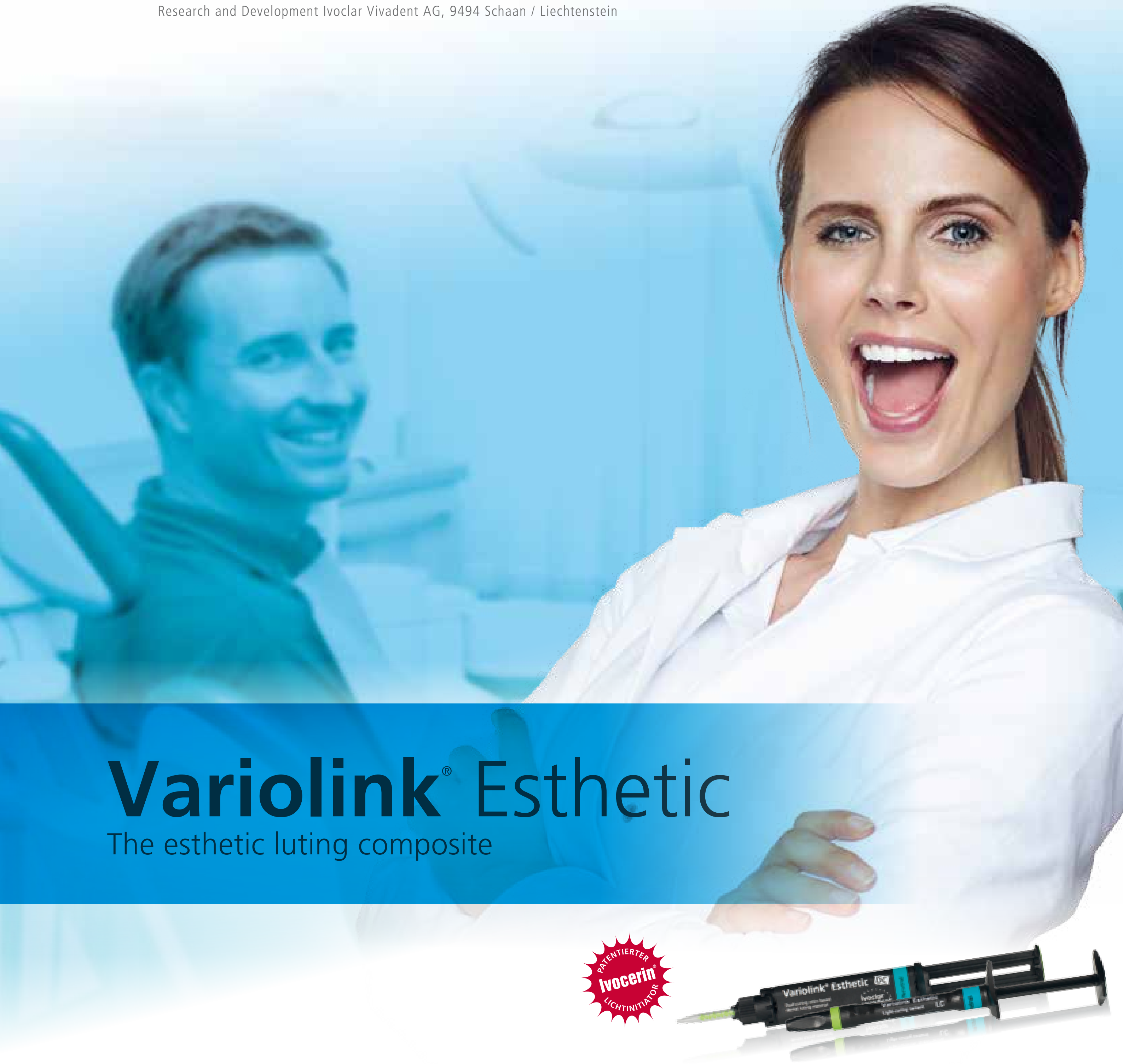
No. 22
July 2016

REPORT

Research and Development Ivoclar Vivadent AG, 9494 Schaan / Liechtenstein



Variolink® Esthetic

The esthetic luting composite

ivoclar vivadent®
passion vision innovation

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For a long time, phosphate cement was the accepted material for placing indirect restorations. In the 1980s, Ivoclar Vivadent was one of the first dental manufacturers to produce luting composites, especially for the adhesive cementation of Isosit and Concept restorations, the company's two microfilled, heat-curing restorative composites. Accordingly, the first luting composite developed by Ivoclar Vivadent was a microfilled material called Dual Cement. In order to enhance its radio-pacity, this product contained the patented ytterbium fluoride filler. At the beginning of the 1990s, glass-filled composites were launched on the market. Variolink® was developed in response to this trend in 1992. Its successor Variolink II was introduced only five years later. Today, this product looks back on more than twenty years of effective clinical use. Variolink II is characterized by high radiopacity, low wear, high strength and reactivity. Millions of restorations have been successfully placed with this luting composite. Over the years, nevertheless, many clinicians voiced the need for a material that is less reactive and would therefore facilitate the removal of excess material. In the case of Variolink II, excess had to be removed in a non-polymerized state, which was quite time-consuming.

With the rapid development of dental CAD/CAM materials, and ceramics in particular (IPS Empress® CAD, IPS e.max® CAD, IPS e.max® ZirCAD), straightforward and reliable luting has become a topic of great interest. Variolink Esthetic with its easy clean-up formula was developed to meet this need. Excess amounts of the product can be removed in a cured state without any time pressure. Its innovative colour system based on Effect shades allows restorations to be luted almost invisibly. The product incorporates the patented Ivocerin® light initiator, which means that it is amine-free. Furthermore, the shade of the luting composite does not shift over time.

This edition of the R&D Report will look at the chemistry of luting composites in general and examine the development of Variolink Esthetic in detail. In addition, it will describe the clinical applications of these materials.

Contents

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Variolink® Esthetic – a milestone in adhesive cementation

State-of-the-art dentistry – dual-cure polymerization in dentistry

Historical background of the cementation of dental restorations

Two main categories of materials are available for the placement of restorations: traditional cement and resin-based luting materials. Traditional cement relies on the combination of an inorganic component and water in order to cure. Dental cements have been in use for more than a century: This category of materials includes, for example,

- Phosphate cement also known as Harvard or Hoffmann cement: Phosphoric acid reacts with zinc oxide to produce a white, opaque and hard material. This type of cement is inexpensive and still very popular today, particularly for placing metal-supported restorations. The material does not generate a bond to the tooth structure. Nevertheless, if the tooth is prepared appropriately, adequate retention can be established.

- Carboxylate cement: Polyacrylic acid reacts with zinc oxide. This type of cement was developed after phosphate cement. Its popularity has been declining steadily.

Luting composites have been around since the 1980s. Since they do not require a reaction to take place between an inorganic filler and water, they are, in actual fact, not cements. However, the dental literature does not strictly adhere to this terminology. In luting composites, filled methacrylate systems polymerize to form a polymer network. Essentially the same monomers and fillers are used as those contained in composite restorative materials. Consequently, the requirements of luting composites and composite restorative materials are summarized in one ISO standard, that is, ISO 4049 Dentistry – Polymer-based restorative materials.

According to this standard, resin-based luting agents have to fulfil the following requirements:

Film thickness:	< 50 µm
Working time at 23 °C:	≥ 60 s after mixing started, the consistency should be homogenous
Curing time at 37 °C:	< 10 min
Depth of cure:	≥ 1 mm for opaque shades ≥ 1.5 mm for other shades
Flexural strength:	> 50 MPa
Water sorption:	≤ 40 µg/mm^3
Water solubility:	≤ 7.5 µg/mm^3
Radiopacity:	> 100 % Al

The monomer composition of luting composites is usually based on BisGMA, UDMA, TEGDMA, HEMA and GDMA to the amount of approx. 30 wt%. The monomers are responsible for the particular strength, consistency and water sorption and solubility of the material.

Fillers such as barium glass, strontium glass, fluorsilicate glass, ytterbiumfluoride, pyrogenic silica and mixed oxides composed of silica and zirconium oxide are used in luting composites. They influence the materials' handling, strength, radiopacity, fluoride release, polishability and film thickness. The following information regarding the fillers is generally true. The polishing results are superior if the grain size of the filler is very small and the film thickness therefore is very low. Fillers containing elements with a high proton number, for example, strontium, barium and ytterbium increase the radiopacity of the materials. Fluoride glasses have a positive effect on the fluoride releasing properties: Nevertheless, it is not as marked in resin-based luting agents as it is in glass ionomer cements.

The refractive index of the monomer and that of the filler have to be well matched in order to ensure the appropriate translucency of the luting agent and therefore the depth of cure.

Luting composites are categorized according to their curing mechanisms:

- **Light cure (LC):** The polymerization of this single-component material is initiated by exposing it to blue light. Product examples: Varliolink® Veneer, Variolink® Esthetic LC.
- **Self cure (SC):** Two components, which are initially kept separated, are combined to initiate the curing process. Once the components have been mixed, the curing process begins after approx. 100 seconds. Additional light exposure does not influence the result. Product examples: the first generation of Multilink® and Panavia 21.
- **Dual cure (DC):** As the name suggests, dual-cure materials are polymerized using a combination of two mechanisms: light cure and self cure. Once the two components have been mixed, the self-cure reaction begins. It can be accelerated by the additional exposure to light. Product examples: Multilink Automix, Variolink Esthetic DC, Variolink II.

Detailed description of the different curing mechanisms

Light cure

In the light-curing process, a light initiator, for example, camphorquinone, acylphosphine oxide or Ivocerin® is activated with blue light to induce radical formation. The radicals react with the polymer matrix to form a densely crosslinked network. Light-curing luting composites can only be used to place adequately translucent restorations, which will allow the luting material to cure properly. Light-curing luting composites are preferred for placing veneers. These materials do not contain any additional initiators, such as those required for the self-curing process. This has a positive effect on the colour stability of the material. Furthermore, these composites can be manipulated for an almost unlimited amount of time, provided that the ambient light contains very little blue light.

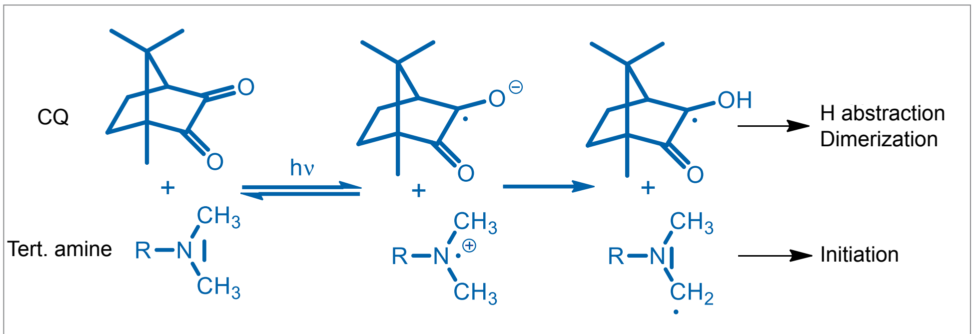

Fig. 1 Light-cure reaction mechanism shown on the basis of champhorquinone (CQ)/amine

Camphorquinone is a Norrish type II photoinitiator. In other words, two components are required in order for light-induced radical formation to take place. Camphorquinone alone demonstrates a poor tendency to form radicals when it is exposed to light. However, its reactivity increases considerably when it is combined with an amine, e.g. EMBO = (4-dimethylamino)-benzoic acid ethyl ester.

Ivocerin®

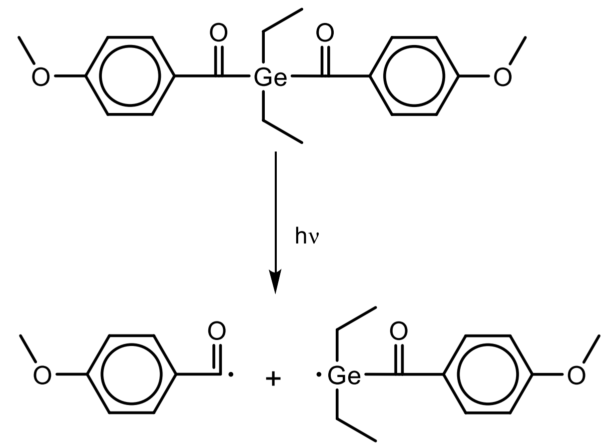

Fig. 2 Light-cure reaction mechanism of Ivocerin

Ivocerin is a Norrish type I photoinitiator. That is, no additional components are needed for radical formation. When the initiator is exposed to light, cleavage of a chemical bond within the initiator molecule takes place and two radicals are formed, which subsequently react with the monomer to produce a polymer network.

