matrix systems for isolation, the option of sub-filling or the cemented base plate is taken, onto which the indirect restoration is adhesively bonded later on. Because the cavity margins of the indirect restoration have thus been elevated, an adequate contamination check can be carried out during the adhesive cementation without problems. An essential condition here, however, is the blasting of the previously placed composite filling with Al_2O_3 as described.

Fig. 2: The isolated working area after blasting the composite surface on lower right 1st molar with 50 µm aluminum oxide.

Finally, the enamel is etched with a 35% phosphoric acid gel for approximately 15 sec. Although self-conditioning systems can ensure an adhesive bond and corresponding retention rate comparable to phosphoric acid etching, significantly more marginal discoloration is seen than with separate phosphoric acid conditioning. This is clearly shown by a 13-year study on Clearfil SE Bond by the Leuven working group [76], in which self-conditioning versus selective enamel etching was investigated using a split-mouth test. Because marginal discoloration is considered by both clinician and patient to be an adverse event for all-ceramic restorations, the risk of discoloration developing should be reduced as far as possible. The best option remains selective enamel etching. After enamel conditioning with the phosphoric acid gel and sufficient rinsing for 15 sec, a wetting agent, or tooth primer, is required for sufficient full adhesive bonding. The Visalys Tooth Primer that comes with the Visalys CemCore is a self-conditioning single-component primer that does not require separate light curing and thus meets the requirement for self-curing of the adhesive that subsequently takes place in contact with Visalys CemCore. **Figure 3** shows the effect of the Visalys Tooth Primer on the preparation surfaces of both lower right molars. The partial crowns are cemented at the same time with Visalys CemCore using the shade Universal (A2/A3), which was applied beforehand directly onto the partial crowns and not into the cavities **(Fig. 4)**. Although a tack-cure technique option is available, the excess luting material was removed using a modeling spatula, a fresh bonding brush, and dental floss. The somewhat higher consistency and better stability compared to conventional luting composites (primarily due to its function as a core build-up composite) makes removal of the excess considerably easier because the material does not flow away in such a rapid and uncontrolled manner. An initial curing using a high-performance LED polymerization device was carried out. To prevent an oxygen inhibition layer, any conventional glycerin gel can be used.

Fig. 3: The effect of Visalys Tooth Primer on the preparation surfaces of both lower right molars.

Fig. 4: Both partial crowns are cemented at the same time with Visalys CemCore in the shade Universal (A2/A3).

Alternatively, the Visalys CemCore Try-In Paste available from Kettenbach can also be used. Although Visalys CemCore has exceptional self-curing properties, light curing under glycerin gel was nevertheless carried out for 20 sec per surface. Checks of the static and dynamic occlusion may only be performed after completion of the dark curing so that the adhesive integration is not disrupted if there are mechanical impacts on the adhesive surface due to excursion movements during the polymerization process.
Figure 5 shows the clinical outcome at a follow-up check at 2 months: The two lithium disilicate partial crowns have esthetically and harmoniously blended into the surrounding hard tooth structure. The luting composite joins the hard tooth structure and the restoration perfectly with no tendency to discoloration and cannot be differentiated from either the restoration or the hard tooth structure in terms of color. There were no postoperative clinical symptoms, resulting in a highly satisfied patient.

Fig. 5: Clinical outcome at 2-month follow-up. The two lithium disilicate partial crowns have esthetically and harmoniously blended into the surrounding hard tooth structure.

Case 2: Cementation of a monolithic full zirconia crown in the posterior region

For the posterior region, one option is monolithic multi-layer full zirconia crowns, now offered by some manufacturers not only in the standard round blank but also in blocks. In the case of a 52-year-old patient, a gold partial crown on her lower right 1st molar with an open margin required restoration. So as to avoid the loss of additional vertical substance opposite the removed gold restoration and to realize the necessary minimum thickness for a glass-based ceramic, the choice of material was in this case a monolithic multi-layer full zirconia crown (Zolid fx Multilayer, AmannGirrbach).
In the adhesion of full zirconia there are similar traps as for glass ceramic cementation, albeit with some differences. When cleaning the workpiece, it is recommended to use either special cleaning pastes (e.g., Ivoclean) [72] or subsequent blasting. Unlike glass ceramics, in the case of zirconium oxide phosphoric acid must not be applied to the adhesive surface [50]. Blasting with Al_2O_3 or tribochemical silicatization (CoJet, 3M) is essential to establish an adhesive bond of any kind to the zirconium oxide ceramic [57]. To remove all remaining Al_2O_3 particles, cleaning the workpiece in an ultrasonic bath for 10 min is recommended [71]. Tribochemical blasting with silica-coated Al_2O_3 beads with a particle size of 30–50 µm at a pressure of 1–2 bar (CoJet) produces even better bonding strength values on zirconium oxide than blasting alone with uncoated Al_2O_3 [8,11]. Accordingly, Inokoshi and van Meerbeek [49] also recommend this as the optimal procedure when maximal adhesive strength is required. However, with a simple crown, as in the present case, blasting with Al_2O_3 is sufficient.

The next step is the application of a universal primer containing MDP and silane such as the Visalys Restorative Primer from Kettenbach used here **(Fig. 6)** [49]. There is sufficient evidence from the literature confirming that such universal primers have the best bond-enhancing effect on zirconium oxide [48,99]. **Figure 7** shows the adhesive surface of the crown isolated with the rubber dam. The composite core has already been blasted with Al_2O_3. After thorough rinsing with water, the enamel is etched for 15 sec and rinsed thoroughly, and then the Visalys Tooth Primer (Kettenbach; **Fig. 8**) is applied. **Figure 9** shows the monolithic full zirconia crown fully adhered with Visalys CemCore in the shade Universal (A2/A3) on the lower right 1st molar at a check-up of the crown two weeks after insertion.
Because the buccal and lingual crown margins are still in the enamel region here and thus can be very easily accessed, excess luting material was again removed with the modeling spatula, a bonding brush, and dental floss. This is particularly easy due to

Fig. 6: Effect of the MDP/silane Kettenbach Visalys Restorative Primer on the blasted zirconia crown.

Fig. 7: The adhesive surface of the crown isolated with the rubber dam. The composite core has already been blasted with Al_2O_3.

Fig. 8: Effect of the Visalys Tooth Primer.

Fig. 9: The fully adhered monolithic full zirconia crown on the lower right 1st molar two weeks after insertion.

the high stability of Visalys CemCore, as the excess forms like a wreath on the edge of the crown. Visalys CemCore has special physical network formers that generate thixotropic behavior. With shear forces, such as those that develop when positioning the crown, the network is reversibly disrupted, resulting in good flowability. On the edge of the crown, this stress is neutralized again and the network formers lead to a rapid recovery of the stability so that excess material does not flow away.

