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CLINICAL ARTICLE

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Predictable 3D guided adhesive bonding of porcelain veneers using 3D printed trays

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Abstract

Objective: This clinical report describes a novel digital technique to facilitate and improve the porcelain laminate veneers adhesive bonding procedure using a customized 3D printed guide.

Clinical considerations: Porcelain veneers can be stabilized in their fully seated position with a digitally design 3D printed guide before the resin cement is polymerized. The excess cement can be carefully and predictably removed without the risk of dislodgement, rotation or misfit, allowing the clinician to light cure them under controlled pressure in the correct seating position without the risk of fracturing the ceramic material.

Conclusions: Fabricating a custom 3D printed guide for veneer bonding provides significant assistance to an otherwise cumbersome and daunting clinical procedure.

Clinical significance: Adhesive bonding of multiple ceramic veneers is a challenging and technique sensitive procedure. The use of a custom 3D printed guide presented in this article offers a practical aid to achieve a more predictable and precise outcome.

KEYWORDS
3D printed guide, adhesive bonding, digital dentistry, esthetic dentistry, porcelain veneers

1 | INTRODUCTION

Laminate porcelain veneers have being done for more than 40 years. Early articles published that dealt with veneer procedures in a similar way as they are known today were the ones from Calamia and Horn in 1983.[1,2] Since then, several changes in techniques, materials and indications have arisen. The initial discussion was mainly toward the preparation and techniques used. Early reports suggested that intra-enamel preparations were key to assure an esthetic outcome and improve the marginal fit. Margins that finished into dentin showed bond deterioration in the short term, thus compromising the esthetics and overall success rates.[2–4] Subsequently, new materials with better physical properties became available,[5,6] proving to be clinically acceptable over time. However, long-term outcome reports were scarce in the literature of that era.[6] In the following years, several studies were published corroborating these initial positive results, thus increasing the reliability of veneers among clinicians and patients.[7–10] Despite the numerous factors involved in the success/survival rate of porcelain veneers, studies show that the survival of them is over 95% at 5 years and over 90% at 10 years.[11–14]

In recent years, both dentists and the patient population are increasingly exposed to marketing messages on TV, magazines and journals about minimal preparation, thin, non-preparation, pre-fabricated and stronger monolithic CAD-CAM veneers. Current evidence has also proven that these new trends, under strict indication criteria, are effective and comparable to the well established treatment options like Porcelain Fused to Metal crowns.[8,15]

New tooth preparation techniques have also contributed to the improved reliability of porcelain veneers. Last year, a novel method for veneer preparation was presented.[16] Although the idea of controlling the reduction of tooth structure in a precise and measurable way has been proposed previously, the fabrication of 3D printed guides, digitally designed with the *First Fit™ technology* (Viax Dental Technologies, Miami, FL, USA) made it applicable and predictable for the first time. This technique can determine the areas and amount of tooth reduction based on a digital analysis using a software and the fabrication of a 3D printed guide to transfer that plan intraorally and prepare the teeth according to the previously made tooth reduction treatment plan.

Adhesive bonding of veneers has always been a technique sensitive and daunting task, especially if multiple veneers have to be delivered at the same time. The chance of misplacing, rotating and not seating veneers properly are common clinical problems.[17–19] Although adhesive protocols have improved and have been simplified over the years with great success for composites and glass ceramics,[20] little has changed regarding adhesive bonding techniques. It is evident that proper adhesive bonding is critical for the long term survival and success of any indirect restoration. All ceramic restorations and especially porcelain veneers do not offer primary retention, they rely solely on the resin cement bond as the attaching mechanism to tooth structures. This does not only apply for the retention of them, but also for the overall strength of the tooth-restoration complex once the ceramic is tightly bonded to the tooth structure.[20,21] Unfortunately, adhesive resin cements are more challenging to handle compared to traditional cements, because they involve multiple technique-sensitive steps.[22,23]

Some of those steps are seating/fixing the veneers and excess cement removal after the setting of resin cements. The clinician faces a difficult decision when bonding porcelain veneers: since the preparation does not usually provide good stability to the veneer itself, the process of fixing the veneer in place and polymerizing the resin cement happens at the same time, leaving the clinician with little room for error while completing this step. Resin cements have a gradual polymerization reaction, but it is directly dependent on the activation method.[24,25] Light curing cements are usually preferred to bond veneers: they are chemically more stable long-term and clinically more convenient to handle, but the polymerization chain reaction of these cements is still rather fast. Once the cement is light activated it sets quickly in a few seconds, making the removal of the excess cement difficult if not managed properly. Tack curing with small diameter light tips for 1–2 s has been proposed to mitigate this inherent property of the cement,[26] but the seating and excess cement removal are still a complication that can create clinical difficulties. Hand held veneers are difficult to position due to the aforementioned reasons and specific instruments designed for this task (Optrastick, Ivoclar Vivadent, Schaan, Liechtenstein, Pic-N-stick, Pulpdent, Watertown, MA, USA or similar) offer limited help. On the other hand, excess cement removal of resin cement can be very frustrating. Several techniques and instruments have been proposed for this particular procedure as well and there is no agreement on which technique is the best.[17–19] Nevertheless, they agree that any technique should avoid damaging the surrounding periodontal tissues, adjacent teeth, margin and the ceramic surface. Rotary instruments, serrated interproximal saws and any sharp instrument when unproperly used could potentially damage these structures, thus highlighting the importance of applying a controlled and meticulous bonding technique to avoid these drawbacks.

The following clinical report shows a novel technique/appliance fabrication that help clinicians overcome some of the complications mentioned previously and facilitate the bonding of porcelain veneers.

2 | CLINICAL CASE 1

A 35-year-old female patient presented with a fractured left central incisor. The two central incisors were previously restored with two ceramic veneers (Figure 1). After periodontal and radiographic evaluation with a CBCT, it was concluded that the left central incisor presented an old endodontic treatment and a fracture line extending to the bone level.

The treatment proposed to preserve the fractured teeth was to perform crown lengthening in order to provide enough ferrule effect and the placement of a fiber post to retain the build up and a full coverage crown.

After a thorough esthetic analysis of the patient, crown lengthening was proposed for both central incisors since the width/length ratio was greater than 95% (Figure 2). In addition, keeping the symmetry between the two central incisors was also part of the treatment plan. After crown lengthening, a fiber post was placed under rubber dam isolation. Both central incisors were prepared for a full all ceramic crown (Figure 3) and provisional restorations were cemented to allow healing of the soft/hard tissue.

During the healing phase, the patient showed interest in improving her smile appearance. A comprehensive orofacial analysis was performed, and a photographic study was carried out including digital study models and videos. The esthetic evaluation determined that the upper arch corridor could be fuller to provide a wider smile and that the tooth color had to be improved using porcelain laminate veneers. A digital diagnostic wax-up was requested to do a mock-up, with the aim of finding out if the esthetic changes were in accordance with the patient's expectations.

Once the mock up and the new smile design were approved by the patient, the final treatment plan was defined: two all ceramic

FIGURE 1 Initial clinical picture of Case 1

FIGURE 2 Central incisors present a width/length disproportion. After careful analysis, crown lengthening was indicated

FIGURE 3 Full coverage crown preparation of both central incisors

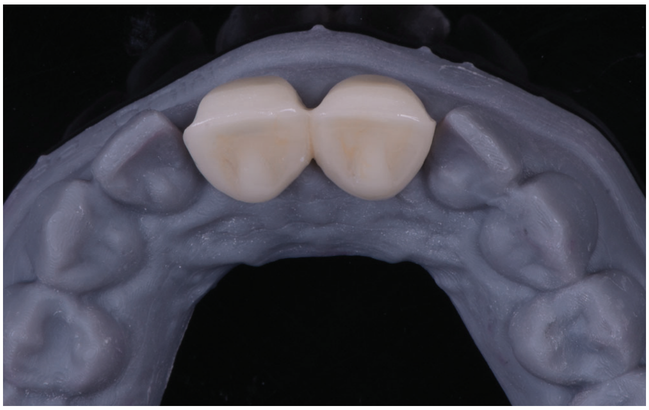

FIGURE 4 #8-#9 FDP design: full coverage, splinted and with veneer preparations (LT block e.max CAD, Ivoclar Vivadent, Schaan, Liechtenstein)

FIGURE 5 #8-#9 FDP try in with upper veneer preparations from upper left second premolar to upper right second premolar (IPS Empress CAD Multi, Ivoclar Vivadent, Schaan, Liechtenstein)

crowns on the central incisors and 10 porcelain laminate veneers from upper right second premolar to upper left second premolar. Considering the limited ferrule effect of the left central incisor, it was decided to splint the two central incisors, with a fixed dental prosthesis. In order to unify the materials for the porcelain veneers and obtain a better esthetic result using a digital workflow, the fixed dental prosthesis' design was full coverage, splinted and with veneer preparations for two bonded leucite reinforced veneers (Figure 4). Tooth reduction was completed using diamond burs (Komet Dental, Lemgo, Germany) aiming for 1.5 mm axial reduction, 1 mm round shoulder, 2 mm incisal reduction (lithium disilicate crowns) and 0.5–1 mm axial reduction with interproximal contacts removal and incisal coverage with palatal butt joint finish line. (leucite-reinforced veneers).

A digital impression of the two central incisor abutments was made using Trios3 intraoral scanner (3Shape, Copenhagen, Denmark) for the fabrication of the two-unit fixed dental prosthesis in monolithic lithium disilicate. (LT block e.max CAD, Ivoclar Vivadent, Schaan, Liechtenstein) Upon try-in of the central incisors, the other teeth were prepared for intra-enamel porcelain veneers, from the upper left second premolar to the upper right second premolar (Figure 5). All preparations were guided by a wax up silicon matrix and using the APT technique, which consists of preparing the teeth through the previously made mock up done intraorally to ensure proper tooth reduction and at the same time to be more conservative by providing the necessary tooth reduction for the restoration thickness.[27]

Once the preparations were finished, 00 (double zero) retraction cord (Ultrapak, Ultradent, South Jordan, UT, USA) was packed into the sulcus, the fixed dental prosthesis was placed on the abutments and a new digital impression was made with the Trios 3 intra oral scanner. (3Shape, Copenhagen, Denmark) The veneer preparations were temporarily restored with bisacryl (Visco, Anaxdent USA, Ardmore, OK, USA) using a silicon matrix.

The .stl files were sent to the lab to fabricate the 10 monolithic porcelain veneers, (IPS Empress CAD Multi, Ivoclar Vivadent, Schaan, Liechtenstein) from the upper left second premolar to the upper right second premolar. Once the veneers were designed (3Shape dental system, Copenhagen, Denmark) by the lab, a .stl was generated with the final veneer design in place (Figure 6) and sent to the lab (VIAX Dental Technologies, Madrid, Spain) to create a 3D printed guide for the porcelain veneers adhesive bonding (Figure 7).

The porcelain veneers were milled using Multi BL3 blocks, (IPS Empress CAD Multi, Ivoclar Vivadent, Schaan, Liechtenstein) stained and adjusted over the printed model (Figure 8).

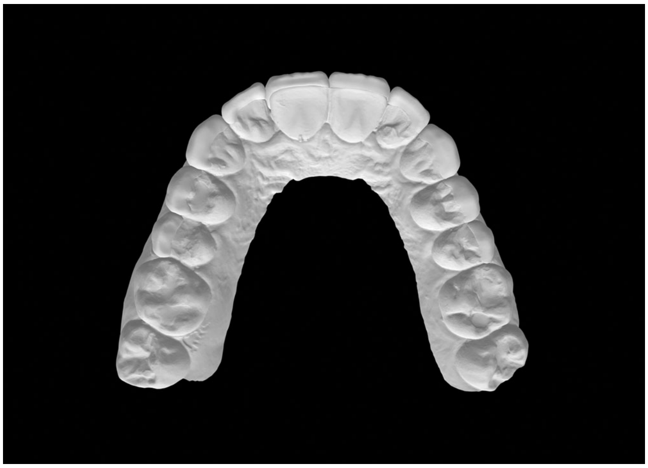

FIGURE 6 Occlusal view of upper veneer design (.stl file)

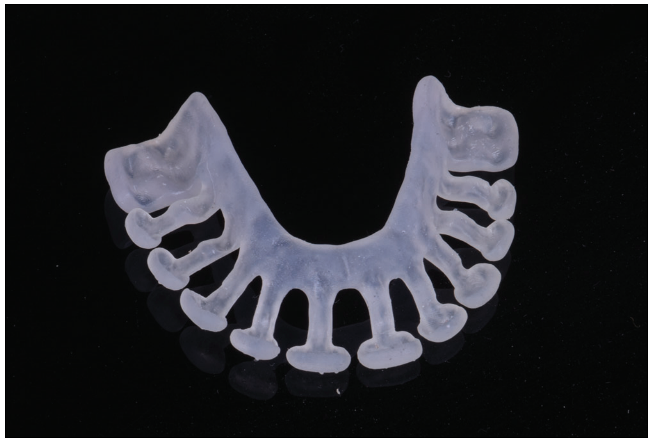

FIGURE 7 View of 3D printed tray to guide porcelain veneers adhesive bonding

FIGURE 8 Frontal view of milled veneers on 3D printed model (IPS Empress CAD Multi, Ivoclar Vivadent, Schaan, Liechtenstein)

FIGURE 9 Fit check of 3D printed tray on 3D printed model with veneers in place

Based on the digital model of the final veneer design, a 3D printed guide was designed from the left upper molar to the first right molar using a specialized software (Geomagic Freeform, 3D Systems, SC, USA) making sure that occlusal molar rests and palatal rests on all other teeth were designed to provide stable support of the structure. Individual concave inciso-buccal support extensions were also designed for each veneer to hold them after try in. This tray design was developed and manufactured by Viax Dental Technologies. (Viax Dental Technologies, Miami, FL, USA under U.S. patent Appl. Publ. Nr.2018/0263726 A1).

This 3D printed guide aims to:

1. Hold the veneers after try-in and if adjustments are needed,
2. Facilitate the adhesive protocol on the inner surface of all the restorations at the same time,
3. Stabilize the restorations during the adhesive bonding process intraorally.

The guide was printed in a flexible resin, (Pico Max UV, Asiga, Alexandria, AUS) which allows to seat all the veneers individually in place with different paths of insertion. When fabricating veneers within the arch, they usually have a different buccal path of insertion, especially if they are meant to be delivered at the same time. One week later, the temporaries were removed, the preps cleaned using pumice and water. After checking the fit of the 3D printed guide on the model (Figure 9), all the veneers were tried in dry, checking internal fit and interproximal contacts individually. Afterward, shade was checked with wet try in using glycerin gel (Liquid Strip, Ivoclar Vivadent, Schaan, Liechtenstein) on the inner surface of the veneers and seating them in place. Once all the veneers were seated, the 3D printed guide was placed intraorally to ensure proper fit. The external surface of the veneers and inciso-buccal support extensions were cleaned using isopropyl alcohol to avoid any contamination that might interfere with bonding. Subsequently, bonding agent (Excite F, Ivoclar Vivadent, Schaan, Liechtenstein) was applied with a microbrush on the incisal edges of the veneers, tip of the cusps, and the internal aspect of the inciso-buccal tray extensions. A small amount of flowable composite resin (Tetric EvoFlow, Ivoclar Vivadent, Schaan, Liechtenstein) was

FIGURE 10 Frontal view of veneers bonded to 3D printed tray

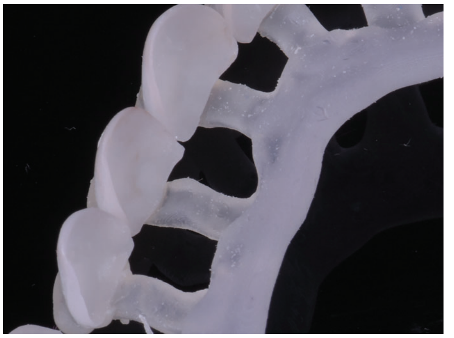

FIGURE 11 Detail view to check that no flowable composite resin went into veneer inner surface

FIGURE 12 Frontal intraoral view of 3D printed tray with veneers ready to be adhesively bonded

FIGURE 13 Frontal intraoral view of #9 veneer being carefully pressed/positioned using 3D printed tray

applied to the concavity of each inciso-buccal guide extension and they were attached/light cured for 20 s to the veneers individually, one by one.

This procedure allows a temporary, flexible bond of the veneers to the 3D guide (Figure 10). The absence of any excess of flowable composite resin inside the veneers was confirmed (Figure 11).

Once the veneers were temporarily bonded to the 3D tray, the inner surface of the veneers were treated with the following protocol: (1) application of cleaning gel (Ivoclean, Ivoclar Vivadent, Schaan, Liechtenstein) for 20 (twenty) seconds. (2) Hydrofluoric acid etchant for 60 (sixty) seconds. (IPS Ceramic etch, Ivoclar Vivadent, Schaan, Liechtenstein) (3) The restorations were then cleaned placing them in an ultrasonic bath with isopropyl alcohol for 4 min. (4) Silane was applied according to the manufacturer's instructions. (Ceramic Primer II GC, Japan).

The inner surface of the lithium disilicate fixed dental prosthesis and the external veneer prepared surfaces were also treated with the same adhesive protocol.

The adhesive bonding technique was performed using relative isolation with cotton rolls and silicone lip retractors. (Optragate, Ivoclar Vivadent, Schaan, Liechtenstein) The two central incisors were etched and bonded using ortho-phosphoric acid for 15 s, rinsed for the same time and bonding agent was applied (Excite F, Ivoclar Vivadent, Schaan, Liechtenstein) according to the manufacturer's instructions. Dual cure resin cement (Variolink Esthetic DC Neutral, Ivoclar Vivadent, Schaan, Liechtenstein) was used for the adhesive bonding of the fixed dental prosthesis. Once in place, all the excess material was cleaned off with a fine paint brush. Each tooth was spot cured for 2 s to allow removal of the excess cement without causing their displacement.

Once the two central incisors were cemented and cleaned off, the veneers were ready to be adhesively bonded using the 3D printed guide, both to the prepared teeth and the #8–9 fixed dental prosthesis (Figure 12).

The teeth were etched with ortho phosphoric acid for 20 s and rinsed for the same time, bonding agent was applied (Excite F, Ivoclar Vivadent, Schaan, Liechtenstein) according to the manufacturer's instructions on each tooth. Light-cure resin cement (Variolink Esthetic LC Neutral, Ivoclar Vivadent, Schaan, Liechtenstein) was applied on the inner surface of the veneers and the 3D printed guide was seated into position, assuring proper fit of the occlusal/palatal rests.

Once in place, each veneer was seated individually, pressing on the inciso-buccal extension, all the excess cement was cleaned off with a fine micro brush, floss was used to clean interproximally. Each veneer was spot cured with a small diameter tip

FIGURE 14 Intraoral view of #7 veneer being spot-cured to ensure proper seating (Variolink Esthetic LC Neutral, Ivoclar Vivadent, Schaan, Liechtenstein)

FIGURE 15 Intraoral view after all veneers were adhesively bonded

FIGURE 16 Extraoral view after the veneers were adhesively bonded

FIGURE 17 Initial intraoral view of clinical Case 2 with patient biting in MIP (maximum intercuspation position)

FIGURE 18 Frontal view of lower arch showing multiple teeth with attrition, gingival recession and dentin exposure

(Bluephase Style, Ivoclar Vivadent, Schaan, Liechtenstein) to fix each veneer and allow removal of the excess cement with no rush (Figures 13 and 14).

After light curing for 10 s each veneer on the buccal aspect, the 3D position guide was removed to facilitate the palatal surface cleaning process. It was done breaking off the bond to the inciso-buccal extension using a universal curette. A final cure was applied through glycerine gel (Liquid Strip, Ivoclar Vivadent, Schaan, Liechtenstein) which had been extruded onto the margins to allow the polymerization of the oxygen inhibited layer. All the margins and interproximal areas were cleaned using a universal curette, 12 blade scalpel and dental floss. Finally, the margins were polished using a rubber polishing cup. The occlusion was checked and oral hygiene instruction and maintenance advice was given to the patient. The final outcome can be seen in Figures 15 and 16.

3 | CLINICAL CASE 2

A 45-year-old male presented to the clinic with multiple recently delivered upper veneers (Figure 17). Lower arch had multiple gingival recessions/dentin exposure, non-matching shade with upper arch, attrition and open anterior bite. In order to rehabilitate the teeth, provide proper occlusion and improve shade and function, it was decided that six porcelain veneers with incisal coverage and two partial coverage crowns were necessary (Figure 18).

The veneers/crowns were fabricated in lithium disilicate (IPS e.max Press, Ivoclar Vivadent, Schaan, Liechtenstein). The same protocol sequence as in Case 1 was followed for the fabrication of the restorations and the 3D printed guide. Figure 19A,B shows in detail how the guide's rests and inciso-buccal extensions were designed. In this case they were connected through a lingual bar. The resin material was the same flexible resin allowing the pretreatment/seating of each restoration individually. Figure 20A,B shows the 3D guide seated on the 3D printed model with the restorations in place and the restorations bonded to each inciso-buccal extension of the guide after they were bonded individually after intraoral try in/adjustments. Figure 21A-D and Figure 22 show the bonding protocol sequence applied to the inner surface of the restorations, which was the same as in Case 1. Figure 23 shows the final try in/seating confirmation before adhesive bonding. 0 (zero) size cord (Ultrapak, Ultradent, South Jordan, UT, USA) was packed intra-sulcus to provide a barrier and protect the soft tissue from the adhesive procedures. Each restoration was bonded using the same protocol as in Case 1: one by one using the same materials and tack-curing to fix them and assure proper seating pushing each extension of the 3D guide in place. Figure 24A,B shows all the veneers/crowns bonded and how the excess cement was removed using a universal curette and dental floss.

4 | DISCUSSION

Contemporary esthetic treatment of dental tissues demands planning and precision driven procedures. The first concerns that arose regarding veneers were about tooth preparation and design. After the publication of the article written by Edelhoff and Sorensen,[28] clinicians became more aware about the importance of removing less tooth structure to offer a predictable and conservative treatment option. Thanks to the advent of digital workflows in dentistry, clinicians can now benefit from a new umbrella of clinical tools. Tooth preparation can be planned and executed with more accuracy. The veneer guided

FIGURE 19 (A),(B) Frontal and posterior view showing design of 3D printed tray

FIGURE 20 (A),(B) Frontal view of tray on 3D printed model and with veneers bonded to it

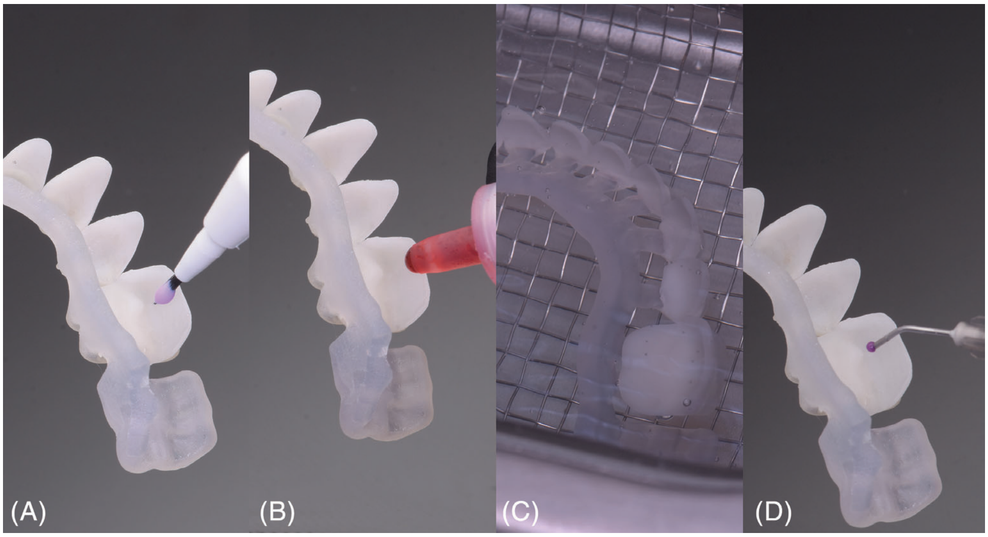

FIGURE 21 Part 1 of adhesive pretreatment protocol applied to inner surface of veneers, which was the same as in Case 1. (A) Ivoclean© (Ivoclar Vivadent, Schaan, Liechtenstein) (B) 5% hydrofluoric acid (IPS Ceramic etch, Ivoclar Vivadent, Schaan, Liechtenstein) (C) Ultrasonic bath with isopropyl alcohol (D) Silane (Ceramic Primer II GC, Japan)

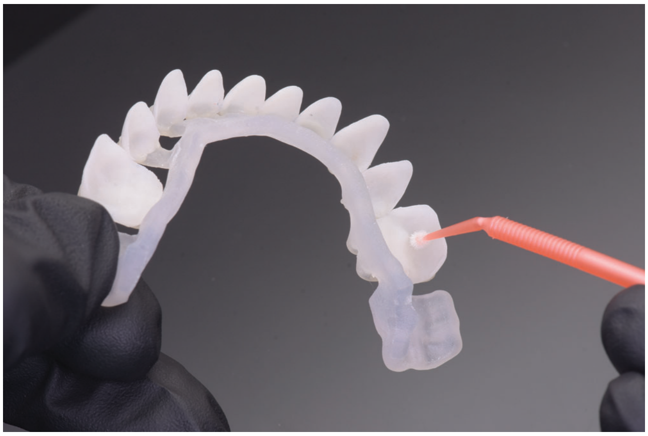

FIGURE 22 Part 2 of adhesive pretreatment protocol applied to inner surface of veneers, depicting the application of bonding agent with a microbrush

FIGURE 23 Intraoral view of tray/veneers in place, confirming seating

FIGURE 24 (A),(B) Intraoral view of excess cement removal after polymerization, using a universal curette and dental floss

prep system[16] can help clinicians prepare teeth for veneers in a predictable and conservative fashion using digital planning tools. The clinician can save time and assure intra-enamel preparations using the 3D printed guides. The specially designed handpiece and guides of the First Fit™ system (Viax Dental Technologies, Miami, FL, USA) allow teeth to be reduced to a pre-planned depth and specific area, in contrast to the use of calibrated burs or silicone guides, which require constant re-evaluation of the preparations during the procedure.[16] As a continuation of that concept, the same technology/tools are used to create a veneer positioning guide, which can help during the etching of the porcelain and the application of the silane. Further development was needed to create the adhesive bonding positioning guide as shown in both cases of this article. Recently developed 3D printing resins and modifications in the design software made this possible. The specific flexibility of the 3D printing resin is key to assure the handling properties/characteristics described in this article to achieve the aid and benefits of the guide while adhesively bonding multiple veneers at the same time. However, other veneer fabrication materials can also be used since the bond between the 3D printed guide's extensions and the veneers themselves is based on flowable composite resin bond without the use of retentions (micromechanical).

The main advantage of this technique is the flexibility of the positioning guide, which allows the clinician to open or press it if needed while seating the veneers. The proper positioning of the veneers is highly likely to be achieved based on the fact that the veneers are bonded to the flexible extensions while being fully seated on the working model, which is the same position they will have when adhesively bonded intraorally. Minimal corrections due to inherent inaccuracies of the indirect fabrication process are possible because of the relative flexibility of the guide extensions and the help of the adjacent veneer that had been bonded beforehand. One disadvantage can be that this part of the technique requires certain training or getting familiar with the material so that the restorations can be adequately cleaned and bonded all at once while not impinging the periodontal tissues. Spot curing is recommended to allow the clinician to clean the excess before definitive curing.

Previous publications have proposed other methods to facilitate the removal of excess cement and verification of veneer seating without the risk of veneer dislodgment. Farah et al[29] proposed the use of mini clothes pins for that purpose. These clips are made out of wood that supposedly do not scratch the veneer and are similar to the orangewood recommended for seating ceramic restorations. The technique seems to be safe, since the force exerted by these clips is only 7.8 N when measured with a digital force gauge[29] and the average seating force exerted by a dentist can be 12–67 N.[30] It is well known by clinicians that uncontrolled pressure while seating a thin veneer can cause cracks or a catastrophic fracture. Therefore, controlled, standardized and homogeneous pressure is desired for the adhesive bonding of veneers. The authors of these article believe that the proposed 3D printed guide can deliver controlled pressure upon adhesive bonding of veneers, albeit not having measured the exact force applied. Other studies like Chen et al[31] proposed a 3D printed guide to cement veneers as well. Despite the fact that it can aid in the positioning of the restorations, it is a stiff retainer-type tray that cannot be pressed or opened accordingly to assure proper controlled seating of the restorations.

Since the early days, studies have demonstrated the relation between the luting cements and the fracture load/resistance of porcelain veneers.[32] Furthermore, there is growing evidence that it is not only the cement, but also the application of it, with sustained seating pressure during cement polymerization that can improve the final bond strength of the resin cement.[33] The application of controlled pressure during the entire course of the setting of a resin cement improves the bond strength and reduces fluid movement from the underlying dentin.[33] It is likely that the application of a sustained seating pressure suppresses the absorption of water and globule formation, resulting in a better quality of adhesive interface.[34]

Relative isolation using cotton rolls and silicone lip retractors was used for this clinical technique. The reason was mainly because the use of the positioning tray requires space and having the palatal aspect of the teeth uncovered to ensure the proper positioning/handling of it. Another reason is to have access to the buccal margins both for positioning and excess cement removal of all veneers simultaneously. There are similar techniques described that can achieve the same outcome but require additional trays or the use of clamps, making the procedure more cumbersome.[35,36] Rubber dam can be used if the 3D printed guide can be positioned passively. This can be achieved by cutting off an opening big enough to ensure proper positioning of the whole guide.[37,38] Although the literature shows increased survival/success rates of restorations using rubber dam, it has been studied mainly with direct restorations.[39,40] There are also reviews that question these results showing no clinical difference in the long term. They mostly blame the existing studies for being low quality and biased.[41,42] Moreover, there are no long term clinical studies indicating that the use of rubber dam results in better clinical outcomes when bonding veneers adhesively. The authors of this article considered the selected isolation method to provide the best field isolation possible without compromising the use of the aforementioned technique and 3D printed positioning tray.