Self cure

Self-curing luting composites are always made up of two components. The initiators that are responsible for the curing mechanism are kept separate to prevent any premature reaction. The initiator system of many of these products consists of benzoyl peroxide (BPO) and a tertiary aromatic amine component, e.g. DABA = diethylamine-3,5-di-tert-butylaniline. The initiators are dissolved in the monomer matrix and together with conventional fillers they form a relatively thin paste. The BPO-containing paste is usually referred to as the catalyst and the amine-containing paste as the base (amines have basic properties). The curing process begins as soon as the two pastes are mixed to a homogenous consistency. The reactivity, in other words, the length of the working time, is determined by the amine concentration of the base paste. At room temperature, luting composites usually have a working time of approx. 100 seconds. The mixed paste can be manipulated during this period of time, without showing any signs of polymerization. The curing reaction is highly temperature dependent. Pastes that are mixed immediately after they are taken from the refrigerator can be manipulated for a longer period of time. During the curing process, the radicals react with the double bonds of the monomers as well as with oxygen in the air. Since the self-curing process proceeds more slowly than the light-curing process, the radicals have more time to react with oxygen.
As a result, an oxygen inhibition layer builds on the luting composite on the mixing pad. This layer is very sticky and may lead the clinician to believe that the material has not cured properly. In clinical situations, the luting composite will cure unhindered between the tooth structure and the restoration, without any contact with oxygen. In this case, an inhibition layer may still be recognizable on the excess material, which is easy to remove. Luting composites that solely rely on self-curing have almost disappeared from the market, since this curing process cannot be

accelerated. Furthermore, excess is usually very difficult to remove and the inhibited layer is much thicker than that which forms after curing with light.

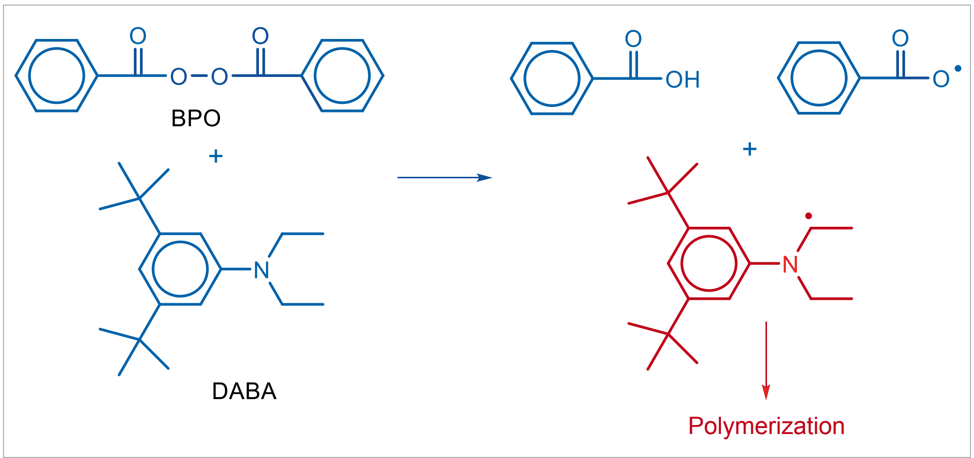

Fig. 3 Light-cure reaction mechanism of BPO/amine (DABA)

The disadvantage of benzoyl peroxide/amine systems is the fact that peroxide is sensitive to high temperatures and therefore these products have to be refrigerated in most cases.

In recent years, however, self-curing and dual-curing luting agents have been developed, which contain an alternative initiator system that is considerably more temperature resistant. As a result, these products no longer require refrigeration. The system is based on stable hydrogen peroxide and thiocarbamide. In addition, the curing reaction can be accelerated by adding very small amounts of copper. The system is described in detail in the next section.

Dual cure

Most of the luting composites available today are supplied in dual-curing form. Their composition is similar to that of self-curing luting composites: that is, they consist of two components. The base paste additionally contains a light initiator like that found in light-curing materials. These products are indicated for all types of restorations, and the clinician does not have to take the translucency of the restorations into consideration.

If the restoration is opaque, the material is allowed to self cure. However, if the restoration is translucent, the light initiators and the self-cure initiators react.

The dual-curing process produces the most radicals and therefore achieves the best polymerization results, since the light-activated camphorquinone induces the disintegration of benzoyl peroxide.

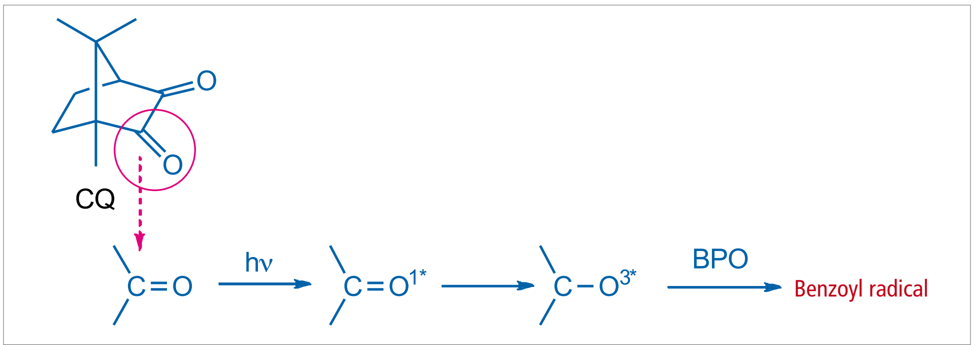

Fig. 4 Camphorquinone-induced disintegration of benzoyl peroxide

The following tables featuring Variolink II and Variolink Esthetic show the influence of curing on the flexural strength and the modulus of elasticity. Clearly, the highest strength values are attained after dual curing.

	Base Light cure	Base + Catalyst Self cure	Base + Catalyst Dual cure
Flexural strength (MPa)	114 ± 6	107 ± 5	132 ± 7
Modulus of elasticity (MPa)	8300 ± 300	6000 ± 300	10500 ± 400

Table 1 Flexural strength and modulus of elasticity of Variolink II

	Base Light cure	Base + Catalyst Self cure	Base + Catalyst Dual cure
Flexural strength (MPa)	99 ± 8	111 ± 14	124 ± 14
Modulus of elasticity (MPa)	4160 ± 160	6460 ± 360	6570 ± 290

Table 2 Flexural strength and modulus of elasticity of Variolink Esthetic

Ivocerin® and hydrogen peroxide/thiocarbamide compared with conventional initiator systems

As discussed in the "Self cure" section, an initiator system that offers an alternative to BPO/amine is based on hydrogen peroxide and thiocarbamide. The incorporation of a peroxide that is more stable than benzoyl peroxide (BPO) allows the luting composite to be stored at room temperature. Moreover, instead of an amine, this initiator system contains a thiocarbamide, which also improves the product's colour stability.

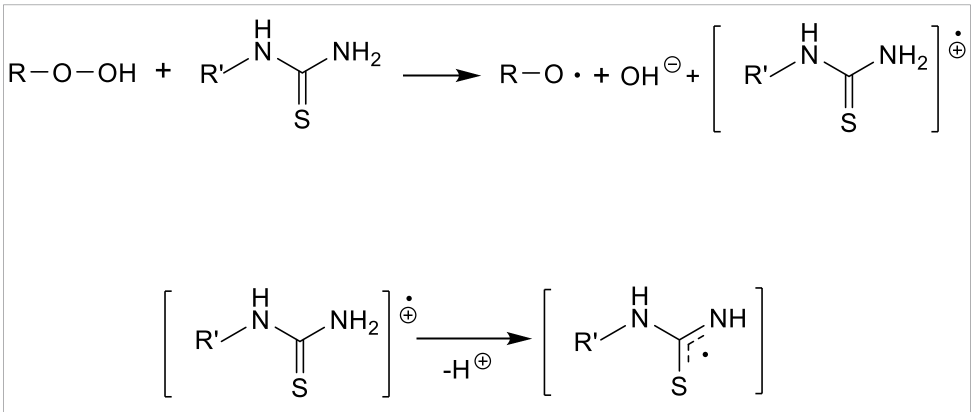

Fig. 5 Radical formation of hydrogen peroxide with thiocarbamide [1]

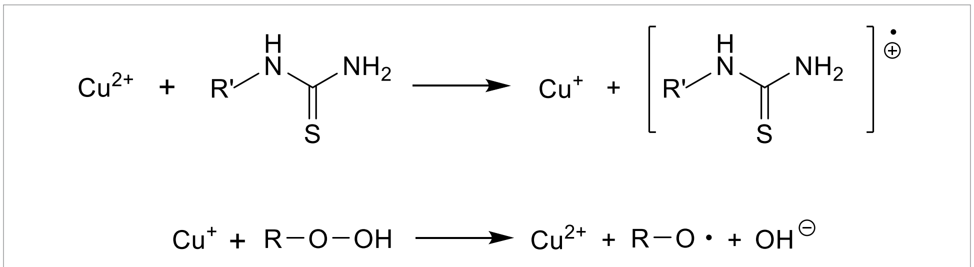

Fig. 6 Redox catalysis mechanism with Cu ions

An impeccable amine-free dual-curing system is obtained when the light activator Ivocerin is added to this initiator system. Conventional dual-curing composites based on BPO/amine and CQ/amine are by far not as colour stable as exclusively light-curing materials, since not only an amine needs to be provided for the light-curing process, but an additional amine is needed for the self-curing process. It is a generally accepted fact that the colour stability of a material decreases as the amine content increases. Variolink Esthetic is the first entirely amine-free luting composite on the market. Some competitive materials are said to be "amine-free" to a certain extent. However, this is only true for the self-curing, but not for the light-curing process.

Since Ivocerin is a Norrish type I initiator, Variolink Esthetic has the benefit of being a completely amine-free luting composite. Whereas the top priority in the development of Tetric EvoCeram Bulk Fill was to ensure the high reactivity of the initiator, the main aim with regard to the initiator in the case of a luting composite such as Variolink Esthetic was to fine tune its reactivity so that the material could be thoroughly cured, while at the same time excess could be removed without difficulty. Therefore, a relatively low concentration of Ivocerin was incorporated into the composite, which enables easy clean-up of excess after curing.

Literature

[1] V. A. Lopyrev, M. G. Vorokov, E. N. Baiborodina, N. S. Shaglayeva, T. N. Rakhmatulina, J. Polym. Sci. Polym. Chem. Ed. 17 (1979) 3411-2

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Luting Materials

From Variolink® II and Variolink® Veneer to Variolink® Esthetic

Introduction

The highly esthetic luting materials Variolink® II and Variolink Veneer from Ivoclar Vivadent have been on the market since 1997 and 2005, respectively. For more than 15 years, these products have been successfully fulfilling the requirements related to the adhesive cementation of highly esthetic restorations. With Variolink Esthetic, a newly designed successor product was introduced in 2014. Variolink Esthetic is a colour stable adhesive luting system for the permanent luting of glass-ceramic, lithium disilicate glass-ceramic, composite and oxide ceramic restorations (inlays, onlays, bridges and veneers). Variolink Esthetic is available in two variants: as the purely light-curing Variolink Esthetic LC (replacing Variolink Veneer) and the dual-curing Variolink Esthetic DC (replacing Variolink II). Variolink Esthetic LC is only suitable for restorations that do not exceed a maximum thickness of 2 mm and offer a sufficient degree of translucency, whereas Variolink Esthetic DC is also suitable for opaque restorations. Both the DC version and the LC version are supplied in the same five shades.

While the compositions of Variolink II and Variolink Veneer differ in terms of monomers and fillers, Variolink Esthetic DC and LC feature both the same formulation. Only the additives are different as the DC version additionally includes self-curing initiators, which are not required in the LC version. Given their identical formulation, the DC and LC variant offer the same handling properties and this considerably facilitates the application procedure.

It goes without saying that a newly developed product such as Variolink Esthetic should feature excellent physical properties to be at the cutting edge of technology. The objective of this new development was to simplify both, the application of Variolink Esthetic and the adhesive bonding procedure, which still has a reputation for being a relatively complex and somewhat error-prone procedure. The intention was to free dentists from worries regarding application errors. Consequently, the main development goal was to redefine and improve the handling properties (in collaboration with internal and external dentists).

One difficulty is to define the handling properties in the first place, as many different opinions prevail on this subject. How exactly do you define stickiness, flowability, stable consistency and excess removal? We had to rise to this challenge in Variolink Esthetic and come up with a solution that, in the end, would result for the user in a significant improvement of the application procedure in terms of simplicity, reliability and performance. The guiding principle was to design Variolink Esthetic to be as easy and reliable to use as possible without compromising its physical properties and to substantially improve certain aspects to ensure, for instance, high colour stability and easy excess removal. Developing a new shade system capable of meeting the highest esthetic demands with a minimum number of shades was another major goal.

Chemical composition

Initiators (Ivocerin®) and additives

For the first time, Ivocerin®, the germanium based light-activated initiator system developed and patented by Ivoclar Vivadent, has been used in a luting material. In addition, the conventional tertiary amine benzoyl peroxide system has been substituted with a new thiocarbamide hydroperoxide self-curing initiator system. These two new initatior systems offer the advantage that they no longer require the use of an amine system, neither for light-curing nor for self-curing. Some commercial products claim to be amine free, however the small print often contains information saying that only self-curing was achieved without classic tertiary amine or that the product contains another amine (not tertiary amine). All light-curing and/or dual-curing composites that have been available on the market thus far contain a conventional camphorquinone / amine system, none of them can do completely without amine. Variolink Esthetic is therefore the first luting composite that is truly and completely free of amine. This takes colour stability to new heights and ensures long-lasting highly esthetic results.