After the initial polymerization, a glycerin gel is applied for final polymerization of the marginal areas to prevent the oxygen inhibition layer and the polymerization is completed. Static and dynamic occlusion are checked again only after effective completion of the dark curing (5 min). The full-adhesively bonded monolithic multi-layer full zirconia crown provides a perfect esthetic and can barely be optically distinguished from the lithium disilicate partial crown used in the previous case. Thanks to the adequate adhesion and the perfect laboratory fabrication with no disruptive occlusal interference, there were no postoperative symptoms at all and a very comfortable feeling for the patient while chewing. This important esthetic aspect for full zirconia illustrates, however, that perfect communication with the laboratory is necessary. The clinician must know precisely what type of ceramic is being ordered and the laboratory must indicate what it has supplied. Only in this way can an appropriate adhesive pre-treatment be ensured that enables adequate and durable adhesion. If all that is written on the laboratory note is "ceramic crown", this becomes difficult. A highly translucent zirconium oxide material can barely be distinguished visually from a lithium disilicate restoration.

Case 3: Cementation of a veneered full zirconia crown in the anterior region

The 32-year-old patient presented with a completely broken-off direct composite core on the lateral left upper incisor that had been prepared elsewhere **(Fig. 10 and 11)**. The incisors on both sides are very small peg-shaped teeth that were esthetically widened several years ago using the direct technique **(Fig. 12)**. Due to the patient's habit of clenching and grinding her teeth, the patient reported that repair work has been necessary several times already. The previous preparation resembled a veneer preparation, meaning that due to the existing preparation and the increased requirements for stability, an indirect type of restoration was preferred during consultation.

Direct anterior restorations with composite usually function outstandingly well and should always be the first choice when considering alternative treatment concepts. [6,31,37,55,58,59,62]. But it should also not be underestimated just how challenging such restorations are [41,42]. Therefore, indirect ceramic restorations – usually of glass ceramic – are a valid alternative when the most stringent esthetic requirements must be satisfied. [3,4, 7,20,34, 40,43,44,57,65,89,98]. If, however, a previous preparation creates an initial situation that does not require much a change in terms of the preparation technique, and if there are increased requirements regarding the fracture strength, an indirect restoration is the first choice because no further invasive preparation is required and the long-term prognosis is better.

Fig. 10: Completely broken off direct composite core on the lateral left upper incisor prepared elsewhere.

Fig. 11: Detailed view of the initial situation on the lateral left upper incisor.

Fig. 12: Both incisors are very small peg-shaped teeth that were esthetically widened several years ago using the direct technique.

The decision was thus made in favor of a labially veneered monolithic all-zirconia crown **(Fig. 13 and 14)**. Consideration was given to restoring the lateral right upper incisor, which had been treated with a comparable composite core, in the same way as the lateral left upper incisor. But because there was no acute incident affecting the lateral right upper incisor, the patient declined this additional treatment option. Regarding the shape, no consideration was given to the current shape of the lateral right upper incisor in the consultation with the patient and a symmetrical treatment was deliberately ignored so if that the lateral right upper incisor was restored in future, no compromises on the shape would be necessary. The shape of the newly designed lateral incisor crown was thus determined entirely by the neighboring teeth and the available vertical dimensions.

After the try-in and esthetic acceptance of the restoration by the patient, the pre-treatment of the crown was then carried out: This was fixed on the incisal edge with a light-curing, elastic material for temporary restorations (Clip, VOCO, Cuxhaven), which was applied in the hollow space of a brush holder **(Fig. 15)**. This allowed optimal pre-treatment without having to hold the crown in the hand. To better visualize the adhesive surface to be blasted and to check that all adhesive surfaces had been reached, the surfaces to be blasted were marked with a permanent marker (**Fig. 16**, personal recommendation from Professor Kern, Head of the Department of Prosthodontics, University of Kiel). Subsequent blasting with CoJet in the next step enabled the surface to be cleaned and tribochemical silicatization to be performed **(Fig. 17)**. The MDP/silane Visalys Restorative Primer was then allowed to act for 60 sec on the adhesive surface **(Fig. 18)**. The excess and the solvent were then carefully removed with a stream of air. This step completed the pre-treatment of the crown. All pre-treatment measures were carried out chairside.

Figure 19 shows the lateral left upper incisor isolated with a rubber dam after cleaning of the surface, and **Figure 20** shows the phosphoric acid conditioning of the entire adhesive surface (enamel and dentin areas can be differentiated visually only with difficulty). Because the Visalys Tooth Primer works just as efficiently on dentin etched with phosphoric acid as in its original self-conditioning primer function, it is better in case of doubt to etch more generously with the phosphoric acid gel. **Figure 21** shows the conditioned tooth stump from the incisal view, and **Figure 22** shows the tooth stump from the labial direction.

Fig. 13: Labially veneered monolithic full zirconia crown. View of the laboratory model from the labial direction.

Fig. 14: Labially veneered monolithic full zirconia crown. View of the laboratory model from the incisal direction.

Fig. 15: Incisal fixation of the crown on a brush holder using a light-curing elastic material for temporary restorations.

Fig. 16: Marking of the surface to be blasted with a permanent marker.

Fig. 17: Tribochemical silicatized adhesive surface.

Fig. 18: The MDP/silane Visalys Restorative Primer is then allowed to act for 60 sec on the adhesive surface.

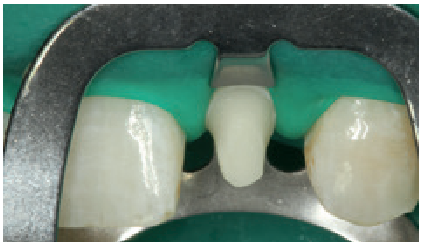

Fig. 19: The lateral left upper incisor isolated with a rubber dam shown after cleaning of the surface.

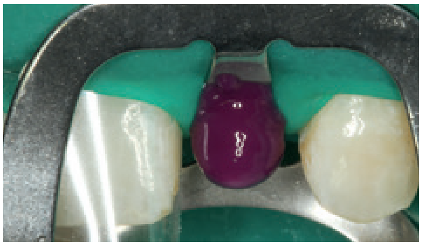

Fig. 20: Phosphoric acid conditioning of the entire adhesive surface.

Fig. 21: The conditioned tooth stump from the incisal view.

Fig. 22: The conditioned tooth stump from the labial view.

Fig. 23: Action of the Visalys Tooth Primer for 20 sec (incisal view).

Fig. 24: Action of the Visalys Tooth Primer for 20 sec (labial view).

As in all previous cases, the Visalys Tooth Primer is applied in the next step, allowed to work for 20 sec **(Fig. 23 and 24)**, following which the excess is removed and the solvent carefully evaporated with a stream of air. This step completed the pre-treatment of the tooth. This crown too was adhesively fixed with Visalys CemCore in the shade Universal (A2/A3). The excess was then completely removed with a clean bonding brush (not a micro-brush) before polymerization **(Fig. 25)**. **Figure 26** shows the cleaned, adhered, veneered full zirconia crown still under the rubber dam while **Figures 27 and 28** show the final clinical outcome for the highly satisfied patient.

