An approach to biomimetics: The natural CAD/CAM restoration: A clinical report

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Those in the dental field have always pursued the perfect dental material for the treatment of compromised teeth. Gold, amalgam, composite resin, glass ionomer, and porcelain have been used. Tooth-like restorative materials (composite resin and porcelain) combined with an effective hard tissue bond have met the growing demand for esthetic or metal-free restorations in the past 15 to 20 years. However, none of those materials can fully mimic the unique properties of dentin (compliance and crack-stopping behavior) and enamel (wear resistance, function). The aim of this article is to report the restoration of an extensively damaged tooth with a natural restoration obtained by milling an extracted third molar tooth with a computer-aided design and computer-aided manufacturing (CAD/CAM) system. The main benefit of this novel technique is the replacement of lost tissues by actual enamel and dentin, with the potential to recover mechanical, esthetic, and biologic properties. The indication for extracting third molars and premolars because of impaction or for orthodontic reasons makes these posterior teeth readily available. The innovation of the method presented here is the optimal use of the extracted tooth substrate thanks to its positioning technique in the CAD/CAM milling chamber. (J Prosthet Dent 2014;111:107-115)

Natural teeth have a timeless beauty and mechanical performance unsurpassed by any porcelain, polymer, or metal alloy. Most of these materials visually resemble the tooth,[1] but none fully behave like natural tissue. Alongside this mismatch, in the past decade, a significant effort to understand the intact dental structure, unchanged through the ages, has brought biomimetic research to the forefront.[2] The definition of the term "biomimetic" in the field of restorative dentistry is the study of the structure, function, and biology of the tooth organ as a model for the design and engineering of materials, techniques, and equipment to restore or replace teeth.[3] An example of this approach is the meticulous combination of materials that better simulate the natural tooth such as the use of porcelain to replace enamel and composite resins to replace dentin, combined to optimized bonding strategies.[2,3]

The concept introduced here represents an additional step toward the biomimetic approach because dental hard tissues were used in a replicable way. It combines a renewable biologic resource (extracted third molars and premolars) with contemporary dental computer-aided manufacturing (CAD/CAM) approaches and modern adhesive technology to rehabilitate original tooth function, mechanical properties, and esthetics. The present article reports the restoration of a structurally compromised mandibular first molar with a restoration obtained by milling an extracted third molar (from a donor) with a CAD/CAM system. The patient was aware that this type of CAD/CAM restoration had not been previously reported but consented to the treatment.

When restoring teeth, dentists usually use direct additive adhesive techniques in which dental materials are inserted into the defect and then are light polymerized. Conversely, adapting an extracted tooth to a recipient site compels the use of a subtractive technique. An existing approach is the freehand subtraction of the donated dental structure until some degree of fit is achieved.[4-6] However, this is an empirical method and yields a poor fit compared with the required standards of indirect restorations. This clinical report, therefore, describes the use of a dental CAD/CAM system to improve accuracy. As with any synthetic material (ceramics, composite resins), extracted teeth can also be milled with high

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precision by means of a predictable process. The use of extracted teeth with the current CAD/CAM systems, however, requires some extra steps to achieve a correct positioning of the specimen for the milling phase.

CLINICAL REPORT

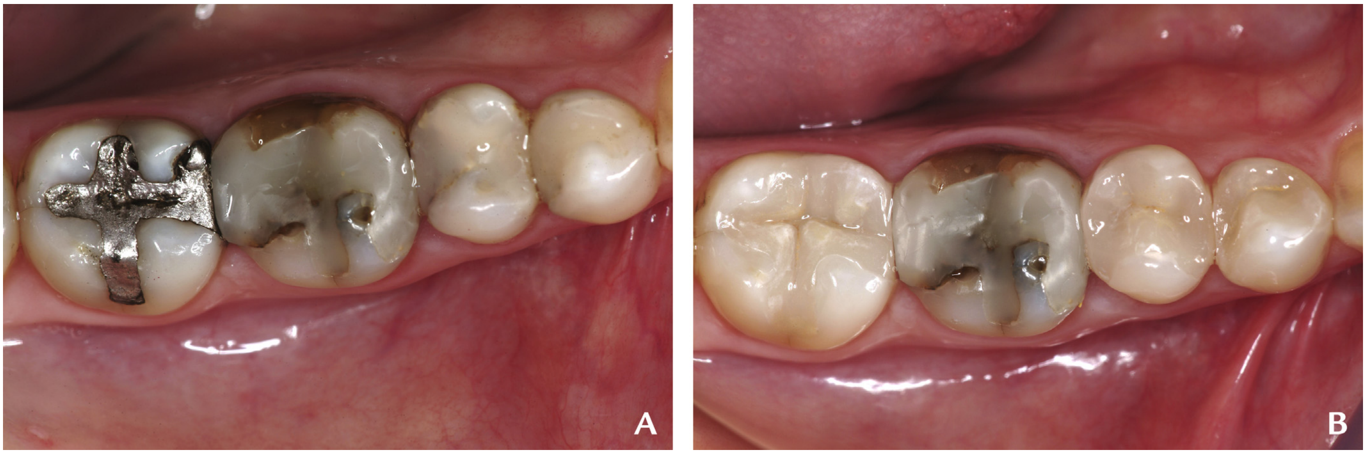
A 41-year-old woman presented in 2010 requesting restorative treatment on posterior teeth in the mandibular right quadrant (Fig. 1A). The patient was concerned with the esthetics of the first molar. All the teeth were vital. During the first appointment, the patient mentioned that her daughter had recently had her wisdom teeth extracted. She was then informed about the possibility of using extracted teeth from a donor (in this case her daughter) to generate a natural restoration. The patient agreed, and the treatment was arranged in 2 phases: indirect bonded ceramic restorations on the premolars and second molar (Fig. 1B), and a bonded natural restoration on the first molar.