Amine free

As both the self-cure and the dual-cure versions contain amine-free initiator systems, Variolink Esthetic does not discolour with age.

Colour stability according to ISO 4049			
Variolink Esthetic LC neutral	illuminated		not illuminated
Variolink Esthetic DC neutral	illuminated		not illuminated

Fig. 1 Colour stability after illumination according to ISO 4049

To determine the colour stability according to ISO 4049, the left half of the sample was constantly irradiated with intensive light for 24 hours and then examined for a possible yellowing effect. No noticeable differences in colour were detected between the half that had been illuminated and the half that had not been illuminated. Variolink Esthetic is colour stable.

Changes in colour after water storage

Many products shift colour after having been in contact with water.

Water storage			
Variolink Esthetic LC	Reference		After water storage
Variolink Esthetic DC	Reference		After water storage

Fig. 2 Variolink Esthetic did not show any colour shift after water storage for 24 weeks.

Natural fluorescence

When natural teeth are illuminated with shortwave light, they appear blue-fluorescent. Restorative materials should also demonstrate a tooth-like fluorescence to achieve a true-to-life appearance. As shown in the Figure below, cured Variolink Esthetic shows a tooth-like fluorescence when illuminated with shortwave light.

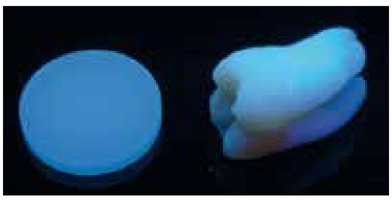
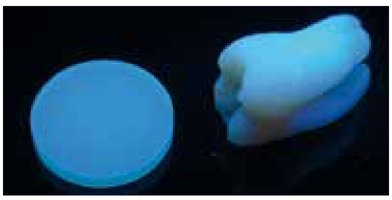
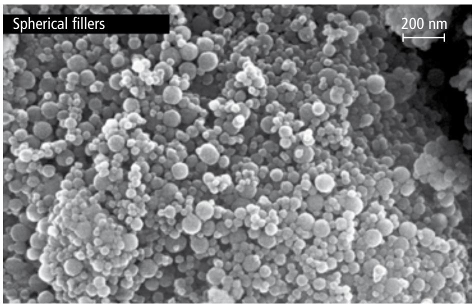
Fluorescence	
Variolink Esthetic LC neutral	
Variolink Esthetic DC neutral	

Fig. 3 The fluorescence of Variolink Esthetic is comparable to that of the natural tooth.

The fillers of Variolink® Esthetic

One objective of the development was to improve the wear resistance and heighten the translucency of the luting composite to allow for a broader spectrum of esthetic shades. For this purpose, fillers of small size were used. The primary particle size was reduced to an average size of 100 – 200 nm, compared to 1 µm in Variolink II. To additionally combine stable consistency and flowability, exclusively spherical fillers were employed. This approach allowed us to increase the translucency of the material and, at the same time, to achieve a radiopacity of over 300% Al in all the shades (enamel has a radiopacity of approx. 200% Al). Such a high radiopacity has never before been seen in a highly translucent shade.



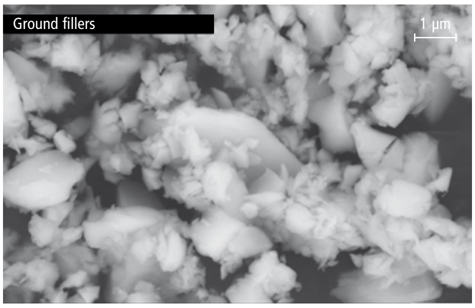


Fig. 4a and b Comparison between spherical fillers (particle size: 100 nm) and ground fillers (particle size: 1 µm). Different scales have been used in the two images, but the differences in the structure are clearly visible.

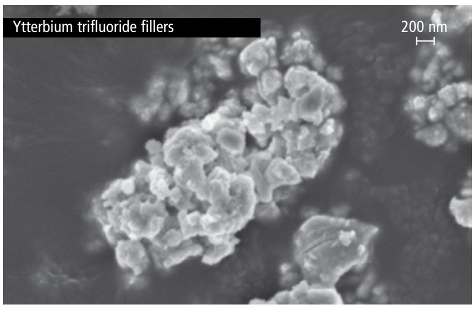


Fig. 5 Rounded ytterbium trifluoride fillers

Composition (wt. %)	Variolink Esthetic	Multilink Automix	Variolink II	Variolink Veneer
Monomer mixture	30–38 %	37 %	25–31 %	36–41 %
Fillers	60–68 %	61 %	67–73 %	57–62 %
Initiators and stabilizers	1–2 %	1–2 %	1–2 %	1–2 %
Pigments	<1 %	<1 %	<1 %	<1 %

Although the particle size of the fillers has been substantially reduced, the filler content is similar to that of other luting composites. This is possible due to the use of low-viscosity monomers. Additionally, the hydrophilic/hydrophobic properties of the monomers were adjusted to the fillers to ensure optimal wetting of the fillers. Moreover, the interaction between the monomer matrix and the spherical fillers imparts an outstandingly high thixotropy to Variolink Esthetic, even if the material has a low viscosity. The advantage of the thixotropic effect is that Variolink Esthetic becomes flowable as soon as light pressure is applied (e.g. when extruding the cement from the syringe, inserting the restoration in the oral cavity). When the force is no longer applied, Variolink Esthetic immediately returns to its stable consistency. The advantage of this effect is that excess material does not flow into the sulcus but remains stable at the restoration margin and can be easily removed. The unique interplay between the spherical fillers and the coordinated monomer mixture provides "flowability on demand", imparting a flexible, situational consistency to the luting material.

Monomer mixture

The use of small-particle fillers necessitated the incorporation of low-viscosity, highly reactive monomers to allow a high filler content. Innovative monomers that have been developed in-house and patented were used for this purpose. These monomers give Variolink Esthetic a creamy and low-viscosity consistency while its filler content is comparable to that of other luting composites.

Physical properties

Shades

In order to ensure an accurate shade match between the restoration and the neighbouring teeth, Ivoclar Vivadent has developed the new, balanced and clearly arranged "Effect shade concept". The shade "neutral" has no shade effect on the finished restoration due to its high translucency. The shades "light" and "light+" create a lighter effect in gradations and the shades "warm" and "warm+" create a darker effect in gradations. The shades are named according to their effect on the finished restoration to make it easier for users to select the correct shade for the given clinical situation.

Shades

Variolink Esthetic LC

Translucency	5 %	10 %	25 %	12 %	8 %

Variolink Esthetic DC

Translucency	5 %	10 %	25 %	12 %	8 %

Fig. 6 Variolink Esthetic LC and DC are both available in the same five shades. This new Effect shade system of Variolink Esthetic covers all previous six shades of Variolink II and seven shades of Variolink Veneer.

Radiopacity

The radiopacity of the DC and LC version of Variolink Esthetic is equally high in all shades.

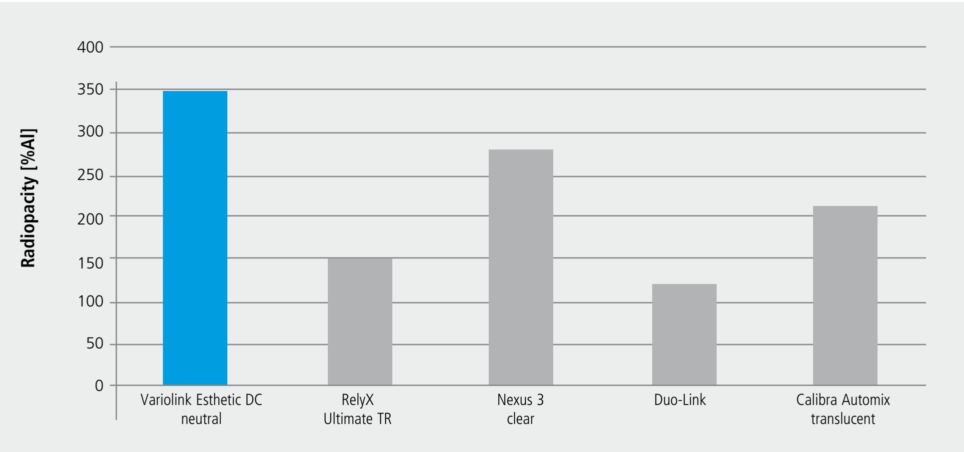


Fig. 7 Radiopacity compared with competitive materials

Compared with other products, Variolink Esthetic has a high radiopacity even in the highly translucent esthetic shades. The material's high radiopacity is achieved by the use of highly translucent spherical fillers combined with ytterbium trifluoride.

Flexural strength

The flexural strength of Variolink Esthetic clearly exceeds the minimum value stipulated by ISO 4049 (>50 MPa) and is comparable with that of established luting composites.

	Variolink Esthetic	Multilink Automix	Variolink II
Self-cured	111 ± 14 MPa (DC*)	91 ± 6 MPa	107 ± 5 MPa
Dual-cured	124 ± 14 MPa (DC*)	114 ± 17 MPa	132 ± 7 MPa
Light-cured	99 ± 8 MPa (LC*)	–	114 ± 6 MPa (Base)

*Versions used: DC – Variolink Esthetic DC; LC – Variolink Esthetic LC

Handling properties

Stickiness

By using spherical fillers and low-viscosity monomers, a thinly viscous material with considerably reduced stickiness has been developed. In a Zwick testing machine, a specified quantity of luting material was applied and then the plunger was withdrawn at consistent speed. Still images of all sample materials were taken immediately before the filament of material tore. The images clearly show that the stickiness of Variolink Esthetic was very low. Compared with the other materials tested, Variolink Esthetic exhibited hardly any stringing. This is a substantial advantage when removing uncured excess material.

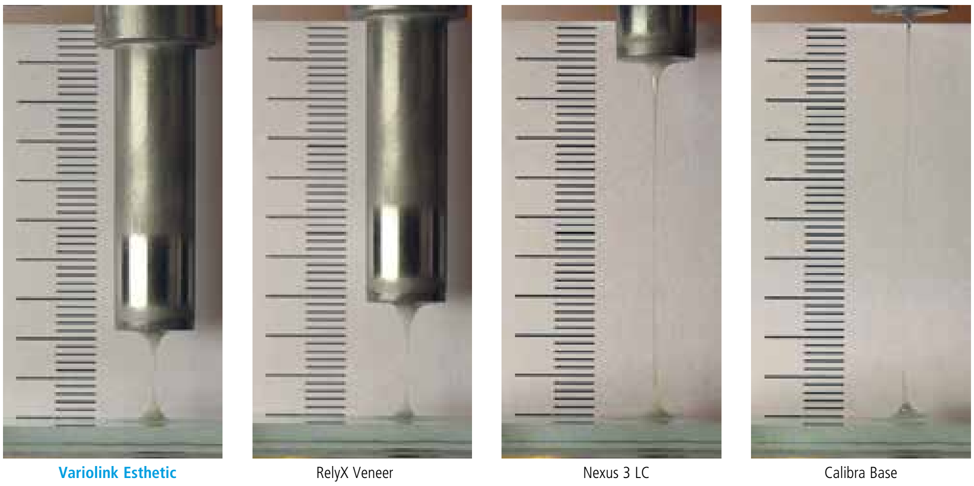


Fig. 8 Variolink Esthetic is by far the least sticky material. Stringing is minimal after contact.

Flexible, situational consistency

When Variolink Esthetic was developed, care was taken to ensure that only minimal force is required to insert the restoration to ease the procedure and enhance clinical safety. This is particularly important when placing delicate, ultra-thin restorations, e.g. veneers.

In spite of its stable consistency, Variolink Esthetic becomes flowable during application due to its thixotropic properties. The thixotropic effect is the result of a special interaction of the monomer mixture with the spherical fillers of the material. As soon as force is applied, for instance when extruding the resin from the syringe or when placing the restoration, Variolink Esthetic begins to flow. When no force is applied, the material immediately returns to its stable consistency. This facilitates excess removal considerably and prevents the material from flowing into the sulcus or to other tooth areas, from where it is difficult to remove.