Fig. 25: Polymerization of the Visalys CemCore after complete removal of excess material.

Fig. 26: The cleaned, adhered, veneered full zirconia crown still under the rubber dam.

Fig. 27: En face view of the completed new restoration on the lateral left upper incisor.

Fig. 28: Detailed view of the overall clinical outcome

Case 4: Adhesive anterior restoration with veneered full zirconia crowns and partial crowns.

The 55-year-old patient was seeking a new esthetic restoration of her anterior situation **(Fig. 29 and 30)**. The central right and lateral left incisors had previously undergone root canal treatments, and all incisors had older, large composite restorations, the color of which no longer matched. The new restoration was fabricated from a monolithic zirconia material, because of the stability and better coverage of the stained tooth areas, with the use of additive veneering ceramic on the labial side **(Fig. 31 and 32)**.

Due to an accident while the patient was wearing the temporary restoration, the incisal third including the underlying composite core inserted after the endodontological treatment broke off the temporary restoration on the central right incisor. In **Figure 33**, which shows the situation prior to the preparation for adhesive fitting of the entire work, the enormous loss of substance on the incisal side is readily apparent: Residue of the bulk flow composite SDR Flow+ (Dentsply Sirona) in the shade U that was used for the core build-up can also be seen as can a small amount of white-opaque Venus Diamond Flow Baseliner (Kulzer). Fortunately, the preparation margin was intact and the laboratory work fitted perfectly. The problem was now the choice of luting material. In principle, a core build-up and adhesive cementation needed to be accomplished at the same time. Because all conventional adhesive luting materials are not approved for core build-up, this ruled out a large group of luting materials. Cementation with an adhesive core build-up material using a „post and core" concept would be a poor compromise, as these materials should not normally be exposed to direct contact with the oral environment due to their poor polishability. The risk of increased plaque deposits or even discoloration at the joint gap would not be taken lightly.

The only material that could be considered in this case in accordance with the manufacturer's information was once again Visalys CemCore, because the material is approved for both adhesive cementation and adhesive core build-up. The stump of the central right incisor was blasted intraorally with 50 µm Al_2O_3 (Rondoflex, Kavo) along with the core composite that was still in place. The adjacent teeth were protected with 2 Frasaco strips **(Fig. 33)**. Finally, the enamel was etched with phosphoric acid gel and Visalys Tooth Primer was again applied – precisely in accordance with the manufacturer's instructions. The pre-treatment of the zirconium oxide crown, which had already been blasted in the laboratory with 50 µm Al_2O_3, was carried out in the same way as the previous case, and involved fixation to a brush holder with Clip (VOCO), disinfection, marking of the adhesive surface with a permanent marker, blasting with CoJet, application, exposure, and removal of the Visalys Restorative Primer. **Figure 34** shows the polymerization of Visalys CemCore (also in shade Universal (A2/A3)) after complete removal of excess adhesive. Because it makes sense to use the same cementation system for cementation of the anterior restorations in one session in order to avoid the risk of negative esthetic outcomes caused by different shades or opacities, the other three adhesive partial crowns were also cemented with Visalys CemCore. These, however, were each done separately as the rubber dam clamps allow only a single tooth to be surrounded and accessed.

Figures 35 and 36 show the fitted work and the satisfied smile of the patient. Unfortunately, in the present case the extremely dark color of the stump of the lateral left incisor could not be fully camouflaged. The use of a very opaque variant of the material

Fig. 29: Anterior situation not considered esthetic by the patient.

Fig. 30: Detailed view of the anterior teeth from a right lateral perspective.

Fig. 31: New restoration with labially veneered monolithic zirconia material.

Fig. 32: View of the laboratory work from the incisal direction: Crown restoration on the central right incisor, partial crowns/veneers on the other teeth.

Fig. 33: Remaining core build-up material in the central right incisor after fracture of the temporary restoration and core caused by an accident.

Fig. 34: Polymerization of Visalys CemCore (also in the shade Universal (A2/A3)) after complete removal of excess adhesive on the lateral right incisor.

that is also available for Visalys CemCore was briefly considered, but then discarded as the very high opacity could quite possibly have a negative effect on the overall esthetic. An example of the use of this opaque cementation and core build-up material is seen later in the final case in this article.

Fig. 35: The fitted work comprising separately veneered full zirconia on the labial side.

Fig. 36: The new satisfied smile of the patient.

Case 5: Adhesive cementation of two single-wing adhesive bridges

The adhesive cementation of resin bonded fixed dental prostheses is the supreme discipline in the adhesive technique. Nowhere else is an adhesive bond placed under so much stress. Consequently, only very few dentists trust themselves to use this type of treatment, even though – when all prerequisites for adequate adhesion are heeded – excellent long-term results and a very high degree of patient satisfaction can be achieved [23,26].
Even the current German S3 guidelines for all-ceramic restorations [67] state that single-retainer all-ceramic resin-bonded fixed dental prostheses (RBFDPs) in the anterior region should be considered as a therapy option when correctly indicated. This recommendation is based on studies of single-retainer all-ceramic resin-bonded fixed dental prostheses that documented a survival rate of 94% for veneered aluminum oxide ceramic after a 10-year observation period [52] and a survival rate of 100% for veneered zirconium oxide ceramic after 5 years [85,86]. Single-retainer all-ceramic resin-bonded fixed dental prostheses are thus superior to the classic "Maryland bridges", the metal-based, two-wing adhesive bridges [13,77]. The 10-year results of the study only appeared after publication of the current S3 guidelines [53], and show that after 10 years there was a survival rate of 98.2% and a success rate of 92% for the originally 108 inserted zirconium oxide single-retainer resin-bonded fixed dental prostheses. The lower success rate is explained by the fact that six adhesive bridges became loose but were successfully re-adhered. Only one was removed upon request of the patient. Such an exceptional survival rate is difficult to find for conventional bridges.
Thus, single-wing adhesive bridges are a valid alternative to implant restorations and are clearly the first choice when it is too early for an implantation, as is the situation in the following case of a 14-year-old adolescent **(Fig. 37)**. The adolescent had lateral incisor agenesis. Due to a wide jaw base, the treating orthodontist, Dr. Christine Nauth, opted for space opening rather than orthodontic space closure. After completion of the orthodontic treatment, the minimally invasive preparation of the two central incisors was carried out for treatment with the adhesive wings [87]. A high-strength zirconium oxide material was used as the framework material that was then veneered around the lateral incisors **(Fig. 38)**. As before, the workpieces were blasted in the laboratory with 50 µm Al_2O_3. After the try-in and cleaning, the adhesive wings were marked with permanent marker for blasting with CoJet **(Fig. 39)**. Removal of the marker makes it extremely easy to check whether the entire adhesive surface has been adequately blasted **(Fig. 40)**. **Figure 41** shows a blasted adhesive wing, **Figure 42** shows the application of the Visalys Restorative Primer, and **Figure 43** shows the adhesive surface wetted with the Visalys Restorative Primer after evaporation of the solvent.