The novel 3D printed bonding guide presented in this article allows the clinician to apply even pressure to all veneers and also to be able to control that pressure due to the relative flexibility of the resin tray. As previously mentioned it is not only difficult for the clinician to control the applied pressure, but also to position the veneer, especially in cases where laterals are involved and only the buccal aspect was prepared, thus having a buccal path of insertion. The use of the guide can also hold them in place while excess removal is taking place. It allows access to most of the interfaces, which might be difficult to view if the restorations are being held by fingers or pin clothes. A final advantage is that the guide is a one piece device that can hold all veneers together individually, which makes the bonding process more stable, accurate and simultaneous compared with individual holders for each veneer.

Advantages of the 3D printed bonding guide:

- holds multiple veneers simultaneously,
- facilitates pre-treatment of ceramic inner surface,
- applies even, controlled pressure during bonding thanks to the flexible resin material,
- offers precision to multiple bonding cases,
- rubber dam can be used for the procedure,
- saves time,
- may increase the accuracy of positioning/bonding veneers.

Disadvantages of the 3D printed bonding guide:

- needs specific software and hardware for the digital workflow,
- there is a learning curve to master the potential benefits,
- availability of the resin tray material.

5 | CONCLUSIONS

This innovative digitally planned technique using a 3D printed guide can make the porcelain veneer adhesive bonding process more predictable, less time consuming, less cumbersome and less technique sensitive. Moreover, the flexible 3D printing resin of the tray allows for controlled/even pressure applied while seating, fixing and bonding the restorations.

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The authors do not have any financial interest in the companies whose materials are included in this article.

AUTHOR CONTRIBUTION

The authors state the order of contribution as shown above.

DATA AVAILABILITY STATEMENT

Data sharing is not applicable to this article as no new data were created or analyzed in this study.

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REFERENCES

1. Calamia JR. Etched porcelain facial veneers: a new treatment modality based on scientific and clinical evidence. *NY Dent*. 1983;53(6):255-259.
2. Horn HR. Porcelain laminate veneers bonded to etched enamel. *Dent Clin N Am*. 1983;27:671.
3. Hekimoglu C, Anil N, Yalçin E. A microleakage study of ceramic laminate veneers by autoradiography: effect of incisal edge preparation. *J Oral Rehabil*. 2004;31(3):265-269.
4. Burke FJ. Survival rates for porcelain laminate veneers with special reference to the effect of preparation in dentin: a literature review. *J Esthet Restor Dent*. 2012;24(4):257-265.
5. Höland W, Schweiger M, Frank M, Rheinberger V. A comparison of the microstructure and properties of the IPS empress 2 and the IPS empress glass-ceramics. *J Biomed Mater Res*. 2000;53(4):297-303.