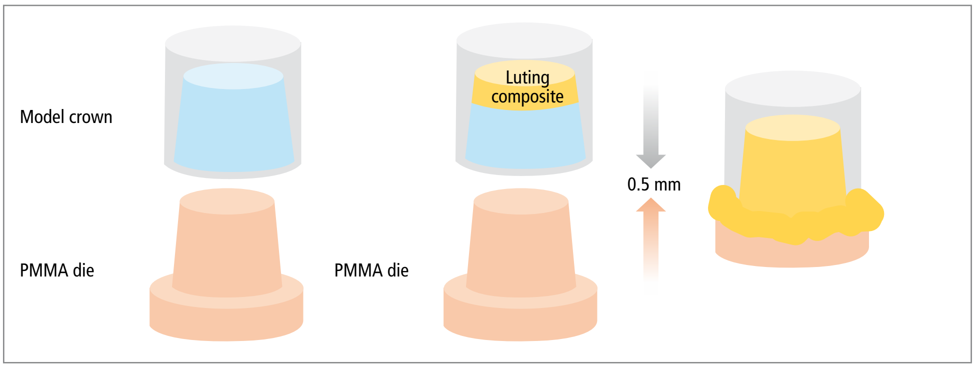
Pyrogenic silicon dioxide is normally employed to impart thixotropy, with the disadvantage, however, that the silica often causes the paste to become thicker. This thickening effect has been avoided in Variolink Esthetic by using raw materials (monomers, fillers) exclusively developed for Ivoclar Vivadent instead of using fumed silica.

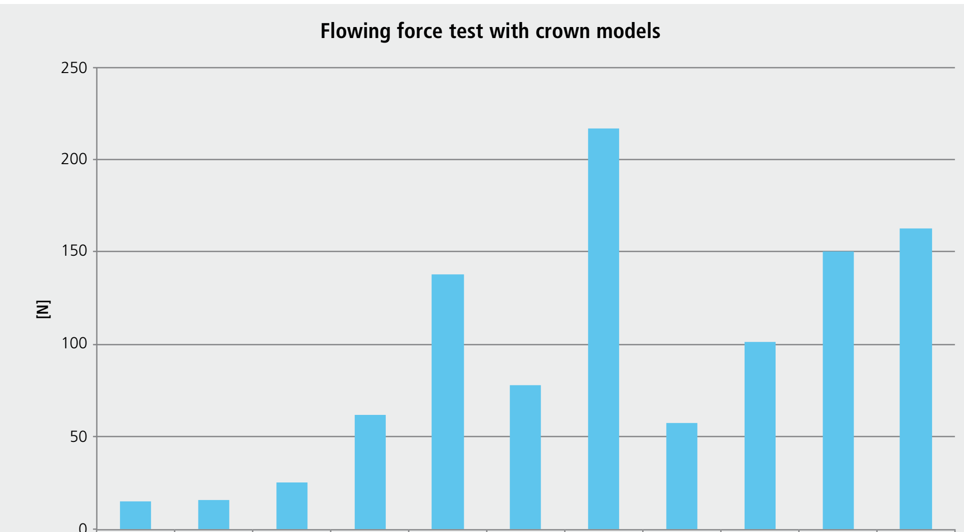
Fig. 9 Stable consistency of luting composites in comparison

Fig. 10 A simulated application in PMMA crowns clearly shows the difference in the behaviour of a stable and a flowable material.

Flowability

Flowability can be determined by measuring the force required to place a restoration on an abutment. To conduct this test, a PMMA model crown was filled with luting composite and pressed onto a PMMA abutment at a speed of 120 mm/min, until a film thickness of 0.5 mm resulted. The less force is required to achieve this film thickness, the better is the flowability of the luting composite.





	Variolink Esthetic DC	Variolink Esthetic LC	RelyX Ultimate	Clearfil Esthetic Cement	Calibra Automix	NX3 Nexus Automix	NX3 Nexus Light-Cure	Panavia V5	Variolink Veneer	Variolink II Base	Variolink II Catalyst low-viscosity
Flow force [N]	15	16	25	62	138	78	217	58	101	150	163

Fig. 11 Schematic representation (above) and results (below) of the flowing force test with luting composites. Variolink Esthetic showed excellent flowability and required only minimal force to seat the crown.

Although Variolink Esthetic has excellent stability, it causes hardly any resistance when a crown is placed due to its high flowability.

Excess removal

Variolink Esthetic relies on the patented highly reactive Ivocerin® initiator as light initiator system. By accurately coordinating the concentration of Ivocerin with suitable initiators and self-cure initiators (dual-cure version), an exceptionally wide exposure window has been achieved, allowing ample time to remove excess material. After initial light activation, excess can be removed using the circular technique for the LC version and the quarter technique for the DC version.

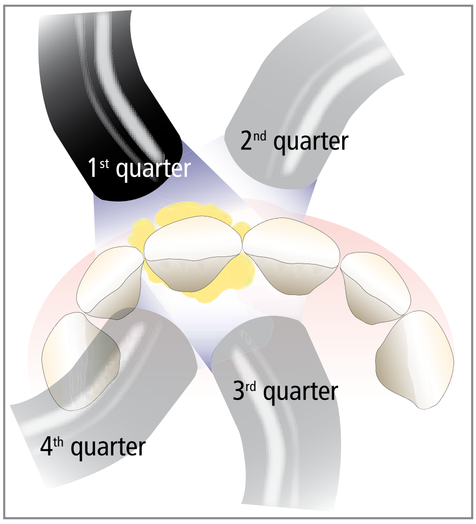
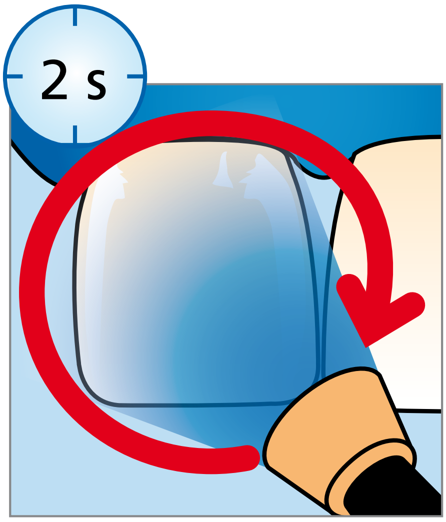


Fig. 12 "Quarter technique" for Variolink Esthetic DC



"Circular technique" for Variolink Esthetic LC

Conclusion

It goes without saying that a modern luting material must meet the highest physical and esthetic requirements and this has been achieved with Variolink Esthetic in an exemplary fashion. The handling properties play an equally salient role. The importance of establishing a procedure that clinicians can reliably use to consistently achieve long-term clinical success cannot be overemphasized. Easy and straightforward application of the luting composite at each stage of the procedure is essential to attain a successful clinical outcome. With this in mind, we invested a great deal of our effort into developing a material with improved application properties and we achieved the following objectives:

- Controlled application to the restoration: Variolink Esthetic does not flow and shows excellent wetting capabilities. The material is flowable during application but returns immediately to its stable consistency as soon as the application finishes.

- Easy placement of restoration: Variolink Esthetic immediately starts to flow with low resistance when the restoration is seated; even delicate restorations such as veneers are unlikely to be damaged and the clinician can concentrate on placing the restoration in the correct position without having to apply a great deal of force. The material's low stringiness further facilitates the procedure, as accidental contact is less likely to result in contamination of the adjacent teeth.

- Convenient excess removal: by using the Ivocerin photoinitiator, a comfortably long time window has been created to tack cure and remove excess material in good time without having to use much force. In contrast to many other products on the market, easy excess removal was not achieved by compromising the material's light-curing properties. To the contrary, the high reactivity of Ivocerin ensures that the resin achieves a complete depth of cure after excess removal.

- Efficient finishing of cement joints: the margins can be easily and effectively finished with polishing instruments in no time at all.

- Esthetic performance: the new Effect Shade Concept increases the shade spectrum and sets new standards in this product category. Independent of the shade used, a distinct chameleon effect is achieved. Using Ivocerin as photoinitiator offers the advantage that the relatively severe yellowing effect of camphorquinone/amine systems is no longer an issue.

Variolink Esthetic is a completely newly designed luting material that combines ease of use, high esthetics and long-term performance.

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Materials science investigations with Variolink® Esthetic

Introduction

During the development of a medical device numerous *in vitro* tests are carried out. Even though these examinations cannot directly predict the clinical performance of a product, they can offer valuable information, for example, about the product's compatibility with other restorative materials, or its tolerance to different working techniques. Variolink® Esthetic has been tested in a wide variety of *in vitro* studies. The most important results of these investigations are summarized below.

Variolink Esthetic owes some of its special properties to the initiator Ivocerin®. This light activator is highly reactive, but also easy to control. The curing process of luting composites ideally takes place in distinct phases. In the first phase, the clinician should have enough time to manipulate the luting composite. In this phase, the material should not polymerize under ambient light. In the next phase, the clinician should be capable of "tack-curing" the composite, so that excess material assumes a gel-like consistency. The luting composite must be prevented from polymerizing completely under any circumstances at this stage, as it would become too hard to remove. Consequently, the polymerization process should proceed very slowly. Once all the excess has been removed, however, the luting composite should polymerize quickly and thoroughly to attain its final hardness. Variolink Esthetic fulfils all these requirements, since it contains Ivocerin, which is very reactive, yet easy to control.

The studies described below show that Variolink Esthetic attains a high final hardness and establishes a strong and durable bond even when it is cured through a restorative material. Since the material's reactivity can be controlled, excess material can be cleaned up very easily. This has also been confirmed by numerous validation tests and the feedback of clinicians.

Polymerization through restorations

Luting composites are cured with a polymerization lamp through restorative materials, which absorb and scatter some of the emitted light. Even translucent restorative materials reduce the light that is available for the polymerization process: however, to a far lesser extent compared with opaque materials (Fig. 1). Only about 20% of the emitted light reaches the luting composite through a 2-mm ceramic layer. Therefore, the properties of the restoration should be taken into consideration when the light-curing parameters are chosen.

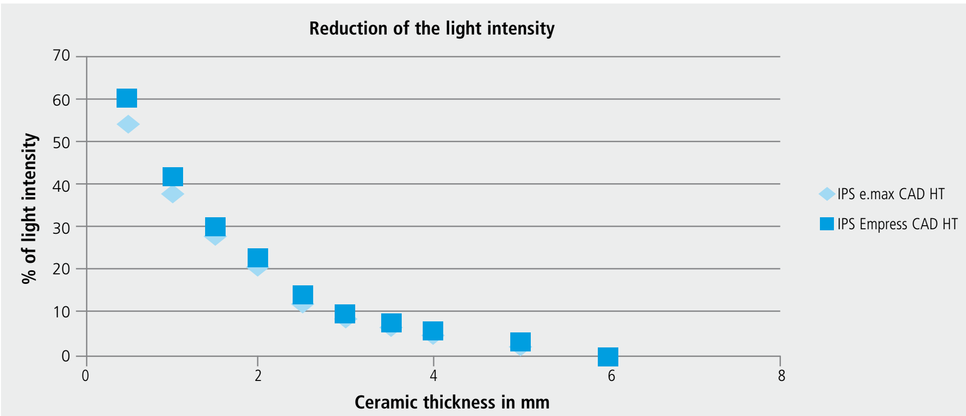

Fig. 1 Reduction of the light intensity of a polymerization light (Bluephase Style) by ceramic materials of different thicknesses (shade: HT A2), N. Ilie, LMU Munich, 2015

Excellent polymerization of a luting composite depends on the use of a suitable polymerization light and the proper setting of the light exposure time in relation to the restoration thickness as well as a highly reactive photoinitiator. Due to the inclusion of Ivocerin light activator, Variolink Esthetic can be reliably polymerized under restorations.

The properties of luting composites are determined by their degree of polymerization that can be determined via hardness tests. For this purpose, layers measuring approximately 500 µm were light cured through ceramic samples of various thicknesses (IPS e.max® CAD HT A2 and IPS Empress® CAD HT A2) with Bluephase® Style for 10 and 20 seconds. The surface hardness of the polymerized specimens was determined after 24-hour immersion in water (Fig. 2).

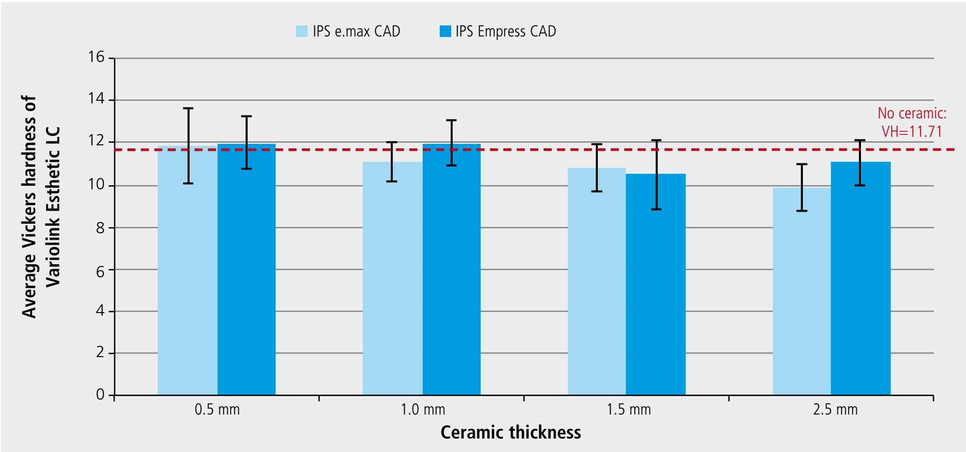

Fig. 2 Average hardness of Variolink Esthetic LC after 10 seconds of light curing with Bluephase Style through ceramic discs of various thicknesses. N. Ilie, LMU Munich, 2015

The hardness of briefly light cured (10 s) Variolink Esthetic decreases as the increment thickness of the ceramic increases. Nevertheless, this effect can be compensated by extending the light-curing time to 20 seconds.

