Porcelain veneer post-bonding crack repair by resin infiltration

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Abstract

Ceramic laminate veneer restorations are indicated in several clinical situations. Indirect restorations are usually chosen if the less-invasive options – bleaching, resin infiltration, or composite resin restorations – are not possible, or when it is too difficult to achieve an esthetically pleasing result in the long term. Bonded indirect partial restorations are highly dependent on their adhesive interface, as these thin restorations have a relatively low cohesive strength. Therefore, preservation of sound enamel, conditioning of the restorations and of the substrate, and luting procedures are of paramount importance for a successful outcome. Even when utmost care is taken during every step of the procedure, failures such as fractures, chipping, or marginal discoloration and defects sometimes occur. Only very few of these cases of failure are presented or are a subject of interest. In this case presentation, a fracture repair is performed using an infiltration technique with a resin composite material.

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Introduction

In articles and presentations dealing with esthetic dentistry, clinicians tend to present their most beautiful cases. Due to their natural appearance, we prefer to present bonded porcelain restorations than, for example, cemented crowns. This is because these restorations are mostly very thin, and the final color and appearance is achieved by the combination of the color of the restoration, the tooth, and the surrounding tissue. Generally, we tend to pick our best cases rather than our mistakes or failures. However, how much do we learn from our successes? Would it not be better to analyze our failures more closely to try and learn from them and prevent others from making the same mistakes? Every child learns at some point that admitting failure means taking the blame. The wisdom of learning from failure is undeniable. Yet professionals who do that properly are extraordinarily rare. This is not due to a lack of commitment to learning. Sometimes it is simply a question of understanding the reason behind a failure, through a reverse approach. Very few lecturers and clinicians have shifted to a culture of safety, in which the rewards of learning from failure can be fully realized. The unfortunate consequence is that many failures go unreported and their lessons are lost.

In general, partial indirect restorations such as bonded ceramic laminate veneers have a very good follow-up.[1] According to the literature, these restorations have proven themselves to withstand 10 to 20 years of follow-up, with a relatively high survival rate of 90% to 96%.[2-8] Fractures and cracks of the ceramic (5.6% to 11%), and large marginal defects (12% to 20%) are the most common reasons for failure.[1,4,9,10] Fractures and debonding were predominantly seen when laminate veneers were cemented to large exposed surfaces of dentin.[1,11] Due to the implementation of "new" adhesive strategies, such as immediate dentin sealing (IDS), the fracture strength of these laminate veneers when bonded to large, exposed dentinal surfaces could be improved.[12,13] Fractures and chippings were also seen in patients with nighttime bruxing or clenching habits. Providing the patient with an occlusal nightguard could prevent these kinds of fractures. Besides fractures, marginal defects were especially noticed at locations where the veneer ended in existing composite resin restorations (8% to 88%).[1,4] On the other hand, in cases where these defects were found, no substrate conditioning of the existing restorations was performed. When substrate conditioning was applied on the existing direct composite restorations in the form of tribochemical silica coating, no differences in marginal defects were evaluated, and no changes in bond strength were noted.[14-16]

Besides these more common fractures (loose fragments) and marginal defects, there are some other fractures that occur, such as stress-releasing cracks (without loose fragments). Postbonding cracks have a multifactorial origin; they are either preparation or cementation errors, or are patient-related. Cracks could be related to preparation errors like sharp internal angles, uneven surfaces, and transitions from thick to thinner parts of the veneer. There are multiple steps in the adhesive process that are important such as cleaning of the intaglio of the veneer, or luting to large exposed surfaces of dentin with the use of IDS. Fabricating the laminate veneer with the right material and following the manufacturer's instructions are mandatory to prevent stress in the ceramic material and thereby causing cracks. Cracks due to trauma, clenching, and bruxism are usually patient-related. When we experience fractures or failures, we have to try our best to help our patient with the failed restoration. Composite is nowadays easy to repair, and we have different kinds of protocols; however, with porcelain we mostly have to replace the full restoration. When we do this, we also remove some extra tooth tissue, and thereby end up with a difficult esthetic challenge.

The present case report describes the application of direct composite restorations and a thin porcelain laminate veneer. After 2 weeks, a crack was visible in the laminate veneer. This veneer was not replaced, but repaired using a step-by-step protocol.

Fig 1 Intraoral anterior view of teeth before treatment.

Fig 2 Intraoral anterior view of maxillary teeth before treatment.