Fig. 37: Agenesis of both lateral incisors in a 14-year-old adolescent.

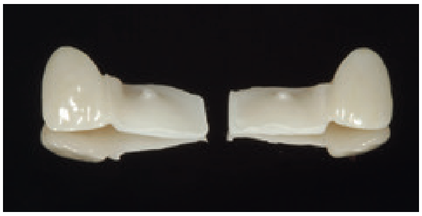

Fig. 38: Single-retainer all-ceramic resin-bonded fixed dental prostheses to replace both upper lateral incisors. The adhesive wings are cemented in both cases to the central incisors.

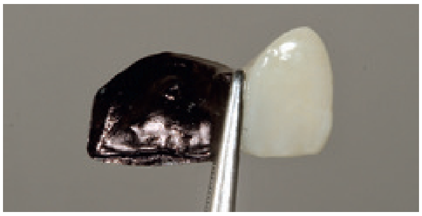

Fig. 39: Marking of the adhesive wing before blasting.


Fig. 40: Chairside blasting with CoJet.

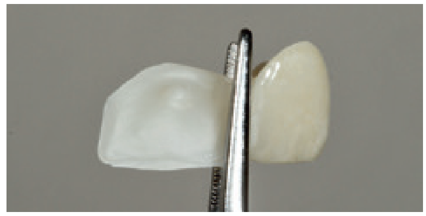
Fig. 41: One of the two blasted adhesive wings.

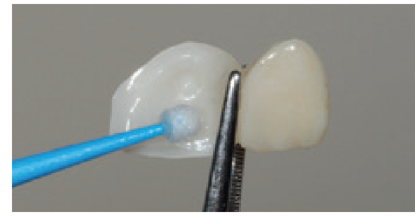
Fig. 42: Application of the Visalys Restorative Primer.


Fig. 43: The adhesive surface wetted with the Visalys Restorative Primer after evaporation of the solvent.


Fig. 44: Rubber dam isolation of the adhesive surfaces. View from the incisal direction. The central right incisor is protected with a piece of Teflon tape.


Fig. 45: Isolated working surface from the labial direction.

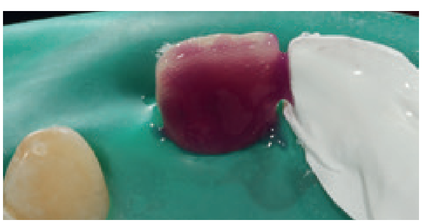
Fig. 46: Phosphoric acid conditioning of the entire adhesive surface on the central right.

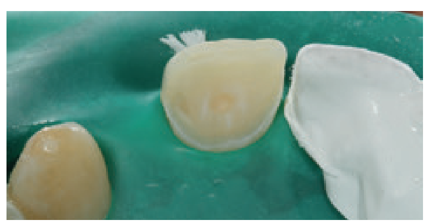
Fig. 47: The etched tooth structure on the palatal surface of the central right incisor.


Fig. 48: Action of the Visalys Tooth Primer for 20 seconds.


Fig. 49: The surface of the tooth after complete pre-treatment for adhesion.


Fig. 50: The luting composite Visalys CemCore was applied directly to the adhesive wing.


Fig. 51: En face view of the restoration with bridges two separate single-retainer resin-bonded fixed dental prostheses to replace the two lateral incisors.

The teeth to be treated were isolated with a rubber dam and cleaned. It was possible to fix the rubber dam on the first premolars with premolar clamps and on the teeth to be adhered using floss ligatures, providing a very good overview **(Fig. 44 and 45)**. Isolation of the adjacent tooth with a piece of teflon tape can be seen in the image. After cleaning of the adhesive surfaces on the tooth by blasting with 50 µm Al_2O_3 (Rondoflex), the entire adhesive surface underwent phosphoric acid etching (here on the central left incisor, **Fig. 46**). The two single-retainer resin-bonded fixed dental prostheses were adhered sequentially rather than at the same time. **Figure 47** shows the etched tooth structure of the palatal surface of the central left incisor, **Figure 48** shows the application of the Visalys Tooth Primer for 20 sec, and **Figure 49** shows the surface of the tooth after complete pre-treatment for adhesion. The luting composite Visalys CemCore was applied directly to the adhesive wing **(Fig. 50)**. Until the excess is completely removed with a fresh bonding brush and the initial polymerization is finished, the adhesive fixed dental prostheses must be held in place with fingers. Alternatively, an insert key prepared by the laboratory can facilitate access to the adhesive surfaces and thus the cleaning. **Figures 51 to 53** show the finished restoration of the 14-year-old, who is extremely happy to have teeth again and no longer need to struggle with a removable temporary prostheses.

Fig. 52: Incisal view of the finished restoration.

Fig. 53: The young patient is pleased with his new teeth.

Case 6: Adhesive core build-up with simultaneous placement of an adhesive glass fiber post

One of the main indications for Visalys CemCore has not yet been addressed: its use as a core build-up composite and for luting glass fiber posts. This application is seen in the last case of a 57-year-old patient who had to have a root canal treatment on the upper left 1st molar. If the endodontist opts to insert a glass fiber post, this should be inserted immediately after the root filling in order to avoid repeat exposure of the canal system, the risks of an additional temporary restoration, and a secondary post preparation.

Figure 54 shows the canal system immediately before the root canal filling while **Figure 55** shows the situation after vertical condensation of the root filling material. To avoid further weakening of the root dentin, the authors prefer passive post insertion with no further post bed preparation. Moreover, and particularly if a tooth will be provided with a post and core build-up, further loss of hard tissue should be avoided as far as possible, as this would further weaken the tooth's prognosis [17,33,88,93]. The conclusion reached by the studies indicated is to omit drilling a hole for the post if a root canal in the coronal third is wide and straight enough to accept a post. This is particularly true for posterior teeth, which are more exposed to an axial load, and is only possible if the post is inserted immediately after the root canal filling.

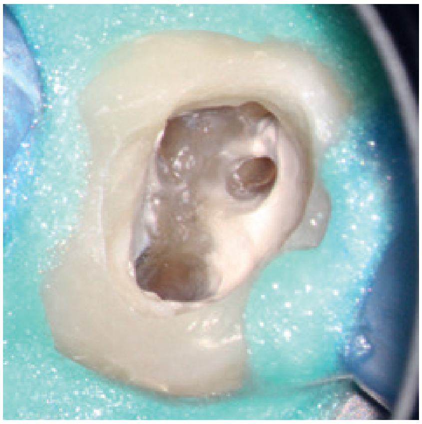

Fig. 54: Canal system in a upper left 1st molar immediately prior to the root canal filling. View through the Zeiss Pro Ergo surgical microscope.