Flexural strength

The flexural strength measures the resistance of a test specimen at the point of fracture when the sample is subjected to flexural stress. In addition to compressive and tensile strength, flexural strength represents a significant parameter for describing the mechanical strength of a material. The flexural strength of a composite material is significantly influenced by its chemical composition.

In flexural strength tests, luting composites were light cured and subsequently immersed in water at 37 °C for 24 hours (test according to ISO 4049).

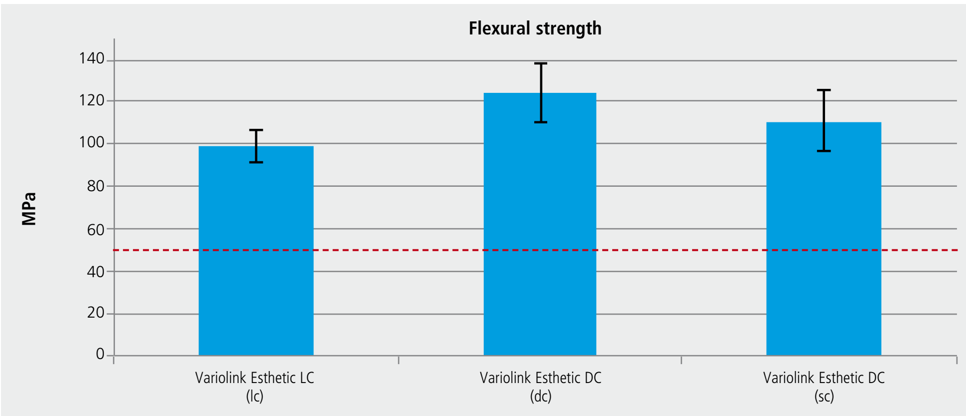

Fig. 3 Flexural strength of Variolink Esthetic LC and DC. The curing mode is indicated in lower case letters (lc = light cure, dc = dual cure, sc = self cure). The dashed red line represents the minimal flexural strength according to ISO 4049 (50 MPa).
R&D Ivoclar Vivadent AG, Schaan, 2013–2014

The high flexural strength of Variolink Esthetic was additionally confirmed in an external investigation conducted by Prof. Irie in Japan. In this study, some of the specimens were measured immediately after application, while others were evaluated after 24-hour immersion in water.

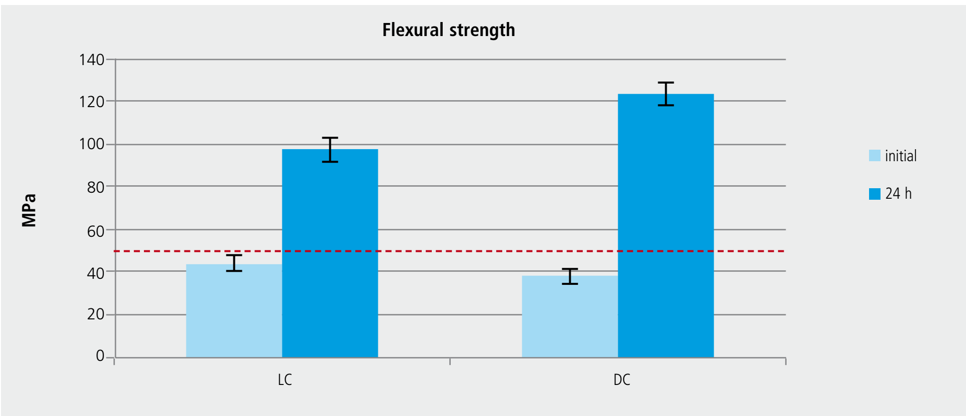

Fig. 4 Flexural strength of Variolink Esthetic LC and DC. Comparison of the values directly after application and after 24 hours. The dashed red line shows the minimal flexural strength according to ISO 4049 (50 MPa after 24 h). M. Irie, Okayama University, Japan, 2014

The initial curing speed of Variolink Esthetic was reduced with the aim of facilitating the removal of excess material. As a result, the initial values are lower than those measured after 24 hours. The ISO standard 4049 defines a minimum flexural strength of 50 MPa after 24 hours. This value is almost attained immediately after bonding.

Bonding on different substrates

Bonding on tooth structure (with adhesive)

The adhesion of Variolink Esthetic in combination with Adhese Universal on various tooth substrates was examined by Prof. Irie at Okayama University. The shear bond strength was investigated using test specimens measuring 3.6 mm according to ISO TR 11405.

The adhesive was applied to the tooth substrate – bovine dentin or enamel – either after phosphoric acid etching (total etch, TE) or without phosphoric acid etching (self etch, SE). Subsequently, the cylinders made of polymerized Tetric EvoCeram® were bonded to the substrate. All the luting composites were dual cured. The shear bond strength was measured after 24-hour immersion in water at 37 °C.

Results:

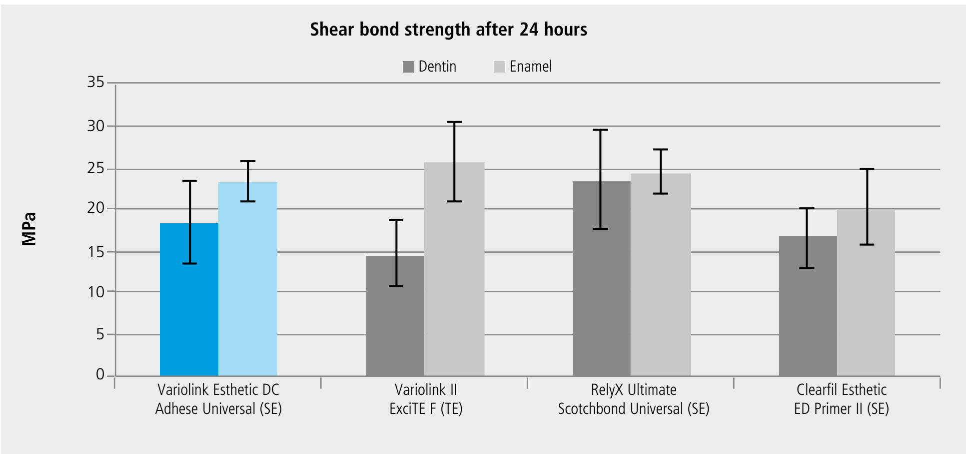

Fig. 5 Shear bond strength on dentin and on enamel 24 hours after application. (TE) total etch, (SE) self etch.
M. Irie, Okayama University, Japan, 2014

In combination with Adhese Universal, Variolink Esthetic produces excellent results on dentin and on enamel.

Bonding on restorative material (with primer)

The shear bond strength on IPS e.max CAD and IPS e.max ZirCAD was examined by Dr Rzanny at the University of Jena. Test specimens measuring 5 mm in diameter were bonded to ceramic substrates in combination with the recommended primers or adhesives and polymerized with a universal curing light for 90 seconds. The shear bond strength was determined after 24-hour immersion in water and 25,000 temperature cycles (TC) from 5 to 55 °C.

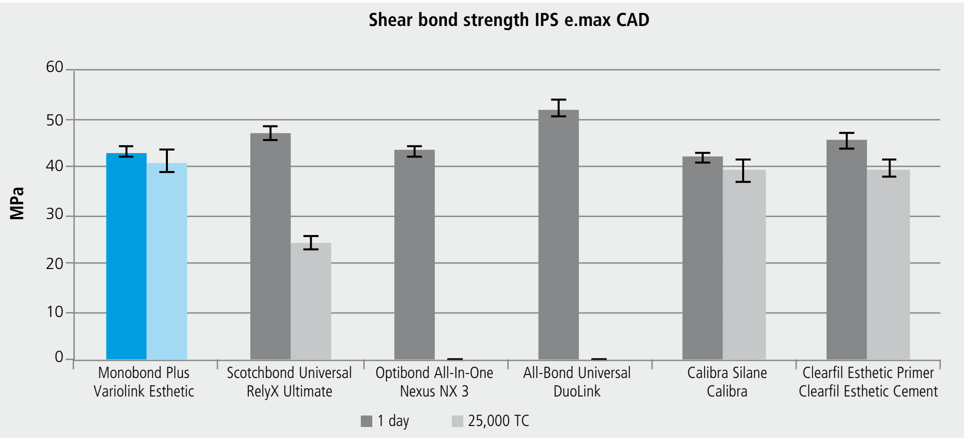

Fig. 6 Shear bond strength between IPS e.max CAD lithium disilicate ceramic and luting composites from different manufacturers using the conditioners recommended by the individual companies. A. Rzanny, University of Jena, 2015

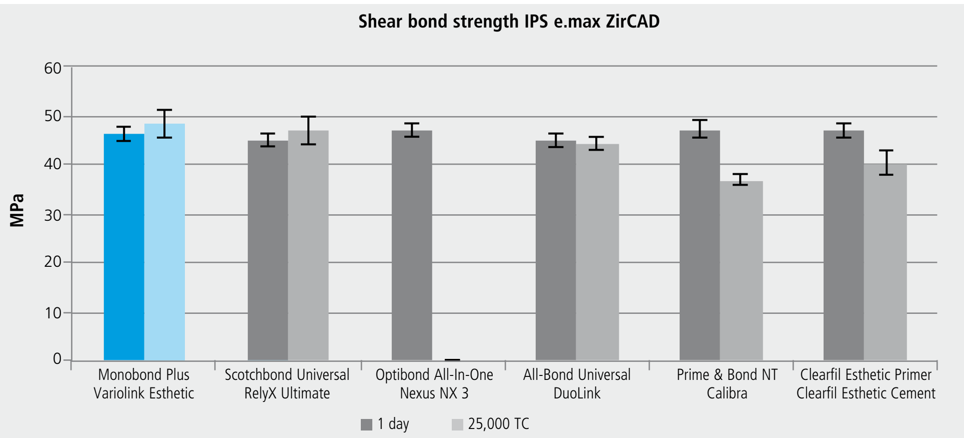

Fig. 7 Shear bond strength between IPS e.max ZirCAD zirconium oxide ceramic and luting composites from different manufacturers using the conditioners recommended by the individual companies. A. Rzanny, University of Jena, 2015

All of the luting composites tested in combination with IPS e.max CAD showed very good values after one-day immersion in water. However, considerable differences were noted between the specimens after 25,000 thermal cycles. The bond between IPS e.max CAD and Variolink Esthetic/Monobond Plus remained virtually unchanged, while it failed completely in the case of two other product combinations. In one other case, the shear bond strength decreased by half.

All the luting composites initially attained very high bonding values on IPS e.max ZirCAD zirconium oxide ceramic. Nevertheless, after 25,000 temperature cycles, the bond of one luting composite failed completely. The bond strength of one other luting composite decreased slightly but significantly.

In another study, Prof. Kern at the University of Kiel examined the tensile strength of various luting composites in combination with the primers or adhesives recommended for use with the different products.

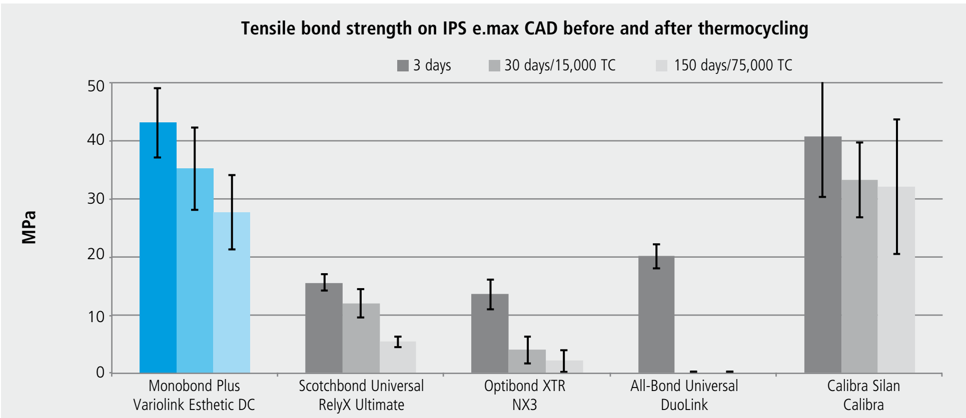

Fig. 8 Tensile bond strength of various luting systems on IPS e.max CAD. M. Kern, University of Kiel, 2015

The combination of Monobond Plus and Variolink Esthetic established a strong adhesive bond to the IPS e.max CAD lithium disilicate ceramic and the Wieland Zenostar T zirconium oxide ceramic (not shown) after three days, 30 days and 15,000 temperature cycles and after 150 days and 75,000 temperature cycles.

Conclusion

Numerous *in vitro* tests have documented the excellent physical characteristics and outstanding bonding properties of Variolink Esthetic on all the indicated materials and surfaces. These investigations – together with many other studies that have not been mentioned here – prove that Variolink Esthetic is capable of establishing a strong and long-lasting bond between the tooth structure and restorative materials.