6. Friedman M. Augmenting restorative dentistry with porcelain veneers. *J Am Dent Assoc*. 1991;122:149.
7. Layton DM, Clarke M. A systematic review and meta-analysis of the survival of non-feldspathic porcelain veneers over 5 and 10 years. *Int J Prosthodont*. 2013;26(2):111-124.
8. Imburgia M, Cortellini D, Valenti M. Minimally invasive vertical preparation design for ceramic veneers: a multicenter retrospective follow-up clinical study of 265 lithium disilicate veneers. *Int J Esthet Dent*. 2019;14(3):286-298.
9. Aslan YU, Uludamar A, Özkan Y. Retrospective analysis of lithium Disilicate laminate veneers applied by experienced dentists: 10-year results. *Int J Prosthodont*. 2019;32(6):471-474.
10. Scotti N, Comba A, Cadenaro M, et al. Effect of lithium Disilicate veneers of different thickness on the degree of conversion and microhardness of a light-curing and a dual-curing cement. *Int J Prosthodont*. 2016;29(4):384-388.
11. Dumfahrt H. Porcelain laminate veneers. A retrospective evaluation after I to 10 years. Part I: clinical procedure. *Int J Prosthodont*. 1999;12:505.
12. Dumfahrt H. Schaffer Fl. Porcelain laminate veneers. A retrospective evaluation after I to 10 years. Part II: clinical results. *Int J Prosthodont*. 2000;13:9.
13. Peumans M, Van Meerbeek B, Lambrechts P, Vuylsteke-Wauters M, Vanherle G. Five-year clinical performance of porcelain veneers. *Quintessence Int*. 1998;29:211.
14. Arif R, Dennison JB, Garcia D, Yaman P. Retrospective evaluation of the clinical performance and longevity of porcelain laminate veneers 7 to 14 years after cementation. *J Prosthet Dent*. 2019;122(1):31-37.
15. Ioannidis A, Mühlemann S, Özcan M, Hüsler J, Hämmerle CHF, Benic GI. Ultra-thin occlusal veneers bonded to enamel and made of ceramic or hybrid materials exhibit load-bearing capacities not different from conventional restorations. *J Mech Behav Biomed Mater*. 2019 Feb;90:433-440.
16. Silva BPD, Stanley K, Gardee J. Laminate veneers: preplanning and treatment using digital guided tooth preparation. *J Esthet Restor Dent*. 2020 Mar;32(2):150-160.
17. Della Bona A, Barghi N. Removal of partially or fully polymerized resin from porcelain veneers. *J Prosthet Dent*. 1993;69:443-444.
18. Vinod Kumar G, Soorya Poduval T. Bipin Reddy, Shesha Reddy P. a study on provisional cements, cementation techniques, and their effects on bonding of porcelain laminate veneers. *J Indian Prosthodont Soc*. 2014;14(1):42-49.
19. Morita RK, Hayashida MF, Pupo YM, Berger G, Reggiani RD, Betiol EAG. Minimally invasive laminate veneers: clinical aspects in treatment planning and cementation procedures. *Case Rep Dent*. 2016;2016:1839793.
20. Blatz MB, Vonderheide M, Conejo J. The effect of resin bonding on long-term success of high-strength ceramics. *J Dent Res*. 2018 Feb;97(2):132-139.
21. Gresnigt MM, Cune MS, de Roos JG, Özcan M. Effect of immediate and delayed dentin sealing on the fracture strength, failure type and Weilbull characteristics of lithiumdisilicate laminate veneers. *Dent Mater*. 2016;32(4):e73-e81.
22. Von Fraunhofer JA. *Dental Materials at a Glance*. 2nd ed. Chichester, UK: Wiley-Blackwell; 2013:63.
23. Sunico-Segarra M, Segarra A. *A Practical Clinical Guide to Resin Cements*. 16th ed. Berlin, Germany: Springer; 2014.
24. Ladha K, Verma M. Conventional and contemporary luting cements: an overview. *J Indian Prosthodont Soc*. 2010;10:79-88.
25. Rosenstiel SF, Land MF, Crispin BJ. Dental luting agents: a review of the current literature. *J Prosthet Dent*. 1998;80:280-301.
26. Stegall D, Tantbirojn D, Perdigão J, Versluis A. Does tack curing luting cements affect the final cure? *J Adhes Dent*. 2017;19(3):239-243.
27. Gurel G, Morimoto S, Calamita MA, Coachman C, Sesma N. Clinical performance of porcelain laminate veneers: outcomes of the aesthetic pre-evaluative temporary (APT) technique. *Int J Periodontics Restorative Dent*. 2012 Dec;32(6):625-635.
28. Edelhoff D, Sorensen JA. Tooth structure removal associated with various preparation designs for anterior teeth. *J Prosthet Dent*. 2002 May;87(5):503-509.
29. Farah RI, Aldhafeeri AF, Alogaili RS. A technique to facilitate ceramic veneer cementation. *J Prosthet Dent*. 2018 Aug;120(2):194-197.
30. Zortuk M, Bolpaca P, Kilic K, Ozdemir E, Aguloglu S. Effects of finger pressure applied by dentists during cementation of all-ceramic crowns. *Eur J Dent*. 2010;4:383-388.
31. Chen X, Zhou N, Ding M, Jing J, Xi Q, Wu G. A digital guiding device to facilitate cementation of porcelain laminate veneers. *J Prosthet Dent*. 2020 Oct;124(4):411-415.
32. Gresnigt MMM, Özcan M, Carvalho M, et al. Effect of luting agent on the load to failure and accelerated-fatigue resistance of lithium disilicate laminate veneers. *Dent Mater*. 2017 Dec;33(12):1392-1401.
33. Chieffi N, Chersoni S, Papacchini F, et al. Effect of the seating pressure on the adhesive bonding of indirect restorations. *Am J Dent*. 2006;19(6):333-336.
34. Chieffi N, Chersoni S, Papacchini F, et al. The effect of application sustained seating pressure on adhesive luting procedure. *Dent Mater*. 2007 Feb;23(2):159-164.
35. Liebenberg WH. The rubber dam-retaining appliance: an adjunct to isolation during placement of multiple veneers. *Quintessence Int*. 1995;26(7):493-500.
36. Liebenberg WH. Porcelain laminate veneers—preparation and isolation innovations. *Gen Dent*. 1995;43(1):50-54. 56-8.
37. Liebenberg WH. Secondary retention of rubber dam: effective moisture control access considerations. *Quintessence Int*. 1995 Apr;26(4):243-252.
38. Wakefield CW Jr. Porcelain veneers: try-in, cementation and maintenance. *Tex Dent J*. 2006;123(10):948-952.
39. Mahn E, Rousson V, Heintze S. Meta-analysis of the influence of bonding parameters on the clinical outcome of tooth-colored cervical restorations. *J Adhes Dent*. 2015;17(5):391-403.
40. Keys W, Carson SJ. Rubber dam may increase the survival time of dental restorations. *Evid Based Dent*. 2017;18(1):19-20.
41. Cajazeira MR, De Sabóia TM, Maia LC. Influence of the operatory field isolation technique on tooth-colored direct dental restorations. *Am J Dent*. 2014 Jun;27(3):155-159.
42. Wang Y, Li C, Yuan H, et al. Rubber dam isolation for restorative treatment in dental patients. *Cochrane Database Syst Rev*. 2016;9(9):CD009858.

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