Case presentation

A 30-year-old female patient (dentist) referred herself to the special care and advanced dental center of the Martini Hospital, Groningen, Netherlands. She was dissatisfied with the esthetic appearance of her anterior teeth (Figs 1 and 2). According to the patient's anamnesis and self-reported history, her discolored tooth 21 was caused by an accident some years ago. This tooth needed an endodontic treatment and was internally bleached several times. Clinically, a small diastema between the central incisors and minimal incisal wear (Basic Erosive Wear Examination [BEWE] 1) was apparent on teeth 12 to 21. Tooth wear was only diagnosed in the anterior region. After thorough diagnosis and analysis, a comprehensive treatment plan was devised that incorporated all of the patient's wishes. The treatment procedure consisted of the following stages: 1) documentation, analysis, and digital treatment planning; 2) wax-up and mock-up; 3) incisal lengthening using direct composite restorations on teeth 12 and 11; 4) minimal invasive preparation and adhesive luting of the indirect porcelain laminate veneer; 5) follow-up controls.

Fig 3 Wax-up of model before treatment.

Fig 4 Patient's smile with the mock-up.

Incisal lengthening with composite

After analysis and treatment planning using a digital workflow, the patient was informed of the different possibilities using minimally invasive treatment modalities. Digital planning, wax-up (Fig 3), and mock-up placement in the mouth (Fig 4) made it possible to predictably inform the patient about form, function, and esthetic appearance.[17] Once the patient was informed about the outcome, we had to decide how to reach our goal and make a choice regarding which materials to use. In general, direct composite restorations perform very well in the anterior zone, with 10-year survival rates of 90% to 95%.[18-21] However, when restorations become extensive, morphology becomes more difficult, and the restorations are more prone to failure. It was therefore decided that in this situation we would treat teeth 12 and 11 using direct composite restorations, and tooth 21 using a porcelain laminate veneer. All restorations were made using a microscope (OPMI pico, Zeiss) with 6 to 25 times magnification. Direct composite restorations (Filtek Supreme XTE, 3M ESPE) were applied to the incisal edges using rubberdam, a three-step etch-and-rinse adhesive system (OptiBond FL, Kerr), and a putty index derived from the wax-up. The mesial aspect of tooth 11 was also restored to close the diastema from both sides, and to obtain a similar width for both central incisors.

Tooth preparation

It is stated that laminate veneers bonded to sound enamel have a good survival rate, since enamel adhesion is the gold standard.[22] Using the diagnostic wax-up, both heavy- and light-body materials (Haptosil D, Bredent; Virtual Light Body Regular Set, Ivoclar Vivadent) were used to produce a mock-up mold (Fig 4). By using this mold to make a mock-up, maximum reduction control was created by only removing as thin a layer of enamel or the existing resin composite restoration as is necessary for the thickness of the porcelain laminate veneer (Fig 5). Uniform preparation of the buccal surface is not preferred, as enamel thickness is varying in the buccal region of the incisors.[23] Therefore, standard depth cutting burs are not advised for laminate veneer preparation.[22] In this case, we only had to remove the composite restoration to gain sufficient space (0.3 in the cervical region, and 0.5 to 0.7 in the buccal region) for the ceramic laminate veneer.

A light chamfer preparation is usually advised for the outline of ceramic veneers.[23-25] An incisal overlap preparation was made, allowing the dental technician to have maximum control of the esthetic characteristics and translucency.[26,27] Therefore, the transition from the buccal to the incisal aspect was smoothened and polished, as this transition could result in internal stress fractures. A sharp bucco-incisal transition makes it more difficult for the ceramist to blend in the restoration. In general, the aim was to confine the preparation to enamel wherever possible, especially at the finish line.

Fig 5 Preparation of tooth 21, and direct composite restorations made on teeth 12 and 11.

Fig 6 Try-in of the ceramic laminate veneer. Note the blanching of the gingiva on the mesial aspect.