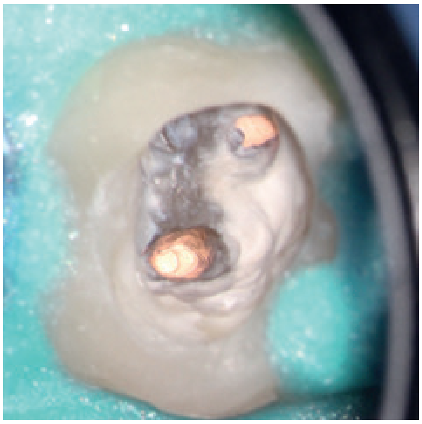

Fig. 55: Clinical situation after vertical condensation of the root filling material.

When cementing a post into an expanded root canal that has not been processed with a post drill, there is, however, rather a loose fit compared to the shape-congruent fit of a suitably prepared post bed. The perceived poorer fit is thus associated primarily with an enlarged gap, which has to be adhesively filled. However, it has been demonstrated that adhesive cementation – even with considerable discrepancies between the size of the post and that of the root canal – did not result in significant differences in the strength of the adhesive bond [70,75].

The root canal corresponds in principle to a very deep class I cavity. The C-factor (configuration factor) was described for the first time in 1987 in connection with composite restorations [32] and illustrates the ratio of bonded to unbonded surfaces. In the root canal this value can rise to 200 [15], which can lead to uncontrollable polymerization shrinkage stresses. There is, however, one study that describes the volume of the adhesive interface as having no effect [2]. The resultant polymerization shrinkage stresses can very easily exceed the bond strength to the root dentin – resulting in cracks and debonding [75,92]. For this reason, it is important to establish an optimal adhesive bond, achieved using Visalys Tooth Primer, and that the cementation and core build-up composite used to adhere the post has the lowest possible polymerization shrinkage stress. This is the case with Visalys CemCore.

Figure 56 shows the try-in of a glass fiber post (EasyPost, Dentsply Sirona). After pretreatment of the post with the Visalys Restorative Primer and cleaning of the canal system with AH Cleanser (Dentsply Sirona), as well as application of the Visalys Tooth Primer in the tooth, the glass fiber post was cemented with Visalys CemCore (this time using the opaque shade) and the internal build-up of the entire tooth was carried out. **Figures 57 to 59** show the two-step insertion of Visalys CemCore Opaque after an interim curing of the first increment for 40 sec and **Figure 60** shows the radiographic check of the root filling and the core build-up. The occlusal part of the cavity was reduced occlusally a few minutes later by a colleague and the definitive restoration was carried out with a traditional light-curing composite.

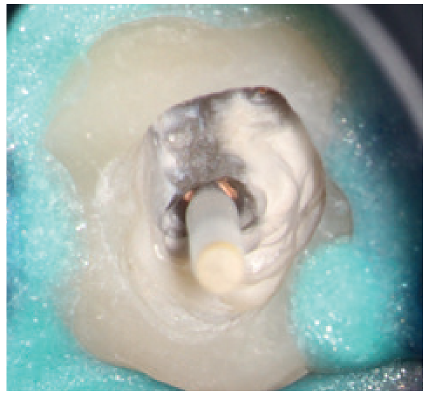

Fig. 56: Try-in of a glass fiber post (EasyPost, Dentsply Sirona).

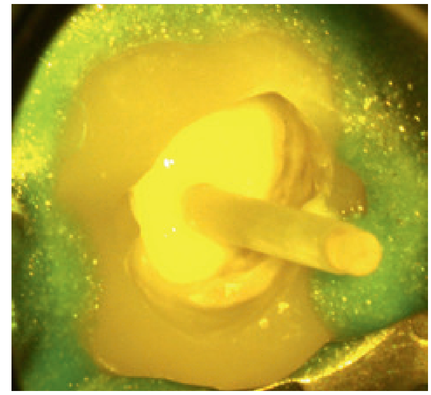

Fig. 57: Cementation of the post with Visalys CemCore Opaque with the yellow filter of the microscope in place.

Fig. 58: First layer of Visalys CemCore Opaque after polymerization without the yellow filter.

Fig. 59: Completed, filled cavity.

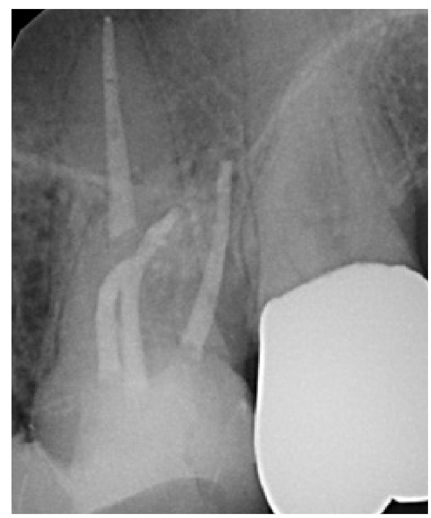

Fig. 60: Radiographic check of the root canal filling and the core build-up applied without any bubbles in the upper left 1st molar.

Summary

The cases presented here show the impressive potential of Visalys CemCore to cover an enormous range of indications: adhesive cementation of glass ceramics and zirconium oxide in the posterior region, and use for adhesive cementation in the esthetically challenging anterior region – whether as single crowns or combined with adhesive partial crowns. Even the supreme discipline of adhesion – the cementation single-retainer all-ceramic resin-bonded fixed dental prostheses – can be achieved without problems. The secondary indications are adhesive core build-up and use in the cementation of glass fiber posts – an indication for which a separate adhesive core build-up composite is usually required. The range of products for dual-curing and dark-curing composites can thus be drastically reduced, a simplification of the stocks held by the clinic that should not be underestimated, making this an essential tool for quality management and for increasing efficiency in stock inventory. ■

List of references available at www.zmk.aktuell.de/literaturlisten

Authors: Prof. Dr. Claus-Peter Ernst, Dr. Andreas Sebus, Dr. Christine Nauth, Dr. Helga Schaffner

Prof. Dr. Claus-Peter Ernst
zahnärztliche Praxisklinik medi+
Haifa-Allee 20, 55128 Mainz
Tel.: 06131 4908080
Ernst@mediplusmainz.de

