The non-vital discolored central incisor dilemma

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Abstract

The restoration of anterior teeth is frequently a demanding mission. Patients generally have high expectations for the anterior region, which makes the emotional side of treatment especially important. When this involves discolored endodontically treated teeth, consensus can hardly ever be found as to the chosen approach. Bleaching with direct composites is undoubtedly the most conservative choice for these cases. However, this may require more maintenance (touch-up bleaching and repairs) in the long term, which is an important issue for adult patients. On the other hand, bonded porcelain veneers represent a more 'high-end' option, as they recover the original biomechanics of the intact tooth, allow an optimal masking of the substrate, remain stable, and have a reasonable biological cost when compared to full-coverage crowns. This strategy is explained in this article and documented with a clinical case. We describe treatment planning based on the biomimetic concept, taking into consideration what is possible with current materials and techniques when combined with the patient's particular needs, including the introduction of an innovative step during dentin sealing – the microsuction. The laboratory work was totally accomplished by 'teledentistry', with no direct contact between the dental technologist and the patient.

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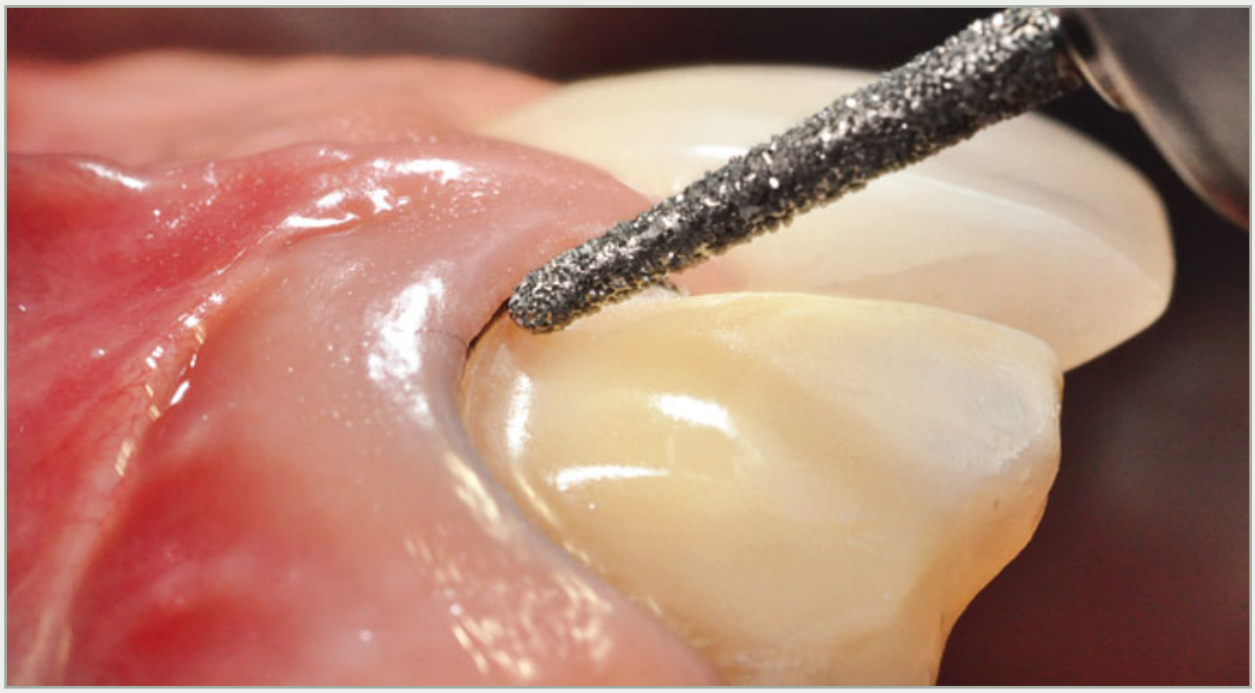