Adhesive luting procedures

After taking the impression, the veneer was fabricated by the dental technician using feldspathic porcelain (Creation CC) and the refractory technique. The veneer in the cervical area was approximately 0.2 to 0.3 mm in thickness (Fig 22). At the try-in, the veneer was checked for color, fit, and contact points (Fig 6). A perfect fit to the preparation is very important, otherwise the resin composite cement layer will be too thick, which could initiate shrinkage and result in stress-induced cracks.[28] For try-in and color check, a paste (Variolink Veneer Tryin, Ivoclar Vivadent) close to the color of the tooth or restoration was taken. Normally, the color of the cement is not critical; however, in this case, where the veneer was very thin, it could have had a small impact.[29,30]

Surface conditioning of the ceramic

The laminate veneer was conditioned using a 9% buffered hydrofluoric acid (Porcelain Etch, Ultradent). It is known that hydrofluoric acid selectively dis-

Fig 7 Silica coating of the existing composite restoration.

Fig 8 Removal of the excess composite material.

Fig 9 Glycerin application before photopolymerization.

solves the glass or crystalline components of the ceramic to produce an irregular porous surface.[31-35] The microporosities in the ceramic increase the surface area, leading to micromechanical interlocking of the resin composite. Post-hydrofluoric-etching cleaning of the debris on the surface was performed in two steps: 35% phosphoric acid (Ultra-Etch, Ultradent), and ultrasonic cleaning. The debris contaminates the intaglio surface, which has an effect on the adhesive strength.[36]

Hydrofluoric acid etching was followed by silanization (Monobond Plus, Ivoclar Vivadent). The silane is a coupling agent that couples the inorganic particles present in the glass-ceramic to the organic matrix of the adhesive. The silanol molecules that are formed after the reaction with water react on the silica surfaces to form covalent siloxane bonds.[37,38] Heat drying of the silane performed in an oven (DI-500, Coltene Whaledent) is suggested to consolidate the three layers of silane into one layer, eliminating water and alcohol to complete the condensation reaction, which promotes the siloxane bond.[39-42]

Surface conditioning of the teeth/restoration

There are two different substrates on the substrate side: enamel, and an existing composite restoration. After rubber dam (Isodam Non Latex Heavy, Sigma Dental Systems) and protecting matrices application, the composite surface was first silica coated using CoJet sand (3M ESPE) (Fig 7). Using silica coating and silanization (Espe Sil, 3M ESPE) for conditioning the existing composite, it is possible to achieve an acceptable and stable bond to composite even after different aging protocols.[43] These conditioning methods were also tested in fracture strength mode and clinically, with the application of laminate veneers.[14,15]

After etching the enamel (35% phosphoric acid, Ultradent) for 30 s, a silane was applied on the silica-coated existing composite restoration, allowing 3 min reaction time. The adhesive was then applied onto the whole substrate; however, it was not polymerized, as this was performed together with the luting material.

Adhesive luting of the laminate veneers

Adhesive luting was facilitated using the reference of the adjacent teeth and a direct composite resin restorative as a "cement" (handling and adhesive properties). Therefore, a microhybrid resin composite (Enamel HFO UD1, Micerium) was used (Fig 8).[44] However, when using a direct composite resin as a luting cement, the thickness of the material can have a relevant influence on the stress distribution in the porcelain veneers. In a finite element analysis, Magne et al[28] concluded that laminate veneers that were thin and had a poor internal fit resulted in higher stresses at both the interface of the restoration and on the surface. This could lead to post-bonding cracks in thin laminate veneers. Therefore, it is advised that the ceramic must be more than three times the thickness of the resin composite cement. In order to prevent a thick cement interface in this case, we heated the resin composite to 55°C in an oven (Ena Heat, Micerium) to obtain a material that would be as thin under pressure as luting cement.

Using composite as a cement allowed total control of the seating of the restoration. Moreover, due to the viscosity of the composite, the excess cement could be easily removed. After the removal of the excess cement, glycerine gel (KY Gel, Johnson & Johnson) was applied at the margins to prevent an oxygen inhibition layer. Total photopolymerization (Bluephase 20i, Ivoclar Vivadent) was then performed (Fig 9). Finishing of the margins was performed using a 12D scalpel, and polishing was done using ceramic polishers (CeraGloss, Edenta). One week after delivery, the patient was seen for evaluation and final pictures (Fig 10).

Cracking of the laminate veneer

Two weeks after delivery, the patient called the clinic to report a crack on the buccal aspect of the indirect laminate veneer. At the subsequent appointment, a crack line was seen on the buccal aspect of the indirect veneer, with minimal access on the mesial aspect. The patient was evaluated, and photographs were taken using cross-polarized light (polar_

Fig 10 Final result after adhesive luting of the laminate veneer.

Fig 11 Cross-polarized photograph 2 weeks after delivery. Note the fracture on the buccal surface.

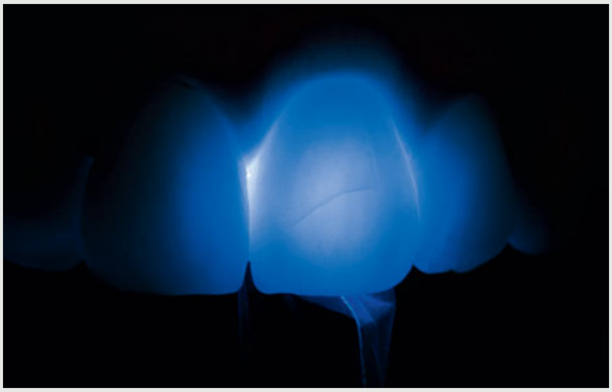

Fig 12 Transmission UV light showing the fracture of the ceramic laminate veneer.

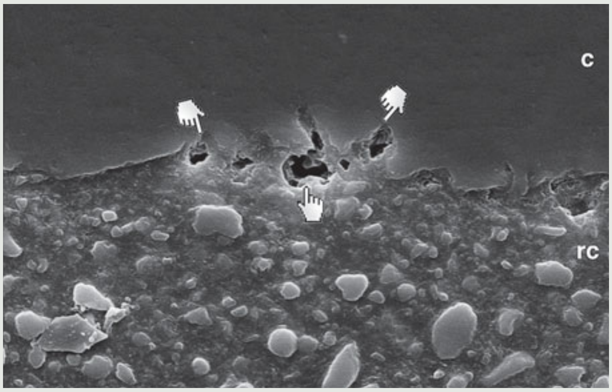

Fig 13 SEM image of a ceramic–resin composite interface. Pointers show interfacial discontinuities that could lead to fracture due to stress concentration at the interface (c: ceramic; rc: resin composite).

eyes, Bio-Emulation) and transmitting ultraviolet (UV) light (Figs 11 and 12). This crack in the ceramic could have been caused by preparation or delivery errors, laminate veneer fabrication errors, or patient-related factors. Since ceramics are brittle, the presence of unfilled areas may decrease their mechanical strength by two main mechanisms: 1) the sharp geometry of the unfilled channels may create spots for stress concentration; and 2) the fragile void area underneath the cement–ceramic margin may concentrate stress when submitted to mechanical loading (Fig 13).

None of the authors of this article saw any flaws in the cementation procedure or materials used for delivery of the ceramic laminate veneer, which was produced and fired according the manufacturer's instructions. Furthermore, the patient did not hear the laminate veneer fracturing, nor could she relate the fracture to any incident during the previous 2 weeks. It was concluded, therefore, that it was an internal stress-releasing crack, probably caused by the transition from thick to thin ceramic. This was concluded after combining the preparation and delivered laminate veneer images, where it was seen that the fracture was on the border of the preparation to the incisal covering part.

Treatment options

The patient was informed of the advantages and disadvantages of three different treatment options, namely: 1) replacing the veneer; 2) leaving the fracture untreated; 3) repairing the fracture using an infiltration technique inspired by the repair of automotive windshields. Removing the veneer could cause extra

Fig 14 Adhesive tape to protect the laminate veneer before sandblasting.

Fig 15 Opening of the fracture after sandblasting.

Fig 16 Infiltration of the fracture using a filled adhesive.

Fig 17 Polishing of the repaired fracture.

biological damage to the tooth, and difficulties in color matching. There have been some *in vitro* and *in vivo* cracks reported in the literature, but they did not cause diminished fracture strength. Purely internal fractures can be left untreated; however, when exposed at the surface, discoloration could diminish the esthetic outcome, which is more difficult to repair later on. Given the fact that replacement is always an option if repair is not satisfactory, it was decided together with the patient to first attempt to repair the crack.

