The injection resin technique using digital design: An interdisciplinary approach

Douglas A. Terry,[1] Wesam Salha,[2] Memo Castro[3] and Markus B. Blatz[4]

The availability of a variety of new materials and application techniques in adhesive dentistry expands the esthetic possibilities for the clinician and ceramist but also mandates that patient, clinician, and ceramist remain in close communication to maintain an elevated level of performance, knowledge, and artistic ability. Esthetic dentistry, though scientific in nature, remains an art form, and like other art forms, the final product must be appealing to the patient. The proper communication between patient, clinician, and ceramist ensures esthetic dental work that truly reflects artistic ability and creativity while resulting in patient satisfaction. To remain competitive and successful in this technologically advancing profession, esthetic dentists can no longer afford to work on "stone models without faces."[1]

Today, digital technology has transformed almost every aspect of modern life. The information provided by digital technology can be utilized for global positioning systems, visual recognition, imaging to interpret and diagnose disease for various disciplines, digital design and fabrication, and precise placement of various dental prostheses (eg, implant guides, intracoronal and extracoronal restorations). Thus, digital design may provide an additional element for interdisciplinary treatment that further integrates the patient in this triangle of communication.

This article highlights the importance of proper communication between members of the restorative team and demonstrates a digital method to transmit information from the clinical arena to the laboratory environment of the benchtop to develop a natural smile—the innovative inverse injection layering technique.

Preoperative considerations

The diagnostic work-up is the foundation of any successful restorative therapy.[2,3] Preoperative considerations during the diagnostic work-up are essential for the development of optimal functional and esthetic restorations. Thus, during the initial diagnosis and treatment planning stages, consideration should be given to tooth type, location in the arch, size and type of any carious lesions present, treatment of decayed or nondecayed unrestored teeth or restoration replacement, and relationship between occlusal function and preparation/preparationless boundaries. Other factors that should be considered are type of biomaterial (ie, ceramic, composite) and restorative technique (ie, direct, semidirect, or indirect), quantity and quality of remaining tooth structure and soft tissue, gingival architecture, mechanical forces on remaining structures, presence of defects, the parameters for extension of the tooth contours to the esthetic zone,[4,5] and the method for communication and esthetic planning (ie, conventional, digital).

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Digital workflow

Digital technology in dentistry has evolved into a multifunctional tool for evaluation, communication and education, diagnosis, risk assessment, decision making, treatment planning,[6] and prosthetic design and development of restorations while enhancing the predictability and outcome of treatment. In the past, clinicians and technicians have relied on written information and utilized procedures and records that have the potential to be translated and repeated inaccurately throughout the diagnostic and treatment process (ie, facebow, articulation of models, impression process).

Digital smile design tools and software have metamorphosed into a scientific system where specific software programs integrate diagnostic data, treatment planning, design, and digital manufacturