Treatment of Extended Anterior Crown Fractures Using Type IIIA Bonded Porcelain Restorations

Pascal Magne, DMD, PhD, and Michel Magne, CDT

Abstract

Novel-design bonded porcelain restorations, the so-called Type IIIA BPRs, represent a reliable and effective procedure when restoring large parts of the coronal volume and length in the anterior dentition. While traditional treatment approaches involve the removal of large amounts of sound tooth substance (with adverse effects on the pulp, gingivae and crown biomechanics, as well as serious financial consequences), the use of adhesive technology instead can provide maximum preservation of tissues and limited costs. Considerable advantages, such as the economical and noninvasive treatment of crown-fractured teeth, are inherent to Type IIIA bonded porcelain restorations, reducing the need for preprosthetic interventions (e.g., root canal therapy and crown-lengthening) and the use of intraradicular posts. This article, illustrated with cases with up to eight and 10 years' follow-up, sets the scientific foundations of this concept, as well as important considerations about function, strength, tooth preparation, laboratory technique, and bonding optimization.

It is generally agreed that bonded porcelain restorations such as porcelain veneers have matured into a predictable restorative concept in terms of longevity, periodontal response and patients' response.[1-6] Owing to intrinsic favorable esthetics in the marginal area, bonded porcelain restorations do not specifically require penetration into the gingival sulcus, which prevents potential damage to the periodontal tissues and biologic width violation. Feldspathic porcelain is also known as being less susceptible to accumulation of bacterial plaque in comparison to gold, resin or even to hard tooth structures.[7,8] The indications for the use of bonded porcelain restorations broadened significantly during the 1990s

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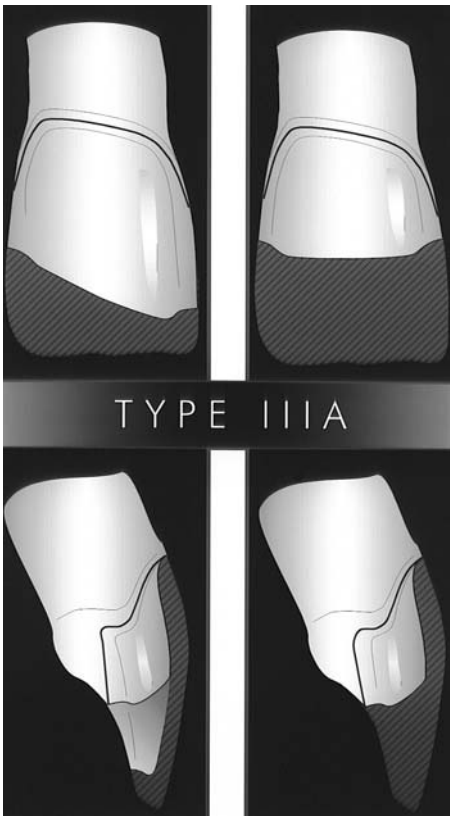

Figure 1. Indication Type IIIA represents a novel-design porcelain veneer for which the veneer includes the missing part of the incisal edge as well as the facial surface.

Table 1

Classification of Indications for Porcelain Veneers

TYPE 1 TEETH RESISTANT TO BLEACHING	
GROUP IA	Tetracycline discoloration of degrees III and IV
GROUP IB	Nonresponse to external or internal bleaching
TYPE II MAJOR MORPHOLOGIC MODIFICATIONS	
GROUP IIA	Conoid teeth
GROUP IIB	Diastemata and interdental triangles to be closed or reduced
GROUP IIC	Augmentation of incisal length and incisive prominence
TYPE III EXTENDED RESTORATIONS (ADULTS)	
GROUP IIIA	Extended crown fractures
GROUP IIIB	Extended loss of enamel by erosion and wear
GROUP IIIC	Generalized malformations and acquired deformities

as a number of researchers expressed confidence in these restorations.[9-14] As a result, innovative preparation designs emerged.[11,14,15] Internal stress distribution and the parameters responsible for postbonding cracks formation were investigated, and preparation design rationalized accordingly.[16-19] Unexplained craze lines, which initially deterred clinicians from using porcelain veneers, were understood and explored experimentally.[19-21]

Based on these considerations, restoration of extensive crown fractures (**Figures 1-3**) have been proposed amongst indications for bonded porcelain restorations, the so-called Type IIIA bonded porcelain restorations according to the classification by Belser and Magne[11] (**Table I, Figure 1**). This approach, used by the author for more than 12 years, has to be considered with special attention because its success and reliability can result in considerable improvements, comprising both the medical-biological aspect (i.e., economy of sound tissues and maintenance of tooth vitality) and the socioeconomical context (i.e., decrease of costs when compared to traditional and more invasive prosthetic treatments).[22] Theoretical bases for such an indication have been documented by experimental and numeric studies demonstrating the sufficient strength and adequate biomechanical behavior of the tooth-restoration complex, provided that adequate design and thickness of the restoration are respected.[9,10,17,22,23] The clinical performance of these novel-design porcelain veneers was confirmed in a medium-term clinical trial.[24] Because traditional porcelain veneers are expected to last 10 to 15 years, these clinical results can be considered only as preliminary.[25] However, bearing in mind that 100 percent of the restorations survived over the average 4.5-year period, a very good prognosis can be anticipated for the new proposed indication. For those incisors with extensive loss of coronal tissues (**Figures 2, 3**), traditional treatment approaches would have involved the removal of large amounts of sound tooth substance, with adverse effects on the pulp, gingivae, and crown biomechanics, as well as significant financial consequences. Using adhesive technology instead of traditional mechanical retention can provide maximum preservation of tissues and limited costs, which also contributes to the absolute satisfaction of the patients. Using Type IIIA bonded porcelain restorations, fractured teeth that are vital before treatment can be kept vital during and after treatment despite considerable hard tissue breakdown. From the periodontal perspective, an additional significant advantage of bonded porcelain restorations is the avoidance of crown lengthening procedures because even very short clinical crowns can be restored (**Figure 2**).

Figure 2a.

Figure 2b.

Figure 2c.

Figure 2d.

Figure 2e.

Figure 2. Typical case of extreme fracture for indication Type IIIA (**2a**). Teeth are vital, and because of adequate treatment planning (additive wax-up technique), only a thin layer of the existing enamel was removed during tooth preparation (**2b**). Feldspathic porcelain restorations were fabricated with a refractory die technique using a significant core of opaque dentin covered with regular dentinoenamel porcelains (**2c**). Note the use of an opaque dentin build up, which proves essential in blending the unsupported porcelain edge with the remaining cervical part of the restoration. Clinical view after 10 years of successful service (**2d**). Note the excellent periodontal response, as well as the absence of detectable wear of the antagonistic dentition despite the restoration of significant guidance. The patient slightly overbleached the aging intact dentition using bleaching strips from her own initiative in order to maintain this result. There are some stains on the palatal surface (mainly on enamel), but no infiltration and no detectable decay (**2e**). Figures 2a and 2b, reprinted with permission from *Int J Peiodontics Restorative Dent* 20(5):441-57, 2000.

Figure 3a.

Figure 3b.

Figure 3. Other case with similar approach as in **Figure 2**. The incisal edge span of porcelain in the mesial part of No. 8 is more than 5 mm (**3a**). Note the outstanding integration of the two bonded porcelain restorations even after eight years of clinical service (**3b**).

Further, the overall behavior of Type IIIA bonded porcelain restorations can be most predictable when adequate treatment planning is carried out. In this regard, high success rates in restoration survival and the patient's satisfaction are also certainly due to the use of additive wax-ups, silicon guides and corresponding diagnostic templates (acrylic mock-ups).[26,27] These strategic elements facilitate three significant steps of the procedure: (1) maximum respect of the patient's desire in the definition of the final functional and esthetic goal; (2) maximum respect of the remaining thickness of enamel during tooth preparation; and (3) restoration of the original enamel thickness and biomimetic recovery of the crown (see next section).

Considerations About Strength

In the veneer technique, the use of porcelain, instead of composite resins is instrumental in the way patients perceive the treatment as demonstrated in a clinical study by Meijering et al.[4] Additionally, porcelain also acts as the most "biomimetic" material when it comes to the replacement of significant amounts of tooth substance, perhaps because of its ability to simulate and restore crown rigidity.[28,29] Owing to their high thermal expansion and elasticity (dentin-like elastic modulus of 10-20 GPa), composite veneers are not able to achieve such goal, which seems to yield unfavorable esthetics, unstable

marginal integrity and decreased survival rate.[30-33] On the other hand, even traditional porcelains such as basic feldspathic materials (enamel-like elastic modulus around 70GPa), are able to compensate for structural tooth weakness. When used in the form of bonded veneers, they can contribute to the recovery of crown biomechanics, including nonvital incisors.[29] When pulpless teeth are treated with traditional prosthodontic procedures (instead of the more conservative veneering techniques), various types of dowels and cores are commonly recommended. This in turn may generate numerous complications, such as cracks and root fractures. It is now established that both the biomechanical properties and the moisture content of nonvital teeth do not differ significantly from those of vital teeth.[34,35] The loss of tooth structure thus becomes the primary cause of failure, not the effect of pulp removal per se. Except in cases of endodontically treated teeth with total breakdown of coronal tooth substance, there is currently no evidence that contraindicates veneering nonvital teeth with Type IIIA bonded porcelain restorations.

The extensive incisal edge span of the ceramic material represents the main challenge of Type IIIA indications. Wall et al. demonstrated that up to 2 mm of incisal edge span of ceramic could be created on lower incisors without affecting the ultimate coronal strength.[36] Andreasen et al. may have been the first authors to advocate the treatment of crown-fractured incisors with bonded porcelain restorations in the early 1990s using Dicor porcelain.[10] This invitro investigation surprisingly claimed ultimate coronal strengths of restored teeth far exceeding that of intact teeth. This conclusion might be more accurate today considering the progress of dentin adhesives and new application modes (see section "Bonding Strategy").[28] It was clearly demonstrated that the potency of the concept lies in the design of the restoration, which is explained through favorable load configuration, geometry and tissue arrangement of upper incisors.[17,37] As a consequence, coronal strength has proven to be sufficient even when using feldspathic bonded porcelain restorations with extensive incisal edge spans of porcelain. Clinical data are supportive because no clinically relevant alterations have been detected up to 5.5 mm of average freestanding feldspathic material.[24] When compared to intact teeth, bonded porcelain restoration-restored crowns featuring extensive incisal edge spans of ceramics are characterized by their "low-stress" design and increased crown stiffness.[23]

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Tooth Preparation

Tooth preparations principles for Type IIIA bonded porcelain restorations do not differ much from those applied in traditional veneer preparations. The adhesive properties and physicochemical characteristics of the luting composites allow the tooth restoration interface to be subjected to substantial stresses. From this viewpoint, the geometric and mechanical parameters of the tooth preparation are of secondary importance. A minimum amount of preparation geometry however, is still required to facilitate placement and positioning of the ceramic workpiece during the final bonding procedure. In the cervical and proximal areas, the creation of a light chamfer margin without internal line angles is universally accepted. A new simplified porcelain laminate preparation driven by an acrylic mock-up was developed and can be applied to the remaining facial cervical third of the fractured tooth.[27] In all cases, an additive diagnostic waxup restoring the original volume of the tooth is used as a reference for tooth reduction. This basic principle will save a significant amount of sound tissue, not only enamel, but also the critical dentinoenamel junction.[26] It is essential to produce preparations without sharp angles, considering that the improved quality of both the preparations (sufficient clearance for the ceramic, smooth contours, absence of undercut) and the final impressions will significantly facilitate the work of the dental ceramist, leading to minimal use of die spacer and thus reducing the risk of postbonding cracks.[19,21,38]

The dilemma of Type IIIA bonded porcelain restorations lies in the fact that the palatal finish line is often localized in palatal fossa, which constitutes a zone of maximum tensile stresses.[37] In this context, the extent of tooth substance loss must be considered because it will significantly influence the location of the palatal finish line. Different patterns of stress are expected on the palatal margin of the veneer depending on the original level of the fracture line (e.g., moderate fracture through the palatal concavity versus extensive fracture through the tubercule of the cingulum).[17] In moderate fractures (incisal 1/3), a palatal mini-chamfer is contraindicated as it would extend the restoration margin in an area of high stress. In such a case, a butt margin limits the extension of the ceramic, thus reducing the amount of stress at the restoration interface and increasing the strength of the tooth restoration complex.[17,39] The use of a butt margin also provides the

margin of the restoration with a strong bulk of porcelain, instead of creating a thin marginal extension of ceramic as with a palatal chamfer. For severe crown fracture (incisal 2/3), the palatal margins are subjected to low tensile forces because they are located in the low stress area of the cingulum. The latter, with its smooth convexity, can be combined either with a butt margin or a mini-chamfer without generating harmful stresses.[17]

Bonding Strategy

Type IIIA bonded porcelain restorations can be placed according to the exact same protocol used for traditional porcelain veneers.[40] Conditioning of the tooth surface is generally limited to a 30-second etching procedure with 37 percent phosphoric acid if the prepared surface is essentially located within the thickness of enamel.

However, if a considerable area of dentin has been exposed during tooth preparation, it is suggested a dentin adhesive be applied strictly according to the manufacturer's instructions. The clinical significance of successful dentin bonding is particularly strong in the case of indirect bonded porcelain restorations, e.g. inlays, onlays and veneers, because the final strength of the tooth restoration complex is highly dependent on adhesive procedures. Long-term clinical trials by Dumfart and Friedman showed that porcelain veneers partially bonded to dentin have an increased risk of failure.[41,25] Recent advances in the knowledge database for dentin bonding agent application suggest these failures can likely be prevented by changing the application procedure of the dentin bonding agent. In fact, there are basic principles to be respected during the clinical procedure of dentin-resin hybridization, the most important of which are related to problem of dentin contamination and susceptibility of the hybrid layer to collapse until it is polymerized. These essential elements when considered within the frame of indirect bonded restorations, especially bonded porcelain restorations, lead to the conclusion that dentin should be sealed immediately after tooth preparation, the so-called immediate dentin

Figure 4a.

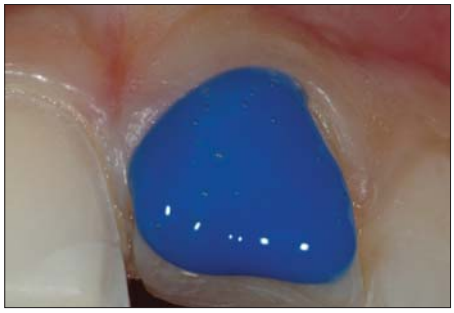
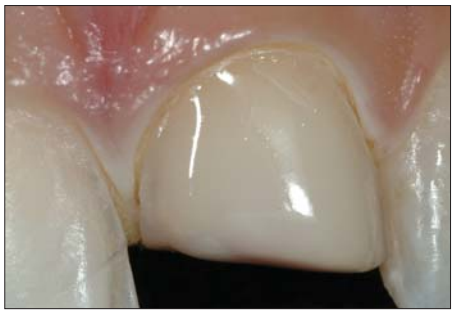


Figure 4b.

Figure 4c.



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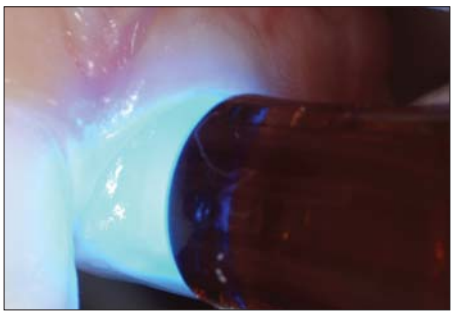

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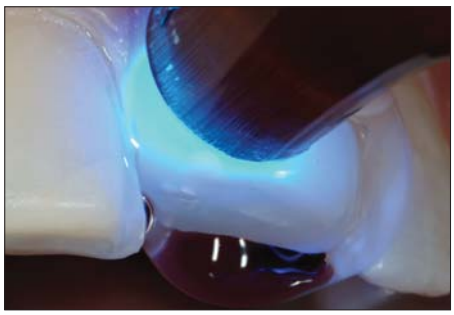

Figure 4f.

Figure 4g.

Figure 4. Clinical situation after preparation of teeth Nos. 8 and 9. Extreme prominence of tooth No. 9 led to a significant exposure of dentin at the facial axial level of the preparation. Margins are still located in enamel. The exposed dentin surface is decontaminated by roughening with a diamond bur (**4a**), then immediately etched for five to 15 seconds, depending on the adhesive system used. It is recommended to extend etching 1 to 2 mm over remaining enamel to assure further adhesion of eventual excess resin (**4b**). Following abundant rinsing, excess water is suctioned and the priming agent (hydrophilic monomer, e.g. Bottle 1 in Optibond FL) is applied to dentin with a gentle brushing motion for 30 seconds (**4c**). Several applications of fresh primer are recommended. The dentin surface is suctioned again to eliminate the solvent (e.g. alcohol in the case of Optibond FL primer) from the priming solution. One coat of adhesive (Bottle 2 in Optibond FL) is then applied, left to diffuse for 20 seconds (**4d**) and cured, first for 20 seconds (**4e**). A thick layer of glycerin jelly is applied to the sealed surface and beyond, and another 10 seconds of light curing is applied to polymerize the air-inhibited layer of the resin (**4f**). Glycerin can be easily removed by rinsing (**4g**) and impression can be carried out. Note the reattached fragment on tooth No. 8, which will be supplemented by the veneer restoration.

sealing (**Figure 4**), prior to impression taking.[42] Amongst the most reliable contemporary systems, OptiBond FL (Kerr, Orange, Calif.) is particularly indicated for immediate dentin sealing because of its ability to form a consistent and uniform layer and its cohesiveness with the final luting composite.[28] Although there is a tendency to simplify bonding procedures, recent data confirm that conventional three-step etch and rinse adhesives still perform most favorably and are most reliable in the long term.[43,44] Just prior to luting procedures (when placing the final restoration), the surface of the adhesive will be meticulously cleansed with pumice or microsandblasting. The entire tooth preparation surface then can be considered and conditioned as it would be done in the absence of dentin exposure: H_3PO_4 etch (30 seconds), rinse, dry and coat with adhesive resin.

There are several rational motives and other practical and technical reasons supporting immediate dentin sealing: Freshly cut dentin is the ideal substrate for dentin bonding.[45-47] Significant reductions in bond strength can occur when simulating dentin contamination with various provisional cements compared to freshly cut dentin. In practice, freshly cut dentin is present only at the time of tooth preparation (before impression).

Precuring of the dentin bonding agent leads to improved bond strength.[48,49] Applying and curing the dentin bonding agent immediately before the insertion of an indirect composite or porcelain restoration could interfere with the complete seating of the restoration. Eventual dentin exposures are therefore sealed immediately, the dentin bonding agent is applied and cured directly after the completion of tooth preparations, before the final impression itself, which was confirmed to generate superior bond strength and less gap formation.[50,51,28,52]

Immediate dentin sealing allows stress-free dentin bond development: Dentin bond strength develops progressively over time. In directly placed adhesive restorations, the weaker early dentin bonding is immediately challenged by the overlaying composite shrinkage and subsequent occlusal forces. On the other hand, when using immediate dentin sealing and indirect bonded restorations, because of the delayed placement of the restoration (intrinsic to indirect techniques) and postponed occlusal loading, the dentin bond can develop without stress, resulting in significantly improved restoration adaptation.[53]

Immediate dentin sealing protects dentin against bacterial leakage and sensitivity during provisionalization.[54-55]

Tooth preparations must be rigorously isolated with a separating medium (e.g., a thick layer of petroleum jelly) during fabrication of the provisional restoration. It is strongly suggested to avoid resin-based provisional cements, but provide mechanical retention and stabilization instead (e.g. locking the restoration through additions of liquid resin in palatal embrasures).

Figure 5a.

Figure 5b.

Figure 5c.

Figure 5d.

Figure 5. Comprehensive case of bonded porcelain restorations including a Type IIIA on tooth No. 9. All of the layering will be performed on a so-called soft tissue cast. Refractory dies have already been dehydrated, coated with the connecting porcelain, and fired (**5a**). The first bake will generate an opaque dentin core on the fractured tooth (**5b**). It is followed by the application of a core of regular dentins and more translucent incisal enamels. An inner translucent enamel skin covers this buildup (**5c**), and then the second bake can be carried out. A slight cutback should allow the application of superficial enamel stains followed by a low-temperature fixation bake. The final volume of the restoration can be accurately obtained through the application of a thin enamel skin (**5d**) and its subsequent firing. Glazing and mechanical polishing are then combined to obtain the final surface texture and gloss. The refractory material is removed by microsandblasting only after completion of surface finishing procedures.

Laboratory Recommendations

From the dental laboratory perspective, it is recommended to fabricate Type IIIA bonded porcelain restorations on refractory dies technique or using a foil technique. Ceramic fired over refractory die is the oldest and most widespread method for fabricating a porcelain piece.[56] Model making can be tedious because multiple dies are required (single dies, refractory dies, soft tissue model). The main advantages of this technique, however, lie in the fact that (1) no special equipment is required, (2) extremely sophisticated effects of color and translucency can be obtained through a full-thickness layering technique, and (3) traditional feldspathic porcelains can be used; and when combined with hydrofluoric acid etching and silanization, these porcelains demonstrate extremely reliable bonding to resins (see next section).[57]

From an esthetic standpoint, the refractory die technique will enable the use of modified opaque dentin as a core buildup during initial layering (**Figures 2c**, **5**). Type IIIA bonded porcelain restorations are characterized by lack of sufficient supporting natural dentin, which must be compensated by a special buildup of opaque dentin that reproduces a similar outline for all preparations (**Figure 5b**). The absence of opaque dentin would result in increased light absorption at the level of the missing natural dentin. Once the core dentin fired, the elaboration will continue with two consecutive firings: the dentinoe-

namel core firing (**Figure 5c**); and the "enamel skin" firing (**Figure 5d**). The final steps will be a glazing bake followed by mechanical polishing and deinvesting by microsandblasting with glass beads.

It is strongly recommended to avoid etching the restorations in the laboratory before the try-in. Etched porcelain is extremely sensitive to contamination. Clinical try-in procedures generally include verification of the marginal fit of the restoration and seating on the original stone dies as well as proximal contacts on a solid model. These procedures can generate significant die stone contamination and subsequent bond strength reduction.[58] Unlike saliva contamination, die stone contamination is not easily cleansable. In any case, one must avoid contact between the etched/silanated porcelain veneers and stone models or tooth surfaces. Both porcelain and tooth surface conditioning should therefore be systematically carried out after try-in, not before.[57]

Bonding to Porcelain

Bonding to feldspathic porcelain can be achieved through etching (10 percent hydrofluoric acid gel during 90 seconds, followed by abundant rinsing) and cleaning. Cleaning the etched porcelain is a critical factor. During the etching process, dissolution of the glassy matrix ultimately leaves retentive holes and tunnels between the acid-resistant crystals. During rinsing, this extremely rough surface is immediately contaminated by ceramic residues and remineralized salts, leaving a typical whitish residue[59] (**Figure 6a**). The whitish area is often misinterpreted as a positive etching outcome. Ultrasonic cleaning, which can be preceded by phosphoric acid precleaning (**Figure 6b**), is essential to remove the residues, enlarging and enhancing access to the microretentive features.[60] Energy dispersive spectroscopy analyses have shown that the crystalline precipitates on the etched surfaces, which are not readily soluble in water, are the reaction products of sodium, potassium, calcium, and aluminum. The precipitates remain on the surface after HF acid application; they can be removed only by ultrasonic cleaning (**Figures 6c**, **6d**), not by rinsing alone.[61]

The micromechanical bond generated through etching and cleaning can be enhanced by chemical coupling, i.e. silanization. Silane solutions contain a significant amount of solvent and must be evaporated for at least five minutes at room temperature (or one minute in a dry furnace at 100 degrees Celsius). This procedure allows the elimination of solvents and other contaminants and enhances the condensation of the silane on the ceramic surface.[57] That specific thermal treatment can also be carried out using a hair dryer.

Practitioners must be extremely prudent when conditioning other types of ceramics. They must be aware that the tensile fracture resistance of the composite-ceramic adhesion zones is controlled primarily by ceramic microstructure and ceramic surface treatment. Procedures that apply to traditional feldspathic porcelain might not apply to other materials, e.g. some pressed ceramics or alumina ceramics.[62,63]

Final Considerations About Function

A concern might be raised through the combination of large incisal edge of porcelain and anterior guidance requirements. There seems to be an association between the absence of anterior guidance (i.e. open bite) and temporomandibular disorders.[64] A key element in the development of harmonious occlusion is therefore by the incisal guidance the steepness of which is not important for neuromuscular harmony.[65,66] To minimize stresses during protrusive movements, some clinicians reduce the length of an esthetically correct tooth. This disastrous approach results in a reverse smile line and ages the patient many years.[66] As proven by clinical results, there should be no fear to rejuvenate the patient's smile by increasing the central incisors' prominence and length because ideal occlusion refers both to an esthetic and physiologic ideal.[24,65,67] Another reason to avoid distributing the anterior guidance over a maximum number of teeth, is the favorable mechanical behavior of bonded porcelain restorations discussed previously. In conclusion, the functional features of teeth restored by bonded porcelain restorations Type IIIA can be identical to those of intact natural teeth. Particular emphasis must be addressed to the maintenance or re-establishment of an adequate and functional anterior guidance regardless of whether this guidance involves the new restorations.

There should be no fear to rejuvenate the patient's smile by increasing the central incisors' prominence and length because ideal occlusion refers both to an esthetic and physiologic ideal.[24,65,67]

Conclusions

Considerable advantages, such as the economical and noninvasive treatment of crown-fractured anterior teeth, are inborn to Type IIIA bonded porcelain restorations, reducing the need for preprosthetic interventions (e.g. root canal therapy and crown lengthening), and the use of intraradicular dowels. The success of the concept lies in the combination of sound adhesive principles, adequate design of the restoration and favorable load configu-

Figure 6a.

Figure 6b.

Figure 6b.

Figure 6d.

Figure 6. Internal view of bonded porcelain restorations after the ceramic has been etched with 10 percent hydrofluoric acid for 90 seconds and rinsed. Even abundant rinsing proves insufficient to clean the porcelain, which is often contaminated by a white residue or deposit (**6a**). The latter can be selectively removed with a brush and phosphoric acid (**6b**), followed by placing the restorations in an ultrasonic bath in distilled water for a few minutes (**6c**). The etched surface is now clean and ready for the application of the silane and subsequent heat treatment (**6d**).

ration, geometry, and tissue arrangement inherent to incisors. Immediate dentin sealing is recommended in case of significant dentin exposure. In the laboratory, the refractory die technique allows the development of a progressive translucency that enhances the blending of the incisal part of the restoration with the remaining cervical aspect of the fractured tooth. Adhesion strength to the feldspathic porcelain can be optimized through specific postetching cleaning and silanization. Given the aforementioned adhesion principles and biomechanical facts, the functional features of teeth restored by bonded porcelain restorations Type IIIA can be identical to those of intact natural teeth. CDA

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