Fracture repair

Before beginning the repair procedures, a rubber dam (Isodam) was placed from first premolar to first premolar. The crack was sandblasted using 30 µm silica-coated alumina oxide sand (CoJet) (5 to 10 s, 2 bar, 90-degree angle). The laminate veneer was protected using adhesive tape to only expose and open the crack (Figs 14 and 15). The crack was then etched using hydrofluoric acid (9% Porcelain Etch) for 90 s. Thorough rinsing with copious amounts of water was performed. A silane (Monobond Plus)

Table 1 Crack repair of the ceramic laminate veneer

1	Protection tape around fracture
2	30 µm alumina oxide sandblasting at 10 mm distance
3	9% hydrofluoric acid etching of the ceramic for 1 min (optional)
4	Rinsing with copious amounts of water for 1 min (optional; only if step 3 is done), followed by air drying
5	Silane coupling agent application for 20 s, then air dry or warm with curing light, and wait 5 min for its evaporation
6	Preheated filled adhesive application (no photopolymerization for 20 min, protect from light with black tape)
7	Photopolymerization for 40 s
8	Direct resin composite application (optional), and photopolymerization
9	Glycerin application and photopolymerization
10	Finishing (scaler, #12 scalpel blade) and polishing with silicon points, goat hair, and felt wheels with diamond and alumina oxide paste)

was used to make the ceramic surface hydrophobic, and to promote the bond between the "silica-based" particles. The adhesive (Optibond FL) was then applied. Before placing the adhesive, the silane was heated using a curing light (twice, for 20 s), thereby turning the hydrophilic surface of the ceramic into a hydrophobic surface, better able to absorb the resin for infiltration.[45] The adhesive was preheated (55°C in Ena Heat, or 68°C in Calset) and left to infiltrate for 20 min with a piece of black tape over the crack so that no light was able to polymerize the adhesive before infiltration (Fig 16). After 20 min of infiltration, a cross-polarized photograph was taken to evaluate the infiltration. Excess was then removed, and the adhesive photopolymerized for 40 s. Then, a direct resin composite was used where the opening of the buccal surface was performed, as highly filled composite resins are less prone to discoloration than flowables or adhesives. The composite was adapted using flat modelling brushes (Gradia Lab Brush, GC), and glycerin applied and photopolymerized for 40 s from two sides. The restoration was finished and polished using silicon points, goat hair and felt wheels, using 3 and 1 µm diamond paste and alumina oxide paste (Enamel Plus Shiny, Micerium) (Fig 17) (Table 1).

Fig 18 Extraoral view of the patient after treatment.

Fig 19 Cross-polarized photograph of the laminate veneer after repair.

Fig 20 Intraoral view of the repaired laminate veneer.

The patient was satisfied with the final result and will be monitored for a longer duration (Figs 18 to 20). An additional case with a successful outcome after 2 years is also presented in Figures 21 to 25.

Conclusions

For various reasons (operator, biological, material), failures in the application of laminate veneers can occur. Two weeks after delivery, a crack line was visible on the buccal aspect of the ceramic laminate veneer. After consulting the patient, the crack was repaired and the veneer was maintained. Crack repair by resin-infiltration was successful even after more than 2 years, and could be one of the treatment modalities to increase the lifespan of full-ceramic indirect restorations. Although the origin of the crack was not identified, it probably originated in the transition between the thin and thick parts of the veneer.

Fig 21 Bonded porcelain crown that fractured 5 years post-placement. Original restorations (bonded crown on right central, and porcelain veneer on left central) were not made by the authors.

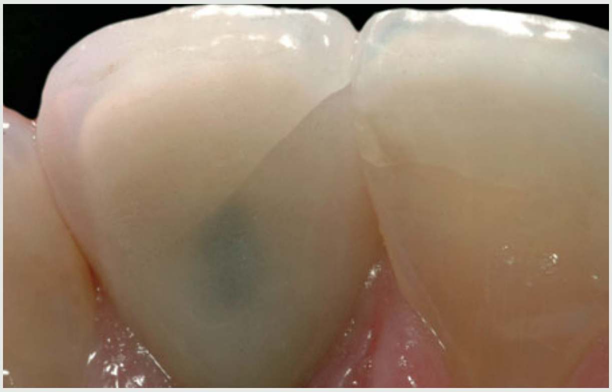

Fig 22 Lingual view showing that the fracture probably started at the lingual fossa, where endodontic post head of underlying build-up is showing through.

Fig 23 Lingual view following airborne particle abrasion of cracked surface. Note similar crack in lingual enamel of neighboring teeth. Application of silane and resin infiltration were achieved from the lingual side only (labial surface was left intact).

Fig 24 Two-year postoperative view showing successful crack infiltration that saved the patient the cost of a new restoration.

Fig 25 Two-year postoperative detail view. Crack is still undetectable.

Disclosure

The authors declare no financial interest in the companies whose materials are used in this article.

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