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Variolink® Esthetic – The influence of luting composites and other factors on the overall appearance of all-ceramic restorations

Introduction

The Variolink® Esthetic Effect shade system has been developed with the aim of providing clinicians with a choice of different luting composite shades (neutral, light, warm) which will allow them to adjust the overall effect of ceramic restorations to suit the corresponding clinical situation (inlay/partial crown, veneer, crown). For an esthetic overall result, it is furthermore important to take into consideration at which angle the cement line will be viewed by the clinician/patient, depending on the type of restoration that is being placed (Figs 1 and 2).

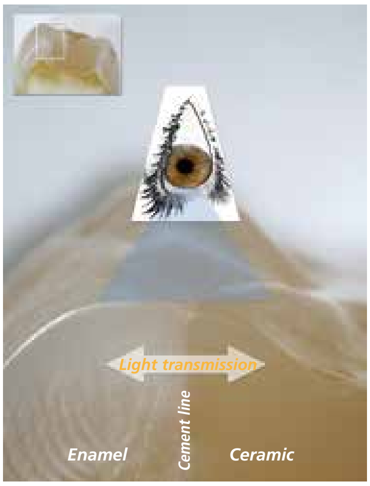

Fig. 1 Viewing angle of the cement line of an inlay

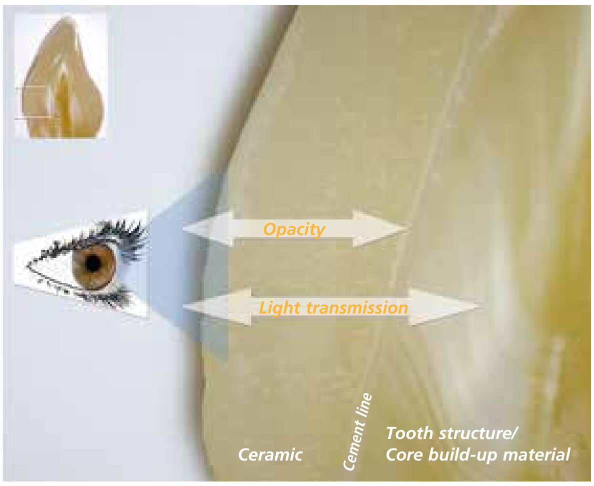

Fig. 2 Viewing angle of the cement line of a veneer or crown

The cement line of an inlay placed with the adhesive technique is viewed directly. Therefore, a highly opaque luting material would block the passage of light between the tooth structure and the ceramic and render the restoration and the cement line visible. As a result, inlays are usually bonded with transparent and lightly shaded luting materials, since they ensure the passage of light between the enamel and the ceramic (Fig. 1) and produce what is known as the "chameleon" effect, which allows the restoration to blend in virtually seamlessly with the tooth structure. In contrast, the cement line of adhesively cemented veneers and crowns is not viewed directly because it is usually located equigingivally or subgingivally in the anterior/visible region. Consequently, an opaque and strongly coloured luting composite can be used in these areas in order to block the passage of light between the restoration and the tooth structure, thereby lightening or darkening the restoration (Figs 2 and 3).

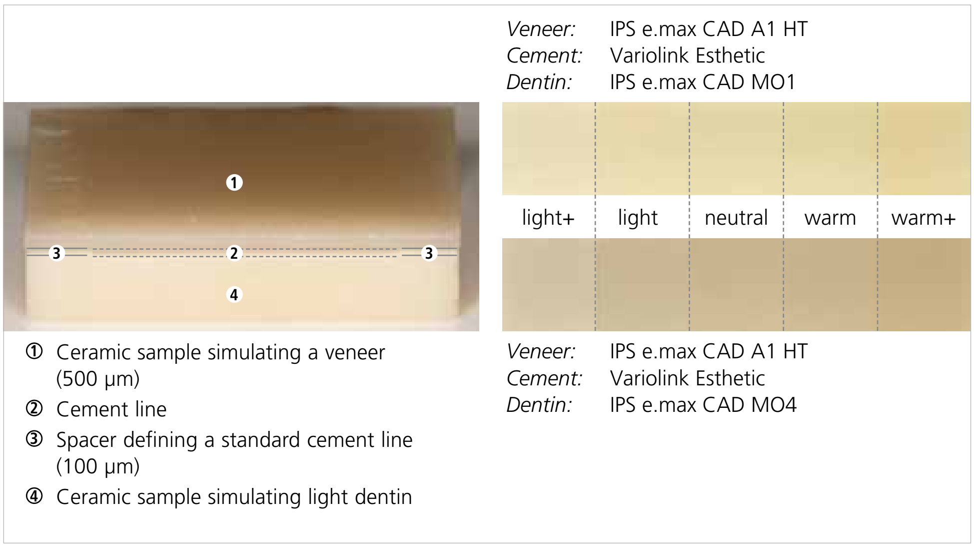

Fig. 3 *In vitro* test setup for the evaluation of the influence of the luting composite on the overall appearance of the restoration

The overall appearance of an adhesively cemented all-ceramic restoration basically depends on the following factors (Fig. 4) [1]:

- the layer thickness, translucency and shade of the natural tooth structure and the core build-up material [2];
- the layer thickness, translucency and shade of the restorative material and
- the layer thickness, translucency and shade of the luting composite.

Fig. 4 Factors influencing the esthetic overall effect of a ceramic restoration placed with the adhesive technique

Influence of the treatment protocol

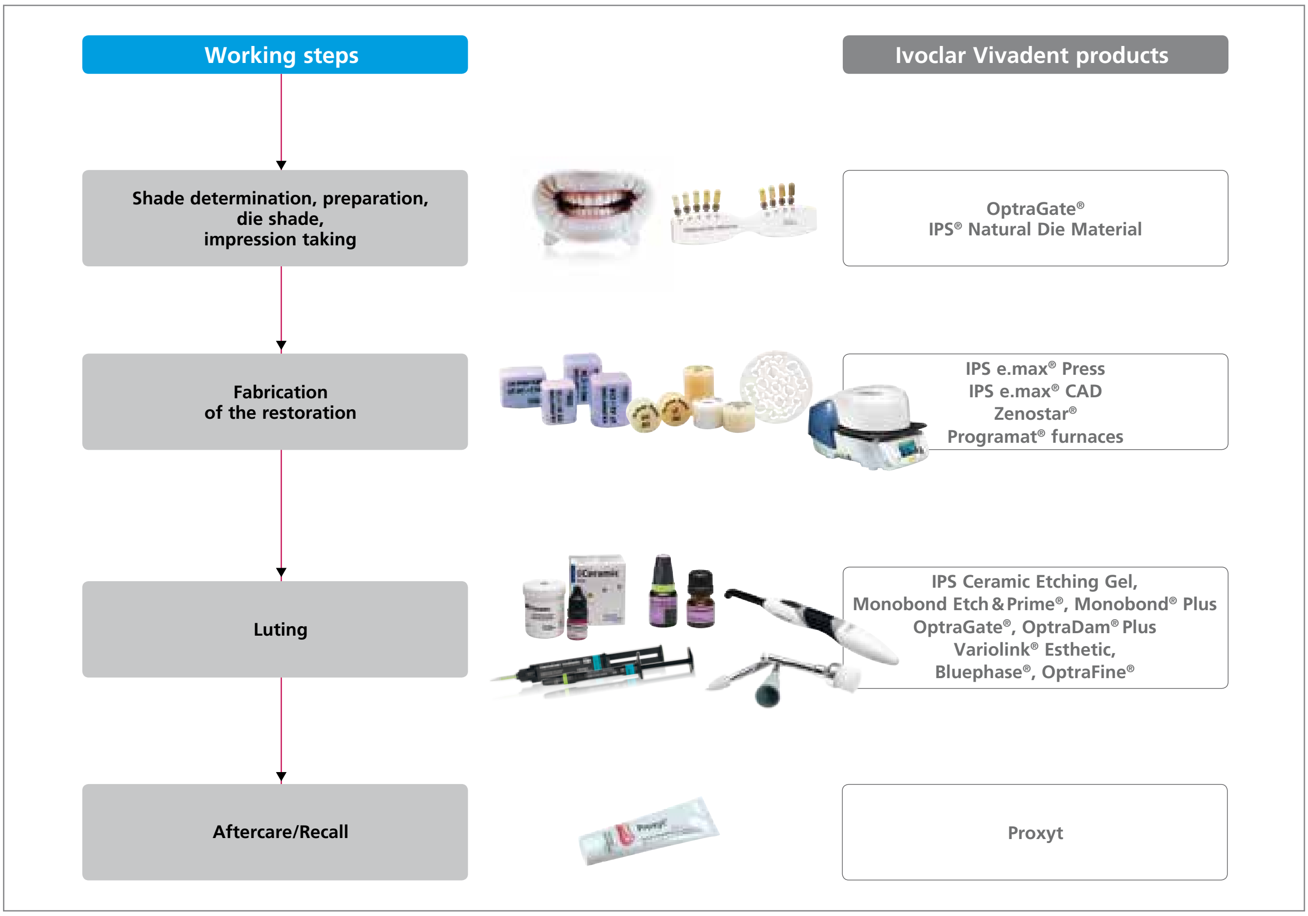

Fig. 5 Flowchart of the fabrication and cementation of an esthetic all-ceramic restoration

The clinical workflow in the fabrication of a lifelike restoration needs to be tightly structured (Fig. 5). Before a tooth is prepared for receiving an indirect restoration, the tooth colour has to be determined with the help of a shade guide. It is important to make sure that the tooth structure is not completely dry during this process, since dental hard tissue looks much lighter/opaquer when it is dry than when it is wet (Figs 6–9).

Fig. 6 Try-in of an IPS e.max CAD HT restoration using Variolink Esthetic Try-In Paste neutral

Fig. 7 Application of a rubber dam around tooth 46 before the all-ceramic restoration is luted

Fig. 8: Situation immediately after the restoration was seated and the rubber dam removed. The tooth structure on the mesial aspect of tooth 46 looks light/opaque because it dried out while it was isolated.

Fig. 9 Baseline situation after about one week *in situ*. The restoration is fully integrated into the natural tooth structure.

Influence of the colour of the remaining tooth structure

In some cases, for example, when the tooth structure is isolated, a lighter shade than that required may be selected and a restoration with an unsuitable colour fabricated as a consequence. The shade should be determined on the basis of the remaining tooth structure after the tooth has been prepared. The IPS Natural Die Material system is designed for this purpose. A separate shade guide is provided for determining the colour of the remaining tooth structure. This allows the dental lab technician to create a model that simulates the clinical situation. With the help of this model, shade and brightness of the restoration are adjusted (Fig. 10).

Fig. 10 Overall appearance of a veneer (500 µm); same luting composite, but different die material shades
Restoration = veneer (500 µm) = IPS e.max CAD HT B1
Luting material = Variolink Esthetic neutral
Die material shade = IPS Natural Die Material No. 1 > 2 > 3 > 4 > 5 > 6 > 7 > 8 > 9

Influence of the restorative material

A wide range of materials in a variety of shades and levels of translucency is available for different types of indications. With increasing thickness, the restorative material exerts an increasing influence on the overall appearance of the all-ceramic restoration (Fig. 11) [3]. The reverse is the case for translucency. If the restorative material is more translucent, the remaining tooth structure and the luting material will have a stronger influence on the overall esthetics. The shade of the restorative additionally influences the appearance of the restoration: the higher the colour intensity, the stronger the effect on the result (Fig. 12).

Fig. 11 Influence of the layer thickness and translucency of the restorative material; same shade, luting composite and die material shade
Restoration –> left = veneer (500 µm, IPS e.max CAD HT B1)
–> right = crown (1.5 mm, IPS e.max CAD LT B1)
Luting material = Variolink Esthetic neutral
Die material shade = IPS Natural Die Material No. 6

Fig. 12 Influence of the restoration shade on the overall appearance; same luting composite and die material shade
Restoration = crown (1.5 mm)
–> IPS e.max CAD LT B1 (left)
–> IPS e.max CAD LT A3 (right)
Luting material = Variolink Esthetic neutral
Die material shade = IPS Natural Die Material No. 7

Influence of the luting composite

Since the luting material layer is very thin in relation to the remaining tooth structure and the restorative material, its influence on the optical effect of the restoration is relatively small, in particular, if the restoration is thick and intensely coloured [4]. The thickness of the luting material layer is defined with the help of an interspace varnish (press technique) or a spacer (CAD/CAM). It should be as thin as possible to prevent any impairment of the fit of the restoration. Nonetheless, by increasing the level of the opacity or colour intensity of the luting composite (lightening or darkening), thin and translucent restorations in particular can be influenced (Fig. 13).