Natural restoration: tooth preparation and bonding strategy

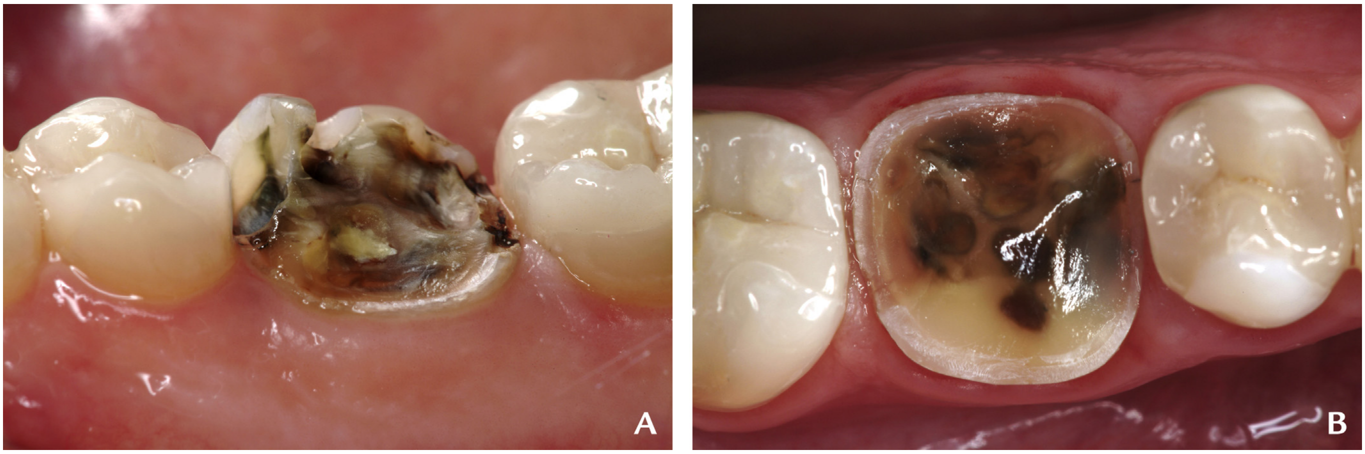
The existing restoration was removed, which left sound dental structure (Fig. 2A). The tooth reduction was limited to the creation of a simplified outline form without macroretentive geometry. Once the preparation was completed, immediate dentin sealing was applied by using a 3-step etch-and-rinse dentin bonding agent (OptiBond FL; Kerr Corp),[7] according to the manufacturer's instructions, without air thinning the adhesive and with an additional light polymerization at 1200 mW/cm^2 (Radii Cal; SDI) for 10 seconds under an air barrier (K-Y Jelly; Johnson & Johnson) to reduce the oxygen-inhibition layer. Excess adhesive resin was then removed from the surrounding enamel by using a round diamond rotary cutting instrument (801- 023; Brasseler USA) at 1500 rpm (Fig. 2B). Pumice was used to remove the residual unpolymerized layer of adhesive to obtain defect-free impressions.[8] Complete-arch polyvinyl siloxane impressions were made with a double-mix and 1-step technique to obtain the working casts (Pearl white GC Fujirock EP; GC America).