Watch nature… the timeless reference

One of the most difficult challenges for any dental professional is restoring a single central incisor and naturally matching the contralateral intact incisor. This dilemma is further heightened when the patient has a high lip line, demands a natural esthetic outcome, and presents a discolored endodontically treated tooth due to a history of dental trauma (Fig 1). The solution in this scenario often constitutes a controversial therapeutic and academic debate. As described in a previous article,[1] options can swing from more aggressive to highly conservative approaches, often driven by esthetic outcomes, convenience (favorite technique) or specific products available on the market. What is the best position to adopt regarding this decision-making pendulum? We should remember that our timeless reference is the intact tooth.[2,3] Therefore, the treatment options should be evidence-based protocols that maintain or recover the physiological balance between the parameters of biology, mechanics, function, and esthetics.[2] We need to know the tooth and look deeply at it because it is our craft. This means not only mastering shape and color, but also understanding how teeth structures behave under normal function, in overloading situations, and in trauma. Combining this skill and understanding with the fact that dental materials can be synergistically used to mimic enamel, dentin, and the dentinoenamel junction (DEJ) results in the conceptual basis of biomimetics. How to apply biomimetics in daily practice is the central challenge of this article.

Choosing the treatment approach – thinking 'biomimetically'

Nowadays, making an appropriate choice in certain clinical situations might be more difficult than it was 20 to 30 years ago.[2] Over the past decades, several ultraconservative treatment strategies have been introduced, and the most conservative one – in-office bleaching – has enjoyed a resurgence.[4] For didactic reasons, the invasive modalities will be discussed first.

Some doctrines from traditional prosthodontics continue to influence many decisions in the modern dental practice. A preconception still exists that anterior pulpless teeth, because of either their endodontic access or their darker shades, should be prepared with coronal coverage, posts, and cores; that porcelain should overlap any preexistent resin restoration; and that longevity will be dependent on 360-degree preparations. It is known that full-coverage crowns sacrifice almost three times the amount of sound structure as do non-retentive partial preparations (68.2% vs 23.5%).[5] The latter therefore promotes a better preservation of natural tissues because the 'principle of combined action' is maintained,[6,7] in that two extremely distinct tissues – enamel and dentin – engineer a structure (intact tooth) with a better combination of properties (compliant to stresses, lifetime wear resistant). The resultant super-stiff crown makes the underlying dentin hypofunctional,[8] ignoring its role in stress dissipation, as well as hyperstressed in cases of extreme loading, when non-restorable failures are more likely to occur.

Fig 1 Initial aspect of an endodontically treated tooth of a 35-year-old female patient **(a to d)**.

Naturally, the opposite standpoint would be the ultraconservative approach, which combines chemical treatments (bleaching) with freehand composites. This should always be the first option, since progression toward more complex treatments is possible anytime, albeit irreversible[2] – the so-called progressive approach concept.[9] Bleaching can be considered the most ultraconservative modality for the treatment of endodontically discolored teeth, as it preserves the biomechanical potential of the restored teeth[10] with virtually no sacrifice of intact tooth structure. However, a significant incidence of discoloration relapse has been reported,[11-13] ranging from 10% to 40% after 2 years and 8 years of follow-up, respectively. In light of this evidence, the predictability of this technique is limited, and this must be discussed with patients. In cases where a discoloration relapse has already occurred, it is highly probable that new bleaching will be a non-permanent treatment, and restorative solutions should be proposed as more predictable treatments for adult teeth.[10] Regarding the large direct composites that are frequently associated with the restoration

of traumatized anterior teeth, the following aspects should be observed: The mechanical properties of contemporary dental composites are adequate due to significant improvements in filler technology, which makes them eligible for both anterior and posterior use.[14] However, concerns still exist regarding wear and fracture (chipping of surfaces and margins)[15] when the materials are utilized under extreme conditions, for example in high-stress situations, for large preparations, in the case of cuspal replacement or for the restoration of the full quadrant.[16] In a 3-year follow-up clinical study,[17] composite veneers presented surface quality changes (slightly rough) 6 times more frequently than was observed for porcelain ones. This phenomenon could simply be unnoticed by patients – and even by dentists – in the posterior region, but not in the anterior region, where mirror symmetry between central incisors is unconsciously expected. In another 3-year clinical study,[18] where 170 anterior restorations were placed by undergraduate dental students, class IV restorations showed the highest prevalence of failure (deficient marginal adaptation and loss of restoration). This is consistent with another important property, the fracture toughness, which even in current composites is bellow 2.0 MPa $m^{½}$ (3 times less than reinforced ceramics).[14]

Finally, our presented approach is distinguished from those discussed above in that it relies on the recovery of the original stiffness of the crown: traditional porcelain veneers. Stiffness plays a key role in the performance of any complex structure, mainly for those subjected to cyclic loads. Recently, an airplane was launched that, thanks to the greater stiffness of its composite fuselage, can be pressurized at a higher level, which simulates a maximum cabin altitude of 6,000 ft (as opposed to the 7,500 to 8,000 ft of typical airplanes) and results in greater comfort for passengers. Coming 'back to earth', a healthy tooth can last for 100 years (even more), as is witnessed in many octogenarian and nonagenarian patients seen in clinical practice. The longevity of teeth is directly related to crown stiffness. Stiffness, in turn, is based on the physical properties of the tissues (enamel and dentin), loading configuration, and geometry.[19] The enamel shell determines the stress distribution over the crown.[8] During functional protrusive movements, in the maxillary incisors for example, the facial enamel blade will be mostly subjected to compressive stresses, while tensile stresses will concentrate in the palatal fossa.[20] This mechanism can provide reciprocal protection during millions of masticatory cycles, yet any threat to this balance can shorten the lifespan of this sophisticated structure. Several studies[19-22] have demonstrated the impact of restorative procedures on crown rigidity. When enamel is replaced by a more flexible material like a microhybrid composite (elastic modulus ≈ 16 GPa), only 76% to 88% of its original rigidity is recovered after the placement of composite restorations[21] and composite veneers,[22] respectively. On the other hand, a study showed that 97% of the crown stiffness is recovered when feldspathic porcelain (elastic modulus ≈ 70 GPa) is used as an enamel substitute.[20] It is worth noting that there is no evidence to show that extra intrinsic strength such

as that of reinforced ceramics would be needed. As for the natural tooth, which is made of extremely brittle enamel, it is the synergistic combination of the materials (ceramic shell and luting agent), as well as the bonding quality, that defines the performance of the restored tooth. Several treatment modalities may usually be associated with endodontically treated teeth (eg, class III composite restorations due to previous caries, or class IV composite restorations related to previous trauma). It has been demonstrated that successive restorative procedures performed on the same tooth significantly influences crown flexure.[19] Only 88% of the original crown stiffness is recovered when class III cavities and endodontic access are restored with composite resin (as the endodontic access is located in a critical area, its contribution to crown rigidity is higher). If this tooth had been endodontically treated at an earlier stage (childhood/adolescence; Fig 1b), this percentage would be even lower. Therefore, any additional replacement of sound enamel by composite is not recommended in these cases. With survival rates of 96%[23] after 10 years, porcelain veneers are the only restorative treatment with no additional effect on crown compliance.

Case presentation

A 35-year-old female dentist presented as a new patient to a private dental practice in Florianópolis, Brazil, in 2010 requesting a full-coverage crown restoration on her maxillary right central incisor (Fig 1). The patient was willing to receive full-coverage crown restorations on both her central incisors to ensure good color matching. The tooth had first been traumatized in 1985 when, at the age of 9, the patient fell and fractured the distoincisal third of the tooth. She was treated with a direct class IV composite restoration on surfaces MIDBL. In 1989, she developed an acute periapical abscess. At this point, root canal therapy was carried out. The patient was not satisfied with the esthetic result, and in 1997 internal bleaching was performed, along with a new class IV composite restoration. Four years later, the tooth was again internally bleached with hydrogen peroxide 35% gel, and a fiber post was placed, followed by external bleaching in 2003, which was done with a laser. When the patient presented in 2010, she insisted that, regardless of the advantages of tissue conservation,[24] she did not want to try bleaching again since she was worried about the risk of root resorption; instead, she would choose either a direct or indirect restorative solution. The patient was esthetically minded, having even undergone surgery in 2009 to decrease her gummy smile.