Fig. 13 Influence of the luting composite shade on a thin, translucent restoration; same die material shade
Restoration = veneer (500 µm) = IPS e.max CAD HT B1
Die material shade = IPS Natural Die Material No. 5
Luting composite = Variolink Esthetic (light+ > light > neutral > warm > warm+)

When trying in restorations before they are permanently cemented, it is of utmost importance to use a try-in paste in a shade that matches that of the permanent luting composite. Without the try-in paste, light refraction on the inner surface of the restoration will not allow the final appearance to be reliably evaluated (Figs 14 and 15). Furthermore, the teeth should not be completely dry when the restoration is tried in, because dry teeth appear brighter and more opaque. This could lead to selecting a luting composite which has too little chroma or is too opaque. Then, when the teeth are eventually rewetted, the shade of the restoration may appear too intense or too bright.

Fig. 14 Try-in of an IPS e.max CAD HT inlay in tooth 16 without try-in paste. Due to the interrupted passage of light between the tooth structure and the restoration, the cement line and the restoration are clearly visible.

Fig. 15 Try-in of an IPS e.max CAD HT inlay in tooth 16 using Variolink Esthetic Try-In Paste neutral. Since light can pass through the tooth structure and the restoration, the cement line is invisible and the restoration blends in seamlessly with the tooth structure.

Conclusion

Variolink Esthetic offers the possibility of enhancing the overall esthetic appearance of all-ceramic restorations in different clinical situations. The finely tuned levels of opacity/translucency of the Effect shades allow restorations to be selectively lightened or darkened. With the help of the special try-in pastes contained in the system, the most appropriate luting composite shade can be selected quickly and easily. Nevertheless, the clinician must be aware of the fact that the luting composite will have only a relatively small effect on the overall appearance of the restoration because the luting material layer is very thin. Therefore, it is very important to pay special attention to the other factors that influence the esthetics of a restoration during the treatment procedure: for example, the determination of the tooth shade and the die material shade and the selection of the restorative material.

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Variolink® Esthetic in clinical use

Introduction

Adhesive composite-based luting materials represent an established group of luting materials. They allow highly esthetic restorations made of ceramic materials such as IPS e.max® CAD/Press to be placed without retentive preparation and consequently enable a tooth-conserving preparation technique. The shade and translucency of adhesive luting composites may be used to enhance the esthetic result, particularly in restorations of a thin material thickness. Adhesive luting materials provide long-term integrity of the cement line due to their low solubility and high wear resistance [1, 2, 3].

Application properties

Easy removal of excess was considered an important user requirement in the development of Variolink® Esthetic. The result is a luting material that offers optional tack curing with light to enable easy removal of excess material while it is in a gel state. In addition, the soft flexible consistency prevents the luting composite from contaminating the neighbouring structures when the restoration is seated and/or pre-cured (see Chapter "From Variolink® II and Variolink® Veneer to Variolink Esthetic"). If the dual-curing version Variolink Esthetic DC is used, the "quarter technique" is applied for tack curing excess material. With this technique, each quarter surface (mesio-oral, disto-oral, mesio-buccal, disto-buccal) is light-cured for two seconds (Clinical Case 1). If the light-curing version Variolink Esthetic LC is applied, all excess cement is tack cured in two seconds by running the light guide along the entire cement line in a continuous motion (known as circular technique). Excess material can also be removed using a conventional wiping technique in conjunction with both the DC and LC versions (clinical case 2).

Clinical experience with Variolink® Esthetic

In the course of clinical observation, experiences with the Variolink Esthetic luting composite were collected and reviewed. The focus was placed on documenting and analysing possible postoperative complaints as well as the esthetic integration and initial marginal quality of the newly seated restorations. The clinical performance of a total of 60 all-ceramic inlays and onlays made of IPS e.max CAD and seated using Variolink Esthetic DC was assessed. Syntac® and Adhese® Universal were used as bonding agents in conjunction with the etch & rinse technique and/or self-etch technique. This set-up resulted in three observation groups (Fig. 1). After having been seated, the IPS e.max CAD restorations were evaluated based on FDI criteria [4, 5] (Table 1) using a **S**emi-**Qua**ntitative **C**linical **E**valuation method (SQUACE). This method assisted in documenting the percentage of marginal irregularities, marginal staining and marginal caries in relation to the total length of restoration margins [6].

Fig. 1 Schematic showing the combinations of materials investigated

	Evaluation of restoration							Evaluation of restoration margin		
	A= esthetic				B = functional	C = biological		A = esthetic	B = functional	C = biological
	Surface lustre	**Surface staining**	**Colour match / translucency**	**Anatomical form**	**Fracture / retention loss**	**Hypersensitivity**	**Adjacent mucosa**	**Staining of restoration margins**	**Marginal adaptation (marginal deficits)**	**Recurrence of caries**
1. Excellent, very good	Lustre comparable to enamel	No staining	Good colour match; no difference in shade and translucency	Form is ideal	No factures / no cracks	No hypersensitivity, normal vitality	Healthy mucosa	No marginal staining	Harmonious outline, no gaps, no white lines or discolourations	No secondary or primary caries
2. Good (after adjusting very good)	Slightly dull, not noticeable from speaking distance, isolated small pores	Minor staining, easily removable by polishing	Minor deviations in shade	Minor deviations	Small hairline cracks	Minor hypersensitivity for a limited period of time; normal vitality	Healthy after removal of mechanical irritations	Minor staining, easily removable by polishing	2.1 Marginal gap < 150 µm, white lines 2.2 Small marginal fracture, removable by polishing 2.3 Slight ditching/ steps; minor marginal irregularities	Small, localized demineralization
3. Sufficient/ satisfactory	3.1 Dull surface but acceptable if covered with film of saliva 3.2 Several small pores	Moderate surface staining, possibly also present on other teeth; esthetically acceptable	Distinct deviation but acceptable; does not affect esthetics	Form differs but is esthetically acceptable	Two or more larger hairline cracks and/or chipping; not affecting the marginal integrity or approximal contact	3.1 Moderate hyper-sensitivity 3.2 Delayed, no sub-jective complaints, no treatment needed	Alteration of mucosa but no causal relation-ship with restoration	Moderate marginal staining; esthetically acceptable; also present on other teeth	3.1 Gap < 250 µm; not removable 3.2 Several small marginal fractures 3.3 Major marginal irregularities; Major steps/ ditching necessary	Larger areas of demineralization; preventive measures
4. Unsatisfactory/ repairable	4.1 Rough surface, cannot be masked by saliva film; simply polishing is not sufficient 4.2 Voids	Unacceptable surface staining; major inter-vention necessary for improvement	Localized clinically unsatisfactory deviations; can be corrected by repair	Form is affected and esthetically unacceptable; correction necessary	4.1 Fracture affecting the marginal integrity or approximal contacts 4.2 Bulk fracture with partial loss (less than half of the restoration)	4.1 Intense hypersensitivity 4.2 Delayed, minor, subjective complaints 4.3 No clinicially detectable sensitivity; intervention necessary, but not replacement	Mild allergic, lichenoid or toxic reaction	Pronounced marginal staining; major intervention necessary for improvement	4.1 Gap > 250 µm or exposed dentin 4.2 Severe ditching or marginal fracture 4.3. Large marginal irregularities or steps (repair necessary)	Caries with cavitation and suspicion of undermining caries
5. Poor (replacement necessary)	Very rough, unacceptable plaque retentive surface	Severe staining and/or subsurface staining not accessible for intervention	Unacceptable; replacement necessary	Form is unsatisfactory; repair not feasible; replacement needed	(Partial) loss of the restoration or multiple fractures	Intense, acute pulpitis or non-vital tooth. Endodontic treatment is necessary and restoration has to be replaced	Severe allergic, lichenoid or toxic reaction	Deep marginal staining, not accessible for intervention	5.1 Restoration is loose but *in situ* 5.2 Generalized major gaps or marginal irregularities	Deep caries not accessible for repair of restoration

Table 1 Explanations on the clinical evaluation of restorations according to FDI criteria

Fig. 2 Pre-operative situation: tooth 36 with defective composite restoration

Fig. 3 Preparation for the placement of a partial ceramic crown made of IPS e.max CAD

Fig. 4 Try-in of the completed IPS e.max CAD crown using Variolink Esthetic Try-In Paste (in the neutral shade)

Fig. 5 The cavity is etched with 37% phosphoric acid (Total Etch).

Fig. 6 Adhese Universal is scrubbed into the tooth surface for 20 seconds, dispersed with compressed air and then light-cured.

Fig. 7 Variolink Esthetic is applied to the bonding surface of the restoration, which is then seated on the tooth using an OptraStick®.

Fig. 8 Excess material is tack cured with a curing light (e.g. Bluephase® Style) for 2 seconds per quarter surface at a distance of 10 mm (quarter technique).

Fig. 9 Using a scaler, excess is removed while it is in a gel state. The pressure on the restoration is maintained until final polymerization.

Fig. 10 Liquid Strip is applied to prevent the formation of an oxygen inhibition layer.

Fig. 11 Final polymerization for 10 seconds per mm of ceramic thickness and quarter surface using a curing light that emits a light intensity of at least 1000 mW/cm^2 (e.g. Bluephase Style).

Fig. 12 The restoration margins are polished using OptraPol®.

Fig. 13 Final result: one week after the successful placement of the restoration

Postoperative sensitivities

The baseline assessment of the 60 restorations did not reveal any hypersensitivities associated with the bonding agent or luting composite. One patient reported slightly heightened sensitivities to cold stimuli, which subsided after a few days. His neighbouring tooth was also sensitive to cold. Another patient noticed a slightly increased sensitivity to cold during the first few days after two restorations had been seated in the same quadrant. However, the complaint may have been caused by the exposed tooth necks present in the same quadrant. In both cases, the complaints disappeared after a few days and therapeutic intervention was not necessary. In addition, the teeth showed normal vitality. For this reason, these restorations were given an FDI score of 2 (clinically good) with regard to hypersensitivity (C=biological), see Table 2. As the three restorations were seated using different combinations of materials, no significant differences in postoperative sensitivity between the Syntac group and the two Adhese Universal groups were present.

Esthetic integration

Sixty inlays and onlays were seated in the course of the clinical observation involving Variolink Esthetic. All of these restorations were made of IPS e.max CAD HT and MT. This indication requires the use of a highly esthetic luting material for two reasons: First, the cement line is located in the visible zone. Consequently, the luting material should offer an adequate level of translucency and shade to be able to facilitate the esthetic integration of the tooth structure and restorative material in what is known as the chameleon effect (see Chapter on "Variolink Esthetic – The influence of luting composites and other factors on the overall appearance of all-ceramic restorations"). Second, IPS e.max CAD HT in particular features a high degree of translucency and therefore allows the clinician to enhance the overall shade effect by selecting a luting material of a suitable shade. In the clinical observation, the shade effect of the luting composite was evaluated with the help of try-in pastes before the final cementation to allow for a preliminary appraisal of the final esthetic outcome of the restoration.

The "neutral" shade of Variolink Esthetic was used for 44 restorations in total, the "warm" shade for 13 restorations, "warm+" for two restorations and "light" for one restoration. The esthetic result of the 60 restorations was appraised on the basis of the FDI criteria at the baseline evaluation. Of all the restorations, 66.7% were rated "very good" and 33.3% were rated "good" due to slight deviations in the ceramic shade or translucency. None of the restorations was rated "satisfactory" or lower.

Fig. 14 Clinical example of an excellent shade match: onlay on tooth 44 (FDI rating=1)

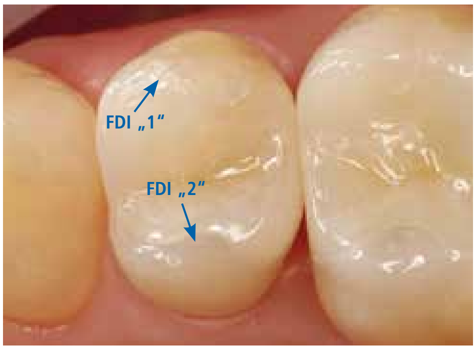

Fig. 15 Clinical example of a restoration on tooth 25 with a slight deviation in shade in the palatal area (FDI rating=2). The esthetic properties of the buccal occlusal area were given an FDI rating of 1.

Initial marginal quality

At baseline, the restorations showed excellent clinical results with 80.4% of the margins of all the restorations (n=60) being rated as "clinically very good" with regard to marginal irregularities; the remaining 19.6% were rated as "good" as they showed a slight step, or slightly enlarged cement line between the restoration and tooth structure (Table 2). These findings may have been the result of slight inaccuracies in the CAD/CAM manufacturing process, unrelated to the luting composite.

Marginal staining was detected in only one patient at baseline. The staining was absolutely minimal, affecting only 0.3% of the entire restoration margins of the Syntac group (n=20). The staining could have been removed by polishing (FDI ranking=2). In addition, the wearer of this restoration was a heavy smoker whose dentition was stained in various other parts. The three test groups did not show any statistically significant differences in the "marginal staining" category.