Natural tooth positioning in the stone cast and restoration design

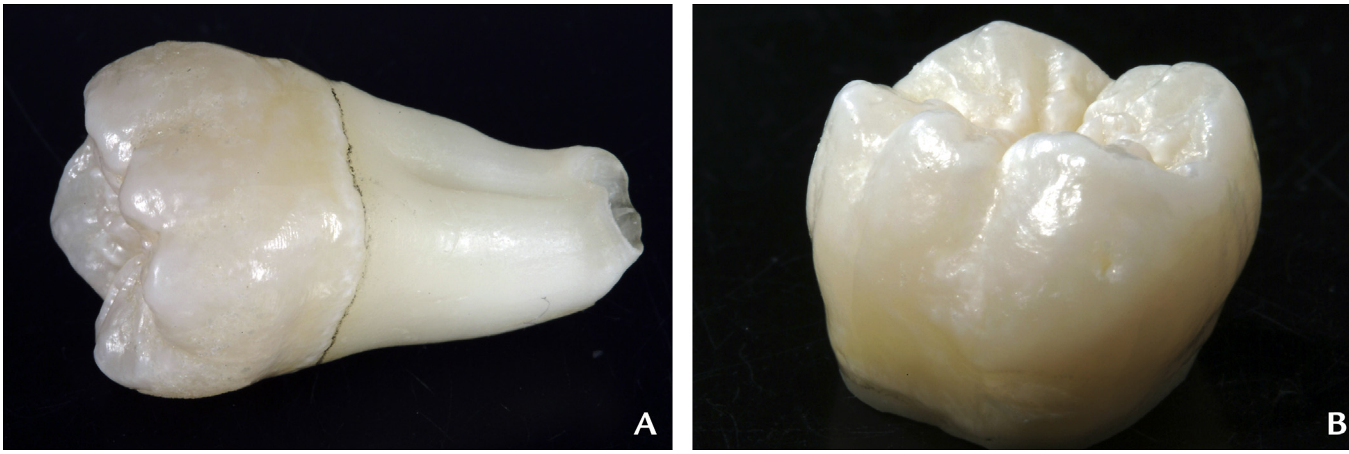
First, 1 of the 3 extracted donor teeth was selected based on its anatomic compatibility with the tooth to be



1 A, Preoperative situation featuring heavily restored vital tooth in mandibular right sextant. B, Premolars and second molar completed with ceramic restorations and first molar to be treated with natural restoration.



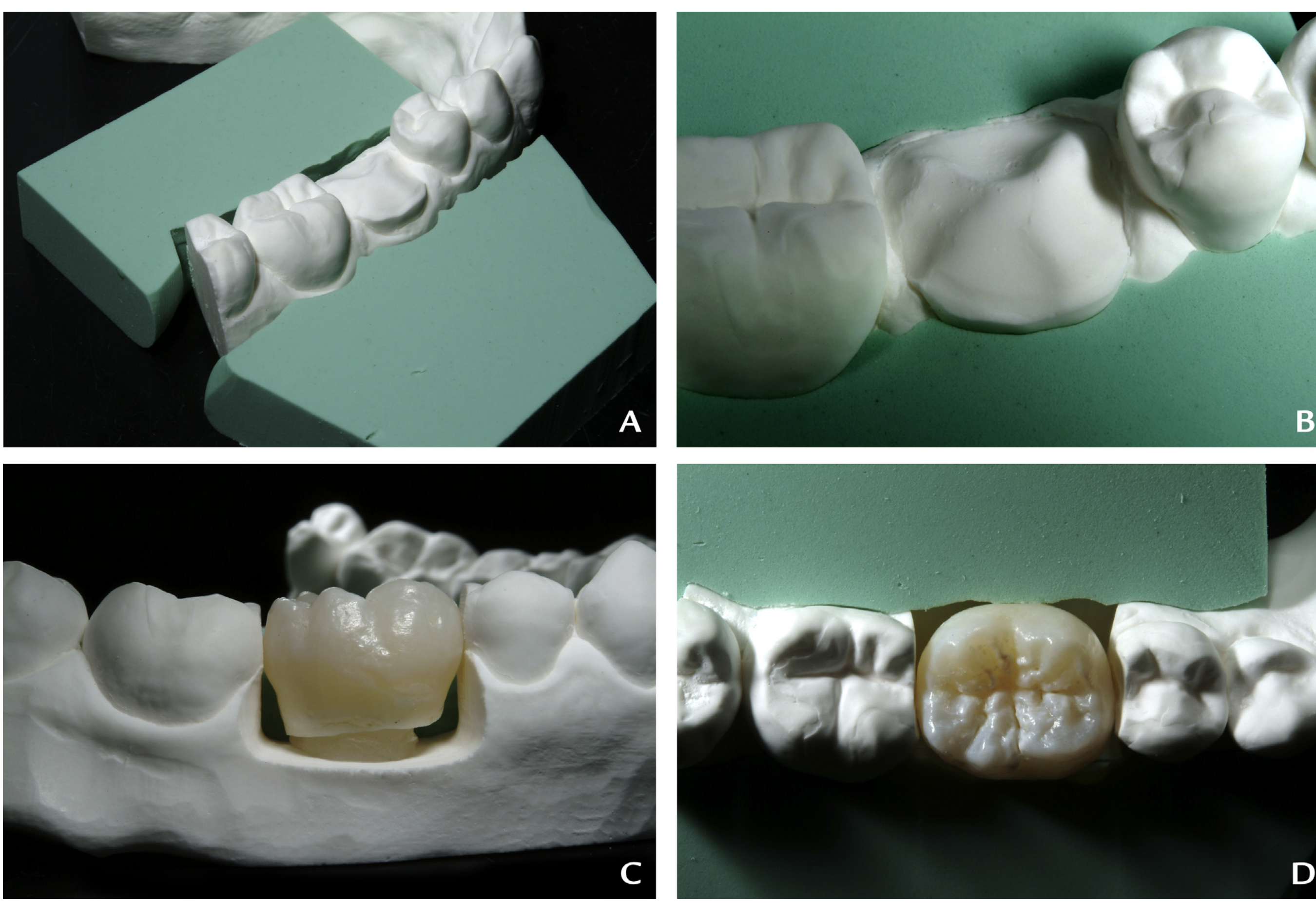
2 A, The remaining tooth after removing failing restoration (lingual view). B, Prepared tooth after immediate dentin sealing (IDS) and removal of excess adhesive resin from enamel.



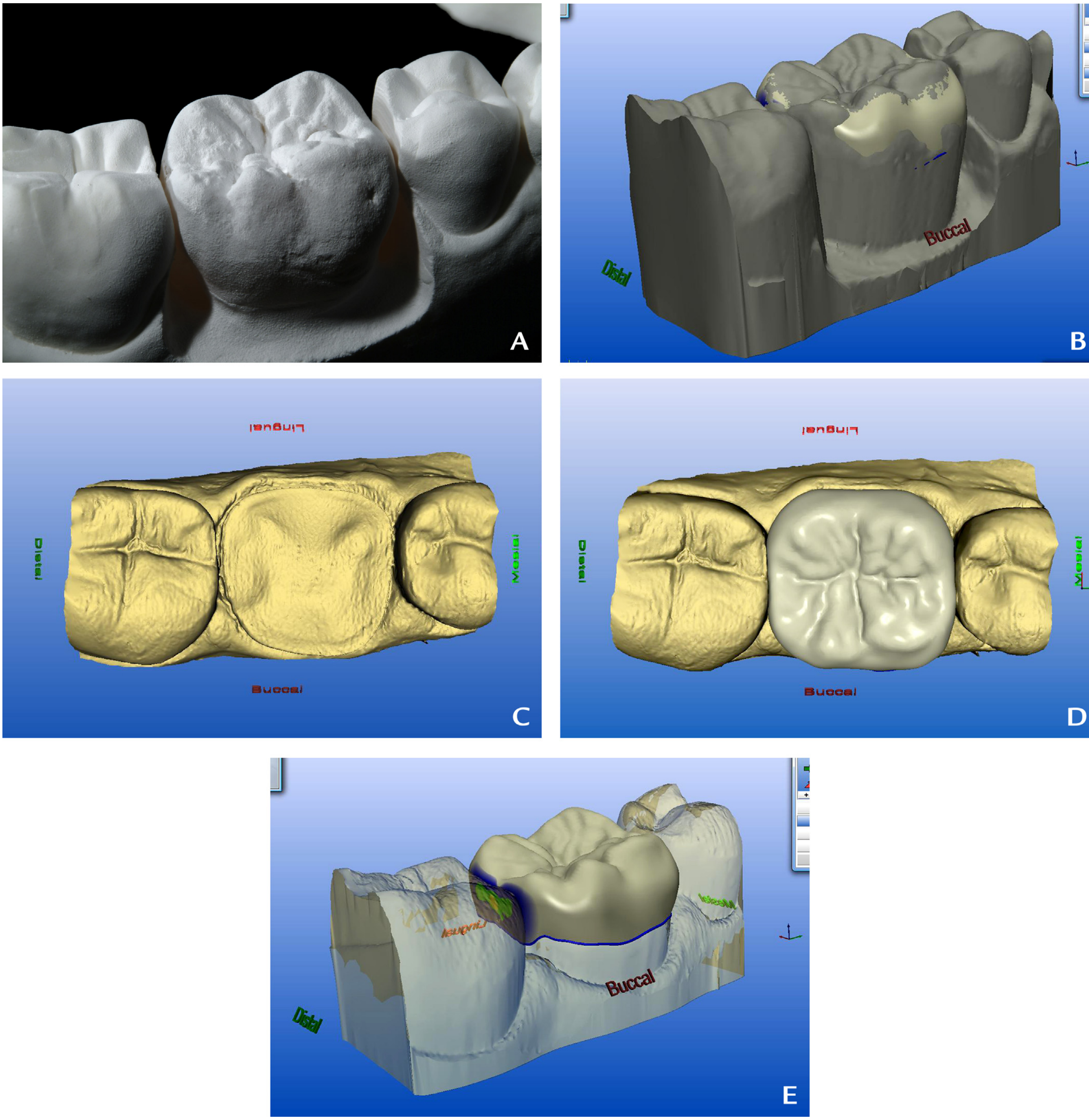
3 A, Extracted third molar donated by patient's daughter. B, Root removal 1 mm below cementoenamel junction.

restored (similar dimensions or preferably slightly larger) (Fig. 3) by using the Cerec AC CAD/CAM system (Sirona Dental Systems GmbH).

A modified CAD/CAM block was used as a platform to hold the natural tooth crown. Because of the complex layered structure of natural teeth, the extracted tooth had to be positioned within the CAD/CAM block at the exact coordinates where the designed restoration would be milled. To achieve the optimal positioning of the natural tooth crown within the dental arch, a silicone index (Platinum 85; Zhermack) recorded the emergence profile of the prepared tooth (Fig. 4A, B). Then, a duplicate stone cast was trimmed to remove the prepared tooth, including some of the neighboring teeth, to place the crown of the extracted tooth in the desired position within the dental arch (Fig. 4C). The silicone index facilitated the correct buccolingual alignment of the tooth (Fig. 4D). The occlusal contacts were checked with the articulated opposing stone casts. Once the ideal tooth position was obtained, the



4 A, Silicone index recorded emergence profile of the remaining tooth. B, Index planed at level of gingival margin. C, Second stone cast trimmed, including some extent of the neighbor teeth, to allow seating of extracted tooth. Soft wax allows free rotation up the optimal position. D, Silicone indexes assisted exact buccal-lingual positioning (articulated casts assisted in vertical positioning).

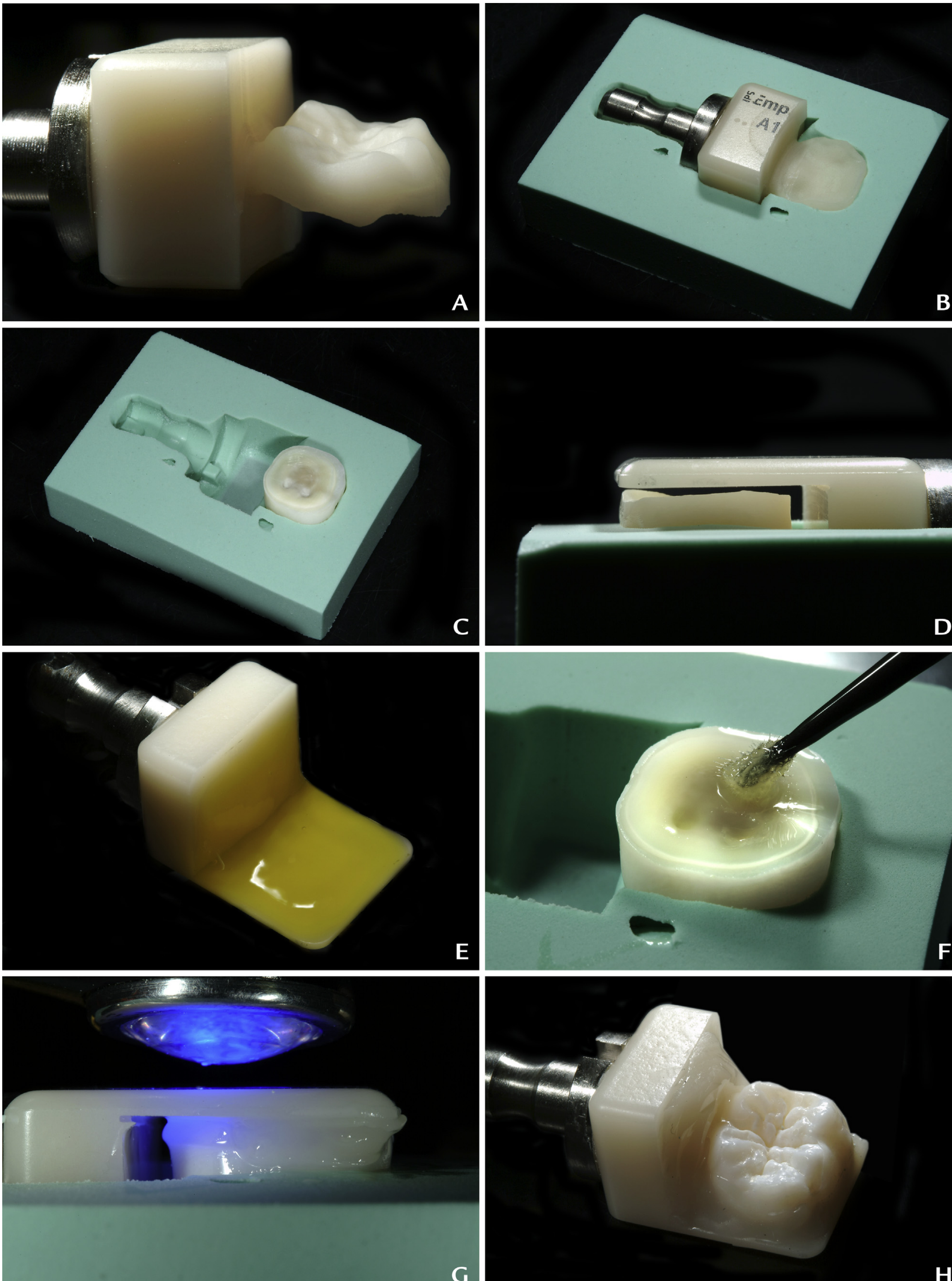


5 A and B, Powdering extracted tooth with titanium dioxide and anatomy acquisition (set in correlation mode). C, Digital impression of preparation (first stone cast). D and E, System designs natural restoration based on anatomy of extracted tooth by means of correlation. Note similarity between virtual restoration (E) and extracted tooth (A).

crown was stabilized with wax and powdered with titanium dioxide (CEREC powder; VITA Zahnfabrik) (Fig. 5A) for optical impression. The modified cast with the extracted tooth was scanned first for correlation Fig. 5B). The stone cast with the tooth preparation was then scanned (Fig. 5C). By using the Design Tools of the Cerec Software (v3.65; Sirona Dental Systems) set in Correlation Mode, the restoration was designed by using as reference the anatomy and positioning of the natural tooth crown. (Fig. 5D, E).

Tooth positioning in the chairside CAD/CAM block

The designed restoration was first milled from a leucite ceramic block (Empress CAD; Ivoclar Vivadent AG). The process was interrupted once the occlusal surface was milled (Fig. 6A). The partially milled block was used to generate another silicone index (Fig. 6B). This silicone guide then served as a reference so that the natural tooth crown could be seated at the same co-ordinates (Fig. 6C) within a second block (Empress CAD; Ivoclar Vivadent AG), customized in an L-shape with a precision sectioning saw (Isomet Low Speed Saw; Buehler). The customized

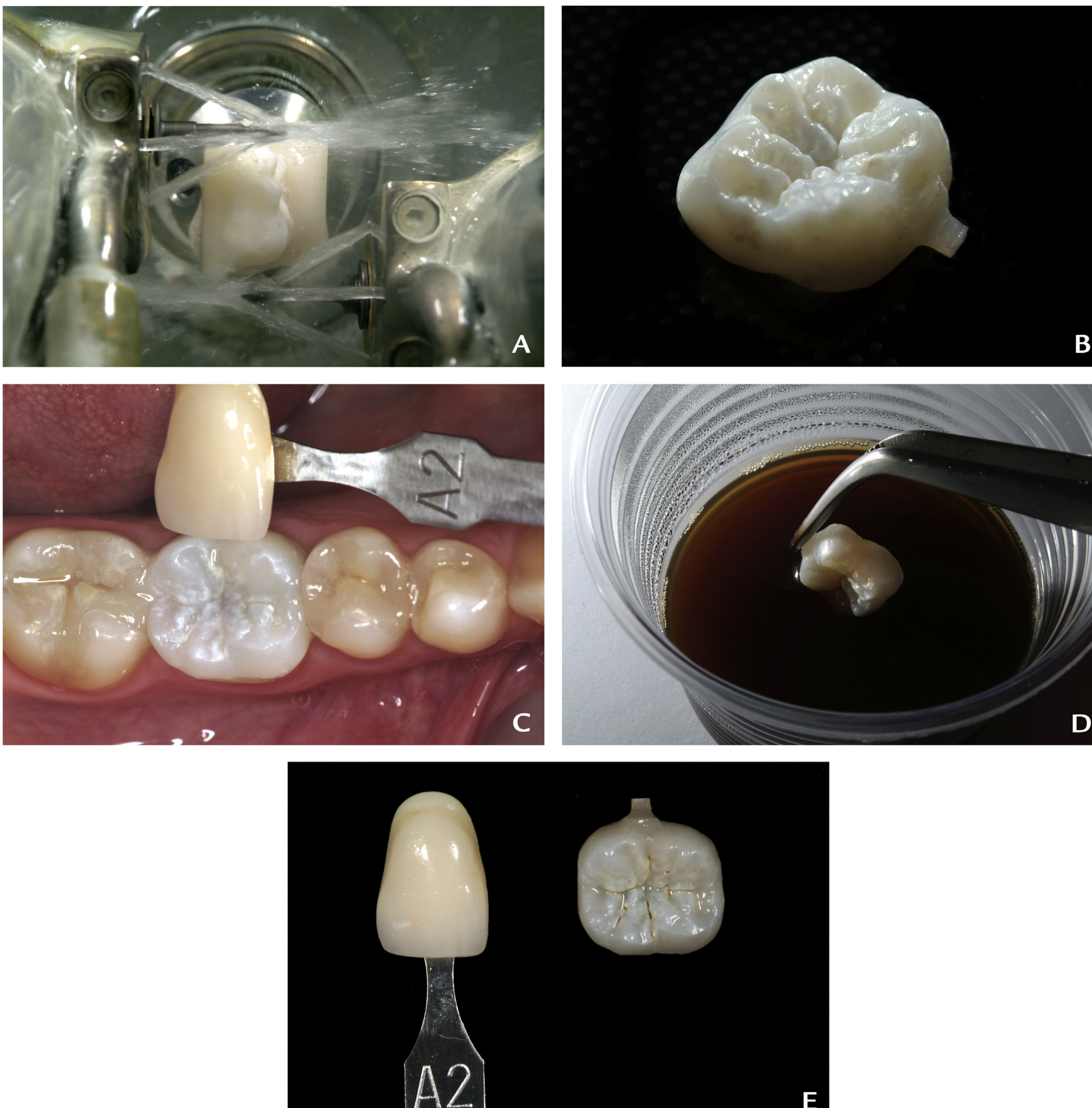


6 A, First, the virtual restoration was milled with a ceramic block. B, Fabrication of silicone index to be used as reference for positioning of donated crown in the block. C, Third molar crown perfectly seated into index. D, Modified block evaluated in index. Observe clearance between block and tooth. E, A 60-second surface conditioning with 9% hydrofluoric acid etching. F and G, The tooth is bonded to block via fourth-generation adhesive system (occlusal surface was not etched) and microhybrid composite resin. H, Donated tooth crown bonded to block.

block was evaluated in the silicone index to ensure that it had seated without contacting the tooth (Fig. 6D). The intaglio of the block was etched with hydrofluoric acid (Porcelain Etch; Ultradent) and silane was applied (Silane; Ultradent) (Fig. 6E). The tooth was bonded to the block with an adhesive system (Optibond FL) and a microhybrid composite resin (inserted in increments) (Filtek Z100; 3M ESPE) (Fig. 6F-H).

Fabrication of the natural restoration and evaluation

By using the recipient block, the restoration was milled in Endo Mode (Fig. 7A) with the sprue at the lingual surface and was inspected to detect milling cracks (Fig. 7B). As previously planned, most of the occlusal surface was not affected by the milling instruments, and its anatomic features were preserved (Fig. 7B). On the definitive die, all the margins were deemed acceptable except for chipping on the buccal margin in the unsupported enamel. At the evaluation appointment, the restoration seated properly with



7 A, Restoration milling. B, Natural restoration after milling. Note fine original morphological details. C, Evaluation of restoration. Shade did not match. D, Staining with espresso coffee. E, Improved shade match after staining.

adequate interproximal contacts and marginal fit. However, the shade did not match (Fig. 7C). The restoration was then stained by immersion in espresso coffee for 6 hours (3 times) at 36°C (heated by Calset; AdDent Inc) (Fig. 7D). A comparison with the reference shade guide (Vita Classical; VITA Zahnfabrik) revealed an acceptable match (Fig. 7E), which was confirmed at the insertion of the restoration. The surface polishing of the natural restoration was performed mechanically with silicon-impregnated rubber polishers (Jiffy; Ultradent) to smooth the residual superficial roughness caused by the milling process.

Adhesive placement

Under isolation with a rubber dam, the tooth preparation was airborne-particle abraded, etched for 30 seconds with 37.5% phosphoric acid (Ultra-Etch; Ultradent), rinsed, and dried. The natural restoration was etched for 30 seconds with 37.5% phosphoric acid (Ultra-Etch), rinsed, air-dried without desiccation for 3 to 5 seconds. This was followed by the application of a primer (Optibond FL, bottle no. 1; Kerr Corp) with a light brushing motion for 15 seconds, air drying for 3 to 5 seconds, and an application of adhesive resin (Optibond FL, bottle no. 2) on enamel and dentin for 20 seconds (no air thinning). The tooth preparation fitting surface was coated with adhesive resin (Optibond FL, Bottle no. 2) and was left unpolymerized until the luting material (Z100/A2; 3M ESPE), preheated to 68°C (Calset; AdDent), was applied to the tooth. The restoration was then inserted, followed by the elimination of excess composite resin (CompoSculp DD1/DD2; Hu-Friedy) and initial light polymerization. Each surface was exposed at 1200 mW/cm^2 (Radii Cal) for 60 seconds (20 seconds per surface, repeated 3 times). The margins were then covered with an air barrier (K-Y Jelly) and light polymerized for an additional 20 seconds. After the rubber dam was removed, a minor occlusal adjustment in the distobuccal cusp was made until the previous contacts were recovered. The margins were finished and polished with silicon-impregnated rubber polishers (Jiffy; Ultradent). A 20-month follow-up revealed no changes in the natural restoration and the conventionally restored neighboring teeth (Fig. 8C). All of them remained vital with normal sensitivity.

DISCUSSION

Several rational motives support the use of natural restorations. First, unlike porcelains and composite resins, enamel and dentin interact with the normal oral environment, constantly exchanging ions in a balanced demineralization and remineralization process.[9] Natural restorations also enable the recovery of the dentinoenamel complex,[10] a unique structural interphase that joins 2 hard tissues with different embryogenic

8 A and B, Occlusal and buccal view 2 weeks after adhesive luting. C, Improved appearance at 20-month follow-up.

origins (ectoderm-mesoderm), matrix composition, and physical properties.[11,12] The excellent biomechanical properties of the dentinoenamel complex can divert and blunt enamel cracks through considerable plastic deformation,[7,11] and its substantial and long-lasting tensile strength - 46.9 MPa[12] allows synergy between enamel and dentin. These natural tissues are designed to withstand a lifetime of mastication. The extreme hardness of enamel (nearly that of carbon steel)[13] protects the underlying softer dentin against wear, which, in turn, provides an elastic foundation for the enamel and prevents its fracture during function.[14] This resistance to damage is also confirmed by the annual wear rate of molar enamel, which is approximately 29 μm.[15] However, this balance could be threatened by the restorative material used in the antagonist tooth. Although ceramic materials are normally wear-resistant, they can cause significantly higher wear on opposing enamel,[16] as seen even with "tooth friendly" systems such as lithium disilicate glass ceramic with an annual wear rate of 88 μm.[17]

Dental enamel is unique in that crystallites are close but not in contact.[18] Besides providing a significant elasticity for a material of such hardness,[18] the intercrystalline spaces are authentic pathways whereby various fluids and low molecular substances may diffuse from the surface to the pulp and vice versa. These dynamics can cause color changes over time. Porcelain and composite resin restorations, although matching the teeth shade at the time of their placement, will look artificial over the years because porcelains are very color stable and modern composite resins still show some color instability. Natural restorations, however, will change over time and mimic the natural dentition. For the present patient, the natural restoration was stained in vitro with espresso coffee (Fig. 7D) to approximate the color of the neighboring teeth because the impacted extracted third molar was stain free (Fig. 3). The rationale is the same when the patient desires brighter teeth. Natural restorations should respond to bleaching, whereas synthetic dental materials will not. Finally, the morphological details of the natural CAD/CAM restoration as observed in Fig. 7B would not have been matched by regular milling of a CAD/CAM material.

The availability of extracted teeth, either third molars or premolars, is directly related to population growth. For instance, results of studies have shown an incidence of impacted teeth in young people (age range, 20-30 years old), which ranged from 55% in Hong Kong, China (most of them third molars),[19] to some 72% in Sweden (at least 1 impacted third molar).[20] If extraction is indicated, then, once the tooth is removed (Fig. 3A), the root and pulp should be removed (Fig. 3B) and the specimen stored in isotonic saline solution at a low temperature (approximately 4°C). To prevent cross-contamination, the specimen can be sterilized by steam autoclaving or, preferably, by gamma irradiation, with no detectable tissue changes.[21,22] For the present patient, steam autoclaving was used because it is more available and its effect on dentin permeability and bond strength is not significant.[23] Biomimetics and hard tissue engineering[24] may represent future alternative sources of enamel-dentin-like biomaterials to be used with CAD/CAM technology.

Unlike traditional restorative materials, natural restorations are susceptible to dental caries. However, all teeth, whether restored or not, require satisfactory oral hygiene. Deep pits and grooves in natural restorations should be preventively sealed. The technique may also be used in implant dentistry. In patients with traumatic root fracture in the anterior region, the extracted natural crown tooth could be adapted to the implant abutment with appropriately designed composite resin abutments.

SUMMARY

This patient treatment represents a proof of concept for a novel therapeutic approach. It brings a new perspective to restorative dental treatment because natural restorations, unlike synthetic dental materials, have the potential to recover the mechanical, esthetic, and biologic properties of damaged teeth. This effort combines biologic resources, such as extracted third molars and premolars (for orthodontic reasons) with dental CAD/CAM systems and adhesive technology. Clinical investigations are now required to evaluate the long-term performance of these restorations.

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Noteworthy Abstracts of the Current Literature

Cyclic fatigue testing of denture teeth for bulk fracture

Kappert PF, Kelly JR.
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Objectives: Clinical experience with implant-supported dentures indicates that fracture and chipping of teeth are becoming an issue. Tooth fracture and chipping rates of approximately 2.5% per year are being experienced at one university. There has been no standardized test developed for bulk fracture or chipping of denture teeth. Such a test would aid in the development of improved teeth and in their evaluation.

Methods: Central incisor teeth were embedded in acrylic and loaded on incisal edges at 90° to their long axes. Teeth tested included ones commercially available and two sets made from improved materials designed to increase toughness. Cyclic loading was done at 5Hz from 20N to 135N, 150N, 175N and 200N. Data was analyzed using lifetime analysis software fit at each of the accelerated loads and then extrapolated to clinical use loads (Alta 7, Reliasoft Corp.) Clinical use loads were derived from extrapolation of probability of failure (Pf) data to 2.5% Pf.

Results: When carefully embedded, teeth could be reproducibly loaded to failure by bulk fracture involving a failure mode similar to that seen clinically. Clinical use loads were calculated to be in the range of 70N. Results from accelerated loading could be fit to similar probability of failure distributions allowing extrapolation to clinical use loads.

Significance: This work was able to develop a clinically valid bulk fracture test for the fatigue failure of incisor denture teeth. It appears that teeth fabricated with improved materials will be expected to perform better clinically. Thus both the null hypotheses were rejected.