List of references

1. Aboushelib MN, Sleem D. Microtensile bond strength of lithium disilicate ceramics to resin adhesives. J Adhes Dent 2014; 16: 547-552.
2. Aksornmuang J, Nakajima M, Senawongse P, Tagami J. Effects of C-factor and resin volume on the bonding to root canal with and without fibre post insertion. J Dent. 2011; 39: 422-429.
3. Aristidis GA, Dimitra B. Five-year clinical performance of porcelain laminate veneers. Quintessence Int 2002; 33:185-189.
4. Aykor A, Ozel E. Five-year clinical evaluation of 300 teeth restored with porcelain laminate veneers using total-etch and a modified self-etch adhesive system. Oper Dent 2009; 34: 516–523.
5. Asmussen E, Peutzfeld A. Short- and long-term bonding efficacy of a self-etching, one-step adhesive. J Adhes Dent 2003; 5: 41–45.
6. Báez Rosales A, De Nordenflycht Carvacho D, Schlieper Cacciutolo R, Gajardo Guineo M, Gandarillas Fuentes C. Conservative Approach for the Esthetic Management of Multiple Interdental Spaces: A Systematic Approach. J Esthet Restor Dent. 2015, 27: 344–354.
7. Barghi N, McAlister E. Porcelain for Veneers. J Esth Dent 1998; 10, 191-197.
8. Bavbek NC, Roulet JF, Ozcan M. Evaluation of microshear bond strength of orthodontic resin cement to monolithic zirconium oxide as a function of surface conditioning method. J Adhes Dent 2014; 16: 473–480.
9. Bitter K, Schubert A, Neumann K, Blunck U, Sterzenbach G, Rüttermann S. Are self-adhesive resin cements suitable as core build-up materials? Analyses of maximum load capability, margin integrity, and physical properties. Clin Oral Investig 2016; 20: 1337–1345.
10. Bock T, Özcan M. Protocol for Removal of Clinically Relevant Contaminants from Glass Ceramic-based Restorations. J Adhes Dent 2015; 17: 474–475.
11. Bömicke W, Schürz A, Krisam J, Rammelsberg P, Rues S. Durability of Resin-Zirconia Bonds Produced Using Methods Available in Dental Practice. J Adhes Dent 2016, 18: 17–27.
12. Bömicke W, Rammelsberg P, Krisam J, Rues S. The Effects of Surface Conditioning and Aging on the Bond Strength Between Composite Cement and Zirconia reinforced Lithium-Silicate Glass-Ceramics. J Adhes Dent 2019; 21: 567–576.
13. Botelho MG, Chan AW, Leung NC, Lam WY. Long-term evaluation of cantilevered versus fixed-fixed resin-bonded fixed partial dentures for missing maxillary incisors. Journal of Dentistry 2016; 45: 59–66.
14. Bottino MA, Snellaert A, Bergoli CD, Özcan M, Bottino MC, Valandro LF. Effect of ceramic etching protocols on resin bond strength to a feldspar ceramic. Oper Dent 2015; 40: 40–46.
15. Bouillaguet S, Troesch S, Wataha JC, et al. Microtensile bond strength between adhesive cements and root canal dentin. Dent Mater 2003; 19: 199–205.
16. Castellanos M, Delgado AJ, Sinhoreti MAC, de Oliveira DCRS, Abdulhame N, Geraldeli S, Roulet JF. Effect of Thickness of Ceramic Veneers on Color Stability and Bond Strength of Resin Luting Cements Containing Alternative Photoinitiators. J Adhes Dent. 2019; 21:67–76.
17. Cecchin D, Farina AP, Guerreiro CA, Carlini-Júnior B. Fracture resistance of roots prosthetically restored with intra-radicular posts of different lengths. J Oral Rehabil 2010; 37: 116–122.
18. Dietschi D, Spreafico R. Current clinical concepts for adhesive cementation of tooth-colored posterior restorations. Pract Periodontics Aesthet Dent 1998; 10: 47–54.
19. Dimitriadi M, Panagiotopoulou A, Pelecanou M, Yannakapoulou K, Eliades G. Stability and reactivity of γ-γPTMS silane in some commercial primer and adhesive formulations. Dent Mater 2018; 34: 1089–1101.
20. Edelhoff D, Prandtner O, Saeidi Pour R, Liebermann A, Stimmelmayr M, Güth JF. Frontzahnrestaurationen: Leistungsfähigkeit von Keramikveneers. Wissen Kompakt 2019; 13 (3): 115–1278.
21. Egilmez F, Ergun G, Cekic-Nagas I, Vallittu PK, Lassila LV. Light Transmission of Novel CAD/CAM Materials and Their Influence on the Degree of Conversion of a Dualcuring Resin Cement. J Adhes Dent 2017; 19: 39–48.
22. Ernst CP. Die einfache adhäsive Befestigung einer Lithiumdisilikat-Teilkrone. ZMK 2012; 28: 244–251.
23. Ernst CP. Mut zur Klebung: die einflügelige Adhäsivbrücke. ZMK 2013; 29: 98-107.
24. Ernst CP. Chairside CAD / CAM-Neuversorgung mit ZLS-Keramik. ZMK 2014; 30: 304–310.
25. Ernst CP. Keramikteilkronen als Versorgungsoption von Zähnen mit Infraktionen. All ceramic partial crowns as a treatment option for cracked, but symptomless teeth. Deutsche Zahnärztl Z 2015; 70: 165–173.
26. Ernst CP, Schaffner H, Nauth C. Vom Exoten zum „State oft he Art“: einflügelige Klebebrücken. ZMK 2016; 32: 650–664.
27. Ernst CP, Glaskeramik vorbehandeln ohne Flusssäure? Dental Magazin 2016; 34: 86–90.
28. Ernst CP, „Innovatives Konzept zur adhäsiven Befestigung am Beispiel zweier IPS e.max-Kronen. ZMK 2015; 31: 833–839.
29. Ernst CP. Die korrekte Vorbehandlung indirekter Restaurationen zur adhäsiven Befestigung. ZMK 2017; 33: 98–110.
30. Ernst CP. Selbstkonditionierender Keramikprimer. Eine erste Metaanalyse zu Monobond Etch&Prime ZMK 2018; 34: 864–873.
31. Ernst CP. Direkte Frontzahnrestaurationen aus Komposit -aktuelle Studienlage und Fallbeispiele. ZMK 2017; 33; 2–8.
32. Feilzer AJ, De Gee AJ, Davidson CL. Setting stress in composite resin in relation to configuration of the restoration. J Dent Res 1987; 66: 1636–1639.
33. Ferrari M, Sorrentino R, Juloski J, Grandini S, Carrabba M, Discepoli N, Ferrari Cagidiaco E. Post-Retained Single Crowns versus Fixed Dental Prostheses: A 7-Year Prospective Clinical Study J Dent Res 2017; 96: 1490–1497.
34. Fradeani M, Redemagni M, Corrado M. Porcelain laminate veneers: 6- to 12-year clinical evaluation – a retrospective study. Int J Periodontics Restorative Dent 2005; 25:9-17.
35. Frankenberger R, Hehn J, Hajto N, Krämer N, Naumann M, Koch A, Roggendorf MJ. Effect of proximal box elevation with resin composite on marginal quality of resin composite inlays in vitro. Clin Oral Investig 2013; 17: 177–183.
36. Frankenberger R, Hartmann VE, Krech M, Krämer N, Reich S, Braun A, Roggendorf. Adhesive luting of new CAD/CAM materials. Int J Comput Dent 2015; 18: 9–20.
37. Frese C, Schiller P, Staehle HJ. Wolff D. Recontouring teeth and closing diastemas with direct composite buildups: a 5-year follow-up. J Dent 2013; 41: 979–985.
38. Giraldo TC, Villada VR, Castillo MP, Gomes OM, Bittencourt BF, Dominguez JA. Active and Passive Application of the Phosphoric Acid on the Bond Strength of Lithium Disilicate. Braz Dent J 2016; 27: 90–94.
39. Guarda GB, Correr AB, Gonçalves LS, Costa AR, Borges GA, Sinhoreti MA, Correr-Sobrinho L. Effects of surface treatments, thermocycling, and cyclic loading on the bond strength of a resin cement bonded to a lithium disilicate glass ceramic. Oper Dent 2013; 38: 208–217.
40. Hajto J. Veneers Materialien und Methoden im Vergleich. Teamwork 2000; 3: 195–202.
41. Hajto J. Freud und Leid mit direktem Komposit. Teil 1: Adhäsive, Indikationsstellung und Chamäleoneffekt. Teamwork 2006; 9: 50063.
42. Hajto J. Freud und Leid mit direktem Komposit. Teil 2: Schichttechnik, Versorgung multipler Füllungen im Frontzahnbereich. Teamwork 2006; 9: 86–97.
43. Hajto J. Frontzahnrestaurationen: Sind Keramikveneers die beste Wahl? Quintessenz 2010; 61: 521–528
44. Hajto J. Veneers – eine wertvolle Ergänzung für jede Praxis. Cosmetic Dentistry 2018; 16: 18–21.
45. Haller B, Merz A. Standortbestimmung Universaladhäsive Teil 2. Der Einfluss der Komposithärtung und die Haftung an Werkstücken zm 2017; 107 (6), 76–82.
46. Ilgenstein I, Zitzmann NU, Bühler J, Wegehaupt FJ, Attin T, Weiger R, Krastl G. Influence of proximal box elevation on the marginal quality and fracture behavior of root-filled molars restored with CAD/CAM ceramic or composite onlays. Clin Oral Investig 2015; 19: 1021-1028.
47. Inokoshi M, De Munck J, Minakuchi S, Van Meerbeek B. Meta-analysis of bonding effectiveness to zirconia ceramics. J Dent Res 2014; 93: 329–334.
48. Inokoshi M, Poitevin A, De Munck J, Minakuchi S, Van Meerbeek B. Bonding effectiveness to different chemically pre-treated dental zirconia. Clin Oral Investig 2014; 18: 1803–1812.
49. Inokoshi M, Van Meerbeek B. Adhesively luted zirconia restorations: why and how? J Adhes Dent 2014;16: 294.
50. Ishii R, Tsujimoto A, Takamizawa T, Tsubota K, Suzuki T, Shimamura Y, Miyazaki M. Influence of surface treatment of contaminated zirconia on surface free energy and resin cement bonding. Dent Mater J 2015; 34: 91–97.
51. Kalavacharla VK, Lawson NC, Ramp LC, Burgess JO. Influence of Etching Protocol and Silane Treatment with a Universal Adhesive on Lithium Disilicate Bond Strength. Oper Dent 2015; 40: 372–378.
52. Kern M, Sasse M. Ten-year survival of anterior all-ceramic resin-bonded fixed dental prostheses. J Adhes Dent 2011;13: 407–410.
53. Kern M, Pasia N, Sasse M, Yazigi C. Ten-year outcome of zirconia ceramic cantilever resin-bonded fixed dental prostheses and the influence of the reasons for missing incisors. J Dent 2017; 65: 521–555.
54. Kim RJ, Woo JS, Lee IB, Yi YA, Hwang JY, Seo DG. Performance of universal adhesives on bonding to leucite-reinforced ceramic. Biomater Res 2015 22; 19: 11.
55. Klaiber B: Alles noninvasiv – Zahnformveränderung, Lückenschluss, Reduktion schwarzer Dreiecke. zm 2006; 96: 52–59.
56. Krejci I, Lutz F., Reimer M. Marginal adaptation and fit of adhesive ceramic inlays. J Dent 1993; 21: 39-46.