Fig. 16 Clinical example of an onlay (on tooth 44) that has been given excellent ratings with regard to marginal staining (FDI rating=1)

Fig. 17 Localized removable marginal discolouration in a heavy smoker (FDI rating=2)

It was also determined if a difference of performance occurred among the three test groups with regard to "marginal irregularities". Marginal irregularities, which were associated with the CAD/CAM manufacturing process of the restorations, were detected in all three groups. However, none of the restoration margins were given a score lower than 2 on the FDI evaluation scale. In the Syntac group (n=20), 29.0% of the total length of restoration margins were affected (Table 3). In the Adhese Universal / Etch & Rinse group, 17.0% of the total length of restoration margins were given a score of 2 on the FDI scale (Table 4), and in the Adhese Universal / Self-Etch group, 12.8% of the total length of restoration margins were affected (Table 5). The absence of statistical significance suggests that the marginal irregularities at the baseline assessment were not related to the individual adhesives used.

Fig. 18 Clinical example showing an onlay on tooth 36 with excellent marginal quality in terms of marginal irregularities (FDI score=1)

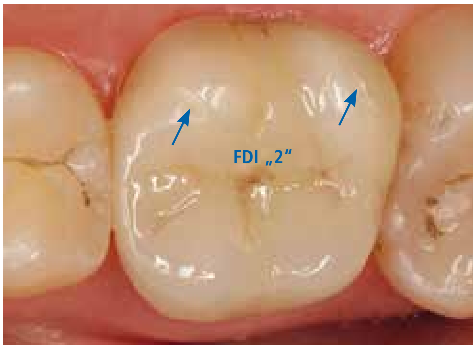

Fig. 19 Small inaccuracies of fit in localized areas related to the CAD/CAM manufacturing process led to slight marginal irregularities in the form of wider cement lines (FDI score=2). The remaining restoration margins were given an FDI score of 1.

Baseline data “Variolink® Esthetic DC” (all adhesives, baseline data n = 60)											
		% of all restorations							% of total length of restoration margins		
		A= esthetic				B = funct.	C = biological		A = esthetic	B = funct.	C = bio-logical
Clinical evaluation	FDI score	Surface lustre	Surface staining	Colour match / translucency	Anatomical form	Fracture / Retention loss	Hyper-sensitivity	Adjacent mucosa	Staining of restoration margins	Marginal irregularities	Recurrence of caries
Excellent, very good	1	98.3	100.0	66.7	95.0	100.0	95.0	91.7	99.9 ± 0.6	80.4 ± 21.2	100.0 ± 0
Good (excellent after refurbishment)	2	1.7	0	33.3	5.0	0	5.0	8.3	0.1 ± 0.6	19.6 ± 21.2	0
Sufficient/ satisfactory	3	0	0	0	0	0	0	0	0	0	0
Unsatisfactory/ repairable	4	0	0	0	0	0	0	0	0	0	0
Poor (replacement necessary)	5	0	0	0	0	0	0	0	0	0	0

Table 2 Results of the baseline assessment of all the restorations. Grading according to FDI criteria (n=60)

Baseline data “Variolink® Esthetic DC” (Syntac®, n = 20)											
		% of all restorations							% of total length of restoration margins		
		A= esthetic				B = funct.	C = biological		A = esthetic	B = funct.	C = bio-logical
Clinical evaluation	FDI score	Surface lustre	Surface staining	Colour match / translucency	Anatomical form	Fracture / Retention loss	Hyper-sensitivity	Adjacent mucosa	Staining of restoration margins	Marginal irregularities	Recurrence of caries
Excellent, very good	1	100,0	100,0	55,0	90,0	100,0	95,0	95,0	99,7 ± 1,1	71,0 ± 28,6	100,0 ± 0
Good (excellent after refurbishment)	2	0	0	45,0	10,0	0	5,0	5,0	0,3 ± 1,1	29,0 ± 28,6	0
Sufficient/ satisfactory	3	0	0	0	0	0	0	0	0	0	0
Unsatisfactory/ repairable	4	0	0	0	0	0	0	0	0	0	0
Poor (replacement necessary)	5	0	0	0	0	0	0	0	0	0	0

Table 3 Results of the baseline assessment of the restorations seated using Syntac. Grading according to FDI criteria (n=20)

Baseline data "Variolink® Esthetic DC" (Adhese® Universal Etch & Rinse, n = 20)											
Clinical evaluation	FDI score	% of all restorations							% of total length of restoration margins		
		A= esthetic				B = funct.	C = biological		A = esthetic	B = funct.	C = bio-logical
		Surface lustre	Surface staining	Colour match / translucency	Anatomical form	Fracture / Retention loss	Hyper-sensitivity	Adjacent mucosa	Staining of restoration margins	Marginal irregularities	Recurrence of caries
Excellent, very good	1	95.0	100.0	75.0	95.0	100.0	95.0	90.0	100.0 ± 0	83.0 ± 17.7	100.0 ± 0
Good (excellent after refurbishment)	2	5.0	0	25.0	5.0	0	5.0	10.0	0	17.0 ± 17.7	0
Sufficient/ satisfactory	3	0	0	0	0	0	0	0	0	0	0
Unsatisfactory/ repairable	4	0	0	0	0	0	0	0	0	0	0
Poor (replacement necessary)	5	0	0	0	0	0	0	0	0	0	0

Tab. 4 Results of the baseline assessment of the restorations seated using Adhese Universal in conjunction with the etch & rinse technique. Grading according to FDI criteria (n=20)

Baseline data "Variolink® Esthetic DC" (Adhese® Universal Self-Etch, n = 20)											
Clinical evaluation	FDI score	% of all restorations							% of total length of restoration margins		
		A= esthetic				B = funct.	C = biological		A = esthetic	B = funct.	C = bio-logical
		Surface lustre	Surface staining	Colour match / translucency	Anatomical form	Fracture / Retention loss	Hyper-sensitivity	Adjacent mucosa	Staining of restoration margins	Marginal irregularities	Recurrence of caries
Excellent, very good	1	100.0	100.0	70.0	100.0	100.0	95.0	90.0	100.0 ± 0	87.2 ± 10.6	100.0 ± 0
Good (excellent after refurbishment)	2	0	0	30.0	0	0	5.0	10.0	0	12.8 ± 10.6	0
Sufficient/ satisfactory	3	0	0	0	0	0	0	0	0	0	0
Unsatisfactory/ repairable	4	0	0	0	0	0	0	0	0	0	0
Poor (replacement necessary)	5	0	0	0	0	0	0	0	0	0	0

Tab. 5 Results of the baseline assessment of the restorations seated using Adhese Universal in conjunction with a self-etch technique. Grading according to FDI criteria (n=20)

Clinical case presentations involving Variolink® Esthetic

Clinical Case 1: Cementation of anterior crown on tooth 11, made of IPS e.max Press LT and seated using Variolink Esthetic DC

A 35-year-old female patient visited the practice because she was unhappy with the esthetics of her upper anterior teeth: tooth 11 appeared greyish after having been subjected to endodontic treatment and showed several large and insufficient composite fillings (Fig. 20). It was therefore decided to restore the tooth with an all-ceramic crown. Tooth 21 was in a slightly retrusive position and the labial tilting of tooth 22 increased this effect visually. To correct the tooth position and to camouflage the esthetically suboptimal incisal edge build-up, tooth 21 was restored with a 360° veneer.

The veneer for tooth 21 was created using IPS e.max Press HT and seated using Variolink Esthetic LC. To mask the greyish tinge of tooth 11, a restoration material with increased opacity (IPS e.max Press LT) was selected. The following images show the insertion of the crown on tooth 11 in conjunction with the dual-curing Variolink Esthetic DC luting composite.

Fig. 20 Preoperative situation: tooth 11 contained large insufficient composite restorations and showed a clearly noticeable greyish tinge after endodontic treatment.

Fig. 21 Mock-up on teeth 11 and 21, created using the self-curing temporary Telio® CS C&B composite.

Fig. 22 Preparation for a full-coverage crown on tooth 11 and a 360° veneer on tooth 21

Fig. 23 Removal of the temporaries from tooth 11 and tooth 21

Fig. 24 The tooth preparations were cleaned with fluoride-free Proxyt® polishing paste.

Fig. 25 At the try-in, the accuracy of fit was assessed.

Fig. 26 Esthetic evaluation of the crown on tooth 11 using the neutral shade of the Variolink Esthetic Try-In Paste

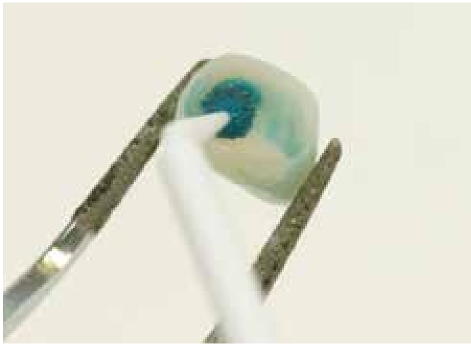

Fig. 27 Conditioning the crown with Monobond Etch&Prime®

Fig. 28 Adhese Universal was scrubbed into the prepared tooth surface for at least 20 s.

Fig. 29 The adhesive was evaporated with oil- and water-free compressed air until a glossy, immobile film resulted.

Fig. 30 The adhesive film was light-cured for 10 s using a Bluephase® Style curing light.

Fig. 31 The restoration was held in place with an OptraSculpt® Pad and excess material was tack cured using the quarter technique.

Fig. 32 Excess was removed while it was in a gel state.

Fig. 33 Final light-curing with Bluephase Style and Liquid Strip

Fig. 34 View one week after insertion of the restorations on teeth 11 and 21

Fig. 35 View 4 months after insertion on the restorations on teeth 11 and 21: visible regrowth of soft tissue, particularly in the interdental space between tooth 11 and tooth 12

Clinical Case 2: Cementation of an anterior veneer on tooth 11, made of IPS e.max Press and seated using Variolink Esthetic LC

A 44-year-old patient who was unhappy with the esthetics of her upper anterior teeth received a non-prep veneer on teeth 11 to correct the malposition of this tooth (Fig. 36). In addition, the restoration served to mask a clearly visible enamel crack on the vestibular aspect of the tooth.

Fig. 36 Preoperative situation: tooth 11 in retrusive position and esthetically impaired by an enamel crack on the vestibular surface.

Fig. 37 Mock-up created using the self-curing temporary Telio CS C&B material

Fig. 38 Try-in of the veneer on tooth 11 using Variolink Esthetic Try-In Paste neutral

Fig. 39 Cleaning the preparation with a fluoride-free polishing paste (Proxyt fluoride-free)

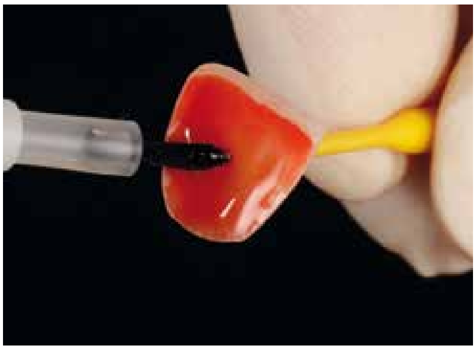

Fig. 40 The bonding surface of the ceramic restoration was etched with IPS Ceramic Etching Gel.

Fig. 41 Monobond® Plus was applied to the bonding surface of the restoration.

Fig. 42 Enamel etching with 37% phosphoric acid Total Etch

Fig. 43 Chalky white enamel surface (acid etch pattern) after phosphoric acid etching

Fig. 44 Adhese Universal was scrubbed into the prepared tooth surface for at least 20 s, before it was dispersed and light-cured.

Fig. 45 Variolink Esthetic was applied to the bonding surface of the restoration and then the restoration was seated and held in place on the tooth using an OptraSculpt Pad.

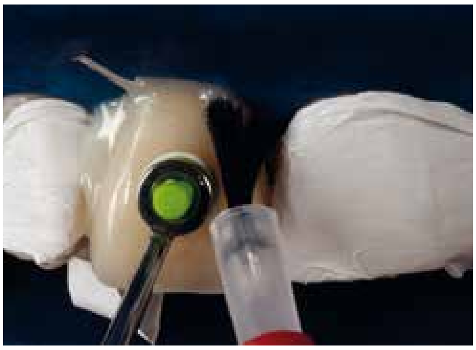

Fig. 46 Excess was removed with a brush across the cement line (wiping technique)

Fig. 47 Liquid Strip was applied to the cement line to prevent the formation of an oxygen inhibition layer.

Fig. 48 Final light-curing for 10 s per mm of ceramic and segment using Bluephase Style.

Fig. 49 Esthetic result: 10 days after insertion of the veneer.

Conclusion

Variolink Esthetic shows excellent clinical application properties with regard to excess removal, consistency, working time and light sensitivity. It generates an excellent bond to the tooth structure when applied in conjunction with Adhese Universal or Syntac. Clinically, postoperative complaints associated with the luting composite were not observed. Variolink Esthetic assists in optimizing the overall esthetic effect and achieving a chameleon effect in restorations in the visible esthetic zone in particular. At the baseline assessment, the quality of the restoration margins was given excellent ratings. No statistically significant differences were detected between the three different groups.

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683341/EN/2016-07