The case illustrates a biomimetic approach with ceramics, where a porcelain veneer preparation completed for a combined indication (types IB and IIIA)[25] allowed for the solving of the problem of the remaining staining of a pulpless tooth and the restoration of an extensive coronal fracture. The palatal endodontic access was treated before the veneer preparation, to both improve the biomechanics through a more anatomical cingulum/palatal fossa and ensure proper bonding through a proven protocol (fourth generation bonding system). The large palatal endodontic

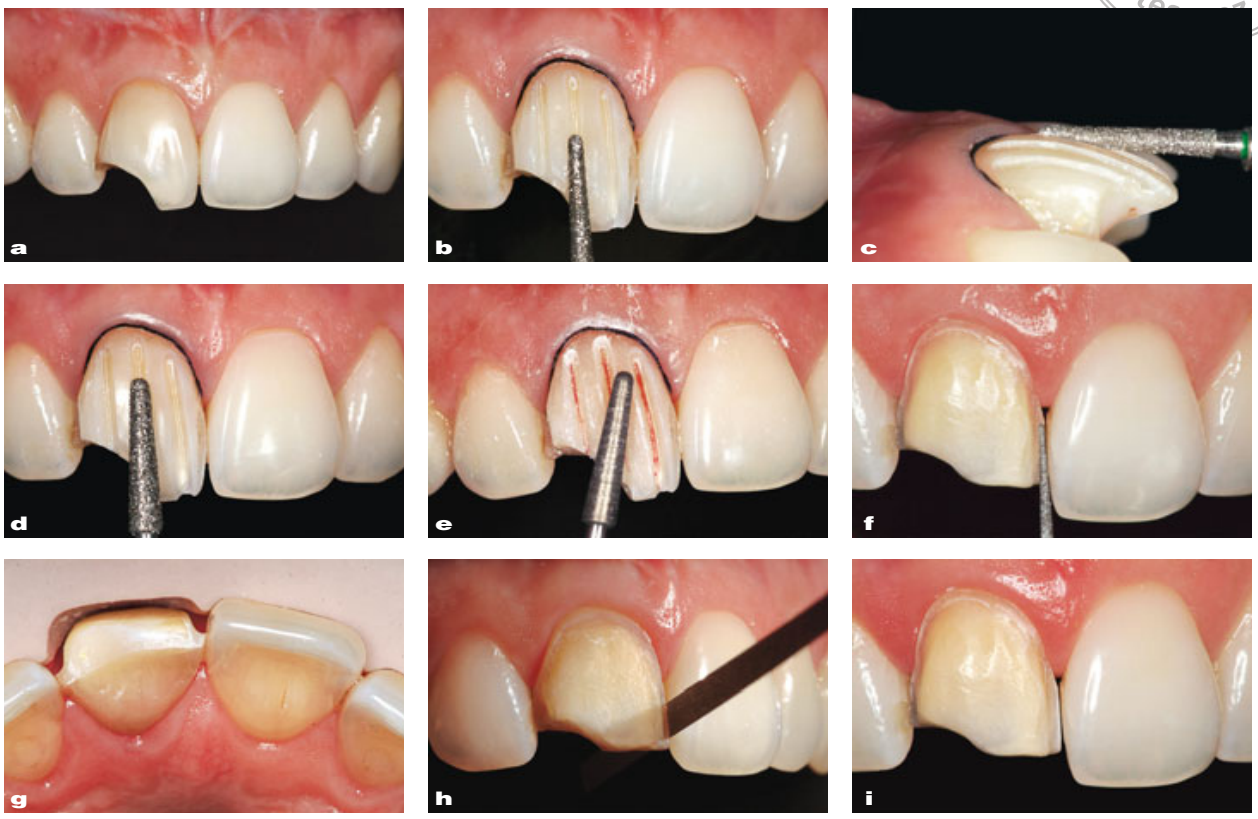

Fig 2 The existing class IV composite is completely removed from the distofacial–incisal angle with a tapered diamond bur, unveiling the type IIIA indication (extensive coronal fracture) **(a)**. After the placement of a deflection cord (eg, Ultrapak #000, Ultradent), facial depth grooves are prepared (recommended bur: 6850.016, Brasseler) **(b and c)**, followed by gross reduction (6850.023, Brasseler) **(d and e)**. In the absence of oscillating instruments, a thin bur should be used to create the proximal margins (eg, 6850.014, Brasseler) **(f)**. Control with the facial silicon index (a uniform space is generated) **(g)**. The large proximal contact demands stripping to prevent deep interdental penetration **(h)**. Regardless of the dark shade, a paragingival margin is chosen **(i)**.

access was removed until natural tissue was reached, leaving only the existing fiber post untouched. In order to simplify the procedures, the post was not removed, since the mechanical principles on which veneer preparation are based are not dependent on intraradicular retention.[26] The pulp chamber was sealed with the total-etch bonding technique (OptiBond FL, Kerr), followed by incrementally placed microhybrid composite (Miris, Coltène Whaledent). The final layer was completed with the aid of a transparent index, based on a previous wax-up (Transil, Ivoclar Vivadent).

The axial reduction for veneers should be agreed upon by both the clinician and the laboratory technician (Fig 2). The depth of the preparation will be determined by the thickness of the bonding layer, the masking agent, and the porcelain itself. Although non-discolor-

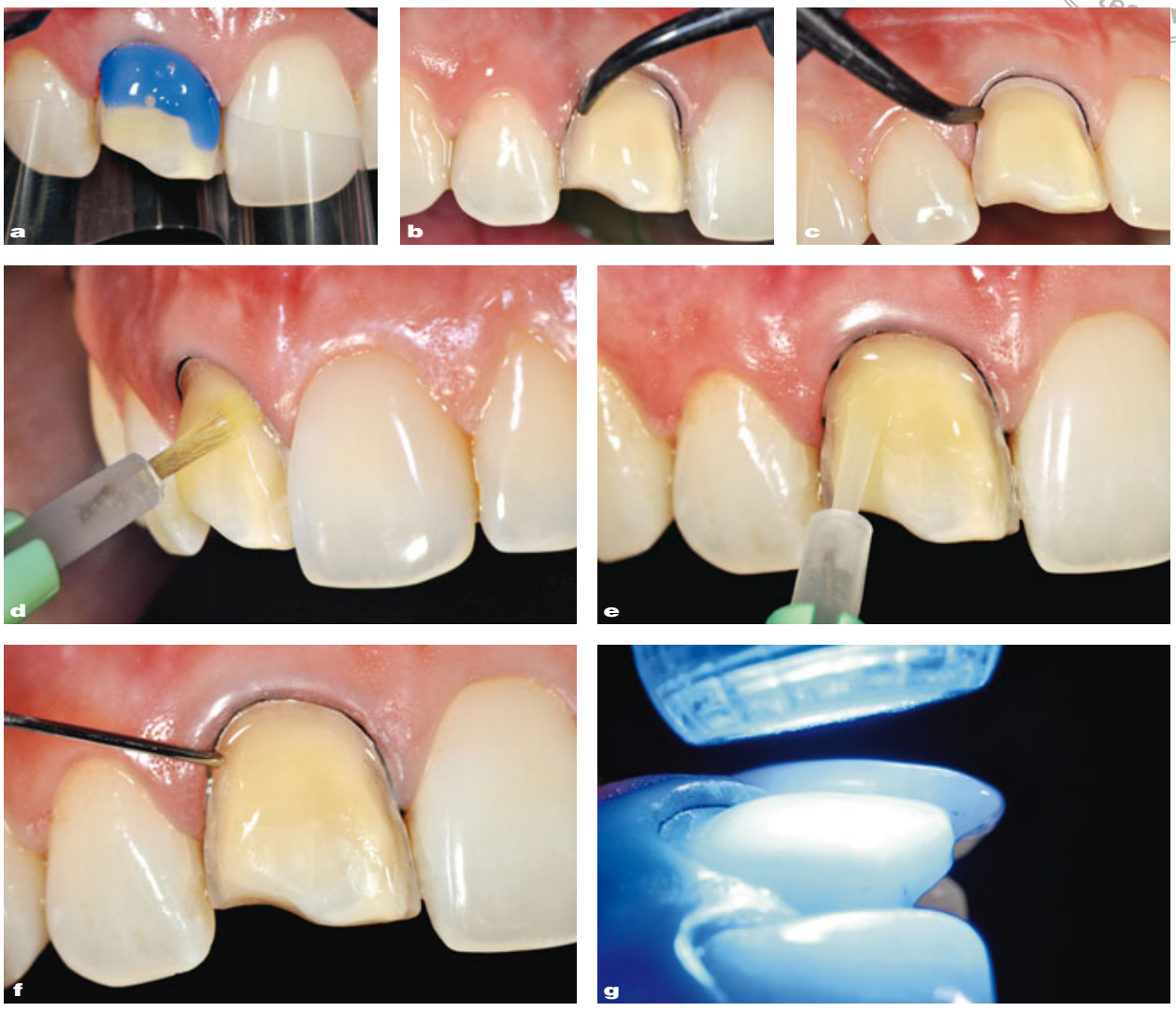

Fig 3 When using a 3-step etch-and-rinse system, the procedure starts by etching the freshly cut dentin with a 35% phosphoric acid (eg, Ultra-etch, Ultradent) **(a)**, followed by rinsing, and the evacuation of excess water by microsuction (eg, Black Mini Tip, Ultradent) **(b and c)**. A hydrophilic monomer (Optibond FL, Bottle no. 1, Kerr) is applied with a gentle brushing motion and the excess solvent is suctioned **(d)**. A thin coat of filled adhesive resin is then applied (Optibond FL, Bottle no. 2, Kerr) **(e)**. In cases where the adhesive surpasses the dentin/enamel margins, an applicator tip can be used to remove most of the excess with pinpoint accuracy by microsuction. No air blowing should be needed, and direct contact with the dentin should be avoided **(f)**. The adhesive is then light-polymerized for 20 s, with an additional 10 s under an air-blocking barrier (eg, K-Y Jelly, Johnson & Johnson) to reduce the oxygen-inhibition layer **(g)**.

ed teeth can be restored with 0.5 mm or less in the gingival third, this particular case required more space for the dental technologist to properly mask and match for the desired shade (Fig 2g). For this case, this space amounted to 0.7 mm in the gingival third, with 0.9 mm at the mid-facial reduction. The chances of dentin exposure at this depth, including the sacrifice of the DEJ, is quite high, mainly in the cervical third, which could jeopardize the chances of success in the long term.[27] Hence, the freshly cut dentin surfaces were immediately sealed with a dentin bonding agent (DBA) following preparation (Fig 3), before the impression was taken. This enhances the potential for adhesion and for recreating the DEJ.[20,28,29]

Immediate dentin sealing (IDS) has many known practical and technical advantages, including increased bond strength, less gap formation, decreased sensitivity, and decreased bacterial leakage during the provisional stage.[30] However, IDS can be technique-sensitive for many practitioners when it comes to dentin margins in veneer preparations. The use of a periodontal probe has been proposed for the more accurate and careful placement of the adhesive when dentin exposure encroaches on the margins.[30] However, it is quite common for the excess adhesive to flow beyond the margins (mainly when it is being applied under motion with a microbrush), which could jeopardize the procedure by confounding margin visualization (Fig 3e). Microsuction is an innovative step that has been developed to eliminate any type of liquid (water, primer, adhesive) during dental procedures with pinpoint precision (Figs 3b, 3c, and 3f). The procedure is quite simple. Blunt-end applicator tips (Fig 4a) are connected to a saliva aspirator (either regular or high-speed; Fig 4b), which is applied where the excess is located (eg, into the gingival sulcus along the preparation margin). Microsuction therefore reduces the need for the extensive use of oscillating (interdentally) or rotary instruments (cervically) when finalizing the preparation margin (Fig 5).

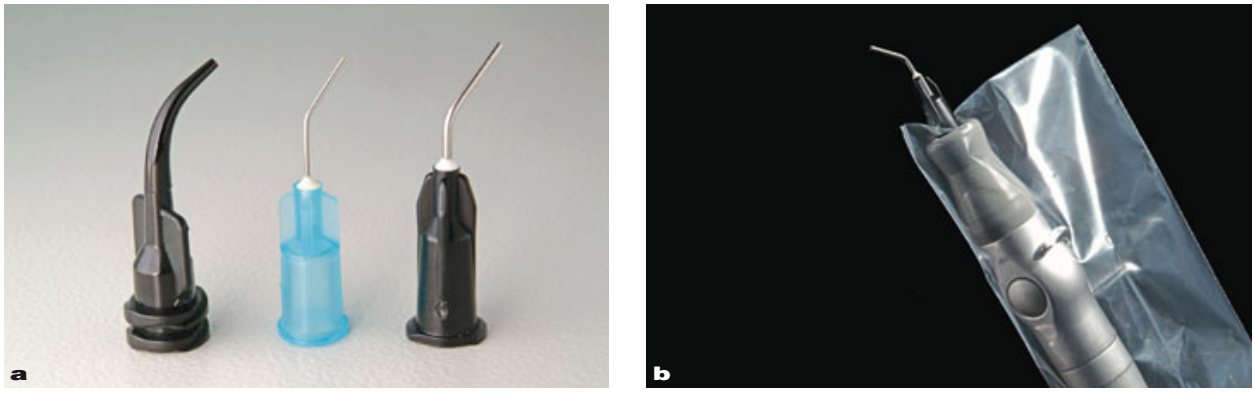

Fig 4 Cannulae tips (from left to right: Black Mini Tip, Blue Micro Tip, Black Micro Tip; Ultradent) **(a)**. A cannulae tip connected to a saliva ejector valve **(b)**.

The laboratory work, performed by MM, included the challenge of not seeing the patient in person. All the communication between the dentist and the dental technician was accomplished by teledentistry (Fig 6). The shade documentation was not performed in the preparation session but in the following visit, to allow full tooth rehydration.

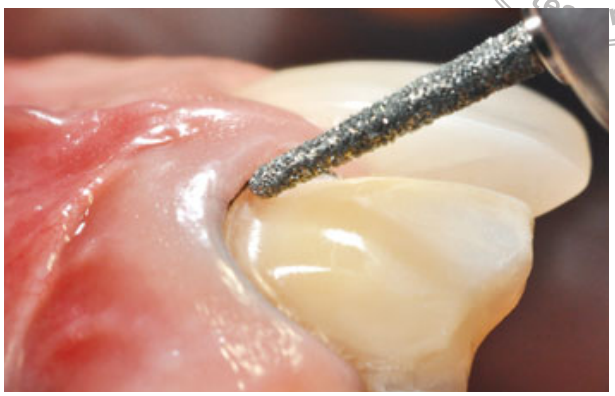

Fig 5 Any excess adhesive on enamel and dentin margins should be carefully removed with diamond burs. Note that the accurate removal of excess adhesive by microsuction leaves minimal or no excess to be cleaned by rotary instruments.

Fig 6 Pumice is used to remove the residual unpolymerized layer of adhesive to obtain defect-free impressions **(a)**. New deflection cords are positioned in the gingival sulcus, allowing the margin to be visible **(b)**. A double-mix/one-step impression is used to capture the margin without tears or defects **(c)**. In the follow-up visit (2-3 weeks later, to allow for rehydration) the shade guides are viewed in the same plane in order to aid the stump shade match for the final restoration **(d and e)**. A strict photographic protocol, including polarized pictures (eg, Polar_eyes) **(f)** is always recommended. It was particularly necessary in this challenging case, where the technician and the patient did not meet because they live in different countries.

Fig 7 Porcelain veneer (Creation CC, Klema) on an optical verification die (alveolar delta die).[31,32] Only one veneer was fabricated, and after the first try-in, a minor correction was performed in the incisal halo region using low-fusion porcelain **(a)**. Field isolation with rubber dam allows full access to the margins, which is the standard for luting procedures of porcelain veneers (clamp 212) **(b)**. Tooth preparation is treated with airborne-particle abrasion and etched for 30 s with 37.5% phosphoric acid (Gel etchant, Kerr) **(c and d)**, rinsed, and dried. Fitting surfaces, restoration, and tooth were coated with adhesive resin (Optibond FL, Bottle no. 2, Kerr) and left unpolymerized until the application of the luting material (Variolink Veneer High Value +1, Ivoclar Vivadent) to the restoration, which was then digitally seated. Before light polymerization, the gross excess luting material is removed with an explorer **(e)**. Microbrushes should be avoided because their fine bristles could extract the luting agent from the margin joint.[2] Still under rubber dam, excess adhesive and luting material are best removed with hand instruments (no. 12 surgical blade) **(f and g)**.

The veneer was fabricated using the refractory die technique (Fig 7a). This option still provides unmatched effects of color and translucency through a full-thickness layering technique,[2] which includes the unique possibility of intrinsic selective masking. Based on intraoral photographic documentation (Fig 6e) and the subsequent masking map, the ceramist will sequentially apply very thin, opaque layers on the refractory die to block the undesired discolored areas. Optionally, the technician can improve predictability by first trying the effects of masking on customized porcelain tabs that are fabricated with a similar color to that of the tooth substrate – the so-called parallel stratification masking technique.[32] The discolored preparation can also be directly masked by the dentist in the mouth using opaque resins (eg, Kolor + Plus, Kerr); however, this will result in a decrease in bond strength.[33] The veneer was delivered following the classical bonding protocol (field isolation with rubber dam, porcelain etching, post-etching cleaning, silane/heat drying, bonding agent, light-curing composite resin; Figs 7b to g). Figures 8 and 9 show the excellent results achieved with tissue and facial integration.

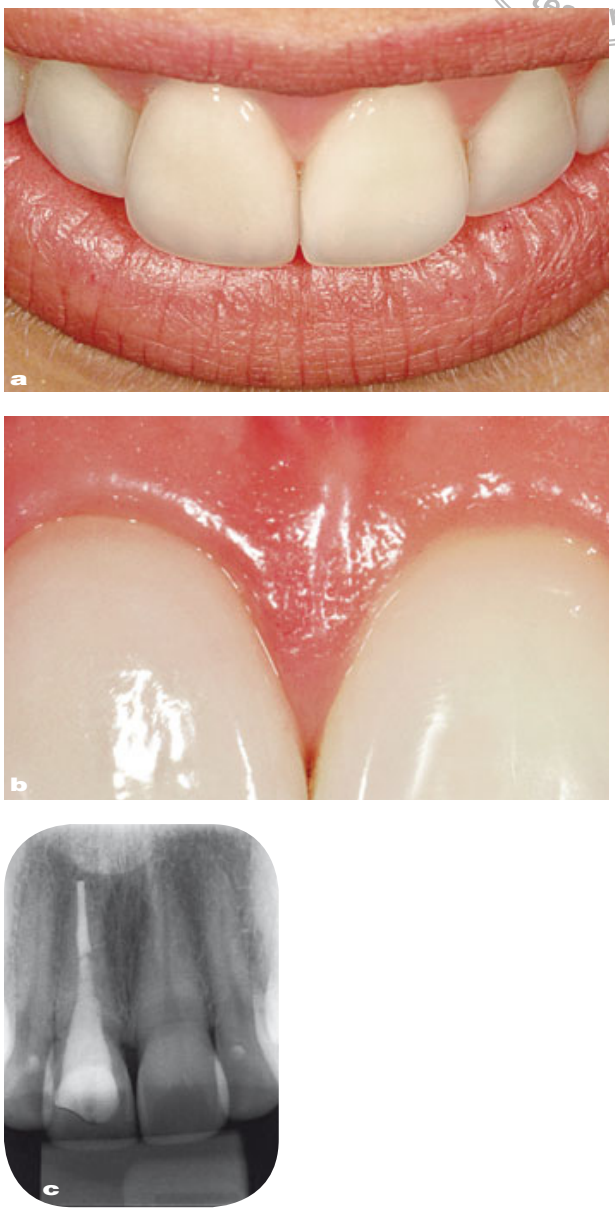

Fig 8 Final restoration after healing **(a)**. Note the periodontal health and matching gingival appearance despite the previously discolored tooth **(b)**. Final radiograph **(c)**.

Fig 9 Smile **(a)**. Under natural light, close to sunset **(b)**. The patient was satisfied with the integration of the restoration **(c)**.

Conclusion

Porcelain veneers bonded through improved protocols provide predictable and reliable treatment for vital, pulpless, and unresponsive discolored teeth. This approach has the principles of biomimetics at its core, which strives to replace damaged dental tissues with human-made materials that mimic those found in nature in a conservative way that re-establishes the biologic crown stiffness and allows for functional stress to pass through the tooth naturally. It must be emphasized that the success of this procedure would not have been possible without the outstanding skills of the ceramist. Microsuction is one innovative technique that can help clinicians to obtain the precision they require in bonding. Its technical advantages could also be implemented for direct techniques. Additional studies are needed to investigate its influence in bonding effectiveness to dentin.

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