57. Kunzelmann KH, Kern M. Das Keramik Veneer. Substanzschonend und ästhetisch. Dental Magazin 2005; 4: 36–41.
58. Lenhard M. Diastemaschluss mit Kompositrestaurationen. Eur J Esthet Dent 2008; 3: 282–292.
59. Lenhard M. Ästhetische Frontzahnrestaurationen mit Komposit. Quintessenz 2004; 55: 961–976.
60. Lambade DP, Gundawar SM, Radke UM. Evaluation of adhesive bonding of lithium disilicate ceramic material with duel cured resin luting agents. J Clin Diagn Res 2015; 9: ZC01-5.
61. Lise D, Perdigão J, Van Ende A, Zidan O, Lopes G. Microshear Bond Strength of Resin Cements to Lithium Disilicate Substrates as a Function of Surface Preparation. Oper Dent 2015; 40: 524–532.
62. Lührs AK: Diastemaschluss mittels direkter Technik im Frontzahnbereich. Deutsch Zahnärtzl Z 2011; 66, 628–635.
63. Lührs AK, Pongprueksa P, De Munck J, Geurtsen W, Van Meerbeek B. Curing mode affects bond strength of adhesively luted composite CAD/CAM restorations to dentin. Dent Mater 2014; 30: 281–291.
64. Lührs AK, De Munck J, Geurtsen W, Van Meerbeek B. Composite cements benefit from light-curing. Dent Mater 2014; 30: 292–301.
65. Magne, P., Douglas, W.H.: Additive Contour of Porcelain Veneers: A Key Element in Enamel Preservation, Adhesion, and Esthetics for Aging Dentition. J Adhesive Dent 1999; 1, 81092.
66. Magne P, Spreafico RC. Deep Margin Elevation: A Paradigm Shift. Am J Esthet Dent 2012; 2: 86-96. Reiner A. "margin elevation technique". zm 2013; 103: 44–46.
67. Meyer G, Ahsbahs S, Kern M (2015). Vollkeramische Kronen und Brücken – S3- Leitlinie (AWMF-Registernummer 083-012). http://www.awmf.org/leitlinien/detail/ll/ 083-012.html.
68. Müller V. Friedl KH, Hahnel S, Handel G, Lang R. Influence of proximal box elevation technique on marginal integrity of adhesively luted Cerec inlays. Clin Oral Investig 2017; 21: 607–612.
69. Neto DS, Naves LZ, Costa AR, Correr AB, Consani S, Borges GA, Correr-Sobrinho L. The Effect of Hydrofluoric Acid Concentration on the Bond Strength and Morphology of the Surface and Interface of Glass Ceramics to a Resin Cement. Oper Dent 2015; 40: 470–479.
70. Nova V, Karygianni L, Altenburger MJ, Wolkewitz M, Kielbassa AM, Wrbas KT. Pull-out bond strength of a fibre-reinforced composite post system luted with self-adhesive resin cements. J Dent 2013; 41: 1020–1026.
71. Özcan M. Air abrasion of zirconia resin-bonded fixed dental prostheses prior to adhesive cementation: why and how? J Adhes Dent 2013; 15: 394.
72. Özcan M, Bock T. Protocol for Removal of Clinically Relevant Contaminants from Zirconium Dioxide Fixed Dental Prostheses. J Adhes Dent 2015; 17: 576–577.
73. Özcan M, Volpato CAM. Surface Conditioning and Bonding Protocol for Polymer-infiltrated Ceramic: How and Why? J Adhes Dent 2016; 18: 174-175.
74. Passia N, Lehmann F, Freitag-Wolf S, Kern M. Tensile bond strength of different universal adhesive systems to lithium disilicate ceramic. J Am Dent Assoc 2015; 146: 729–734.
75. Perdigao J, Gomes G, Augusto V. The effect of dowel space on the bond strengths of fiber posts. J Prosthodont 2007; 16: 154–164.
76. Peumans M, De Munck J, Van Landuyt K, Van Meerbeek B. Thirteen-year randomized controlled clinical trial of a two-step self-etch adhesive in non-carious cervical lesions. Dent Mater 2015; 31: 308–314.
77. Pjetursson BE, Tan WC, Tan K, Brägger U, Zwahlen M, Lang NP. A systematic review of the survival and complication rates of resin-bonded bridges after an observation period of at least 5 years. Clin Oral Implants Res 2008; 19: 131–141.
78. Politano G, Van Meerbeek B, Peumanns M. Nonretentive Bonded Ceramic Partial Crowns: Concept and Simplified Protocol for Long-lasting Dental Restorations. J Adhes Dent 2018; 20: 495–510.
79. Rocca GT, Krejci I. Bonded indirect restorations for posterior teeth: from cavity preparation to provisionalization. Quintessence Int 2007; 38: 371–379.
80. Rocca GT, Krejci I. Bonded indirect restorations for posterior teeth: the luting appointment. Quintessence Int 2007; 38: 543–553.
81. Rocca GT, Gregor L, Sandoval MJ, Krejci I, Dietschi D. In vitro evaluation of marginal and internal adaptation after occlusal stressing of indirect class II composite restorations with different resinous bases and interface treatments. „Post-fatigue adaptation of indirect composite restorations". Clin Oral Investig 2012; 16: 1385–1393.
82. Roggendorf MJ, Krämer N, Dippold C, Vosen VE, Naumann M, Jablonski-Momeni A, Frankenberger R. Effect of proximal box elevation with resin composite on marginal quality of resin composite inlays in vitro. J Dent 2012; 40: 1068–1073.
83. Romanini-Junior JC, Kumagai RY, Ortega LF, Rodrigues JA, Cassoni A, Hirata R, Reis AF. Adhesive/silane application effects on bond strength durability to a lithium disilicate ceramic. J Esthet Restor Dent 2018; 30: 346–351.
84. Roulet JF. Reasonable Adhesion. J Adhes Dent 2010; 12: 255.
85. Sasse M, Kern M. CAD/CAM single retainer zirconia-ceramic resin-bonded fixed dental prostheses: clinical outcome after 5 years. Int J Comput Dent 2013; 16: 109–118.
86. Sasse M, Kern M. Survival of anterior cantilevered all-ceramic resin-bonded fixed dental protheses made from zirconia ceramic. J Dent 2014; 42: 660–663.
87. Sasse M, Kern M. All-ceramic resin-bonded fixed dental prostheses: Treatment planning, clinical procedures, and outcome. Quintessence International 2014; 45: 291–297.
88. Schroeder AA, Ford NL, Coil JM. Micro-computed tomography analysis of post space preparation in root canals filled with carrier-based thermoplasticized gutta-percha. Int Endod J 2017; 50: 293–302.
89. Sidharta JJ. Veneer-System: Ästhetische Korrekturen minimalinvasiv durchführen ZMK 2014; 30: 672–673.
90. Song M, Shin Y, Park JW, Roh BD. A study on the compatibility between one-bottle dentin adhesives and composite resins using micro-shear bond strength. Restor Dent Endod. 2015; 40: 30–36.
91. Sterzenbach G, Karajouli G, Tunjan R, Spintig T, Bitter K, Naumann M. Damage of lithium-disilicate all-ceramic restorations by an experimental self-adhesive resin cement used as core build-ups. Clin Oral Investig 2014; 19: 281–288.
92. Tay FR, Loushine RJ, Lambrechts P, Weller RN, Pashley DH. Geometric factors affecting dentin bonding in root canals: a theoretical modeling approach. J Endod 2005; 31: 584–589.
93. Tey KC, Lui JL. The effect of glass fiber-reinforced epoxy resin dowel diameter on the fracture resistance of endodontically treated teeth. J Prosthodont 2014; 23: 572–581.
94. Tian T, Tsoi JK, Matinlinna JP, Burrow MF. Aspects of bonding between resin luting cements and glass ceramic materials. Dent Mater 2014; 30: e 147–162.
95. Thomsen KB, Peutzfeldt A. Resin composites: strength of the bond to dentin versus mechanical properties. Clin Oral Investig 2007; 11: 45–49.
96. Veneziani M. Adhesive restorations in the posterior area with subgingival cervical margins: new classi cation and differentiated treatment approach. Eur J Esthet Dent 2010; 5: 50–76.
97. Vohra R, Velez LI, Rivera W, Benitez FL, Delaney KA. Recurrent life-threatening ventricular dysrhythmias associated with acute hydrofluoric acid ingestion: observations in one case and implications for mechanism of toxicity. Clin Toxicol (Phila) 2008; 46: 79–84.
98. Wiedhahn K, Kerschbaum T, Fasbinder DF. Clinical long-term results with 617 Cerec veneers: a nine-year report. Int J Comput Dent 2005; 8:233–246.
99. Yang B, Barloi A, Kern M. Influence of air-abrasion on zirconia ceramic bonding using an adhesive composite resin. Dent Mater 2010; 26: 44–50.
100. Yoshida F, Tsujimoto A, Ishii R, Nojiri K, Takamizawa T, Miyazaki M, Latta MA. Influence of surface treatment of contaminated lithium disilicate and leucite glass ceramics on surface free energy and bond strength of universal adhesives. Dent Mater J 2015; 34: 855–862.
101. Yoshihara k, Nagaoka N, Sonoda A Maruo y, Makita Y, Okihara T Irie M, Yoshida Y, V. Meerbeek B. Effectiveness and stability of silane coupling agent incorporated in 'universal' adhesives. Dent Mater 2016, 32: 1218–1225.
102. Zaruba M, Göhring TN, Wegehaupt FJ, Attin RT. Influence of a proximal margin elevation technique on marginal adaptation of ceramic inlays. Acta Odontol Scand 2013; 71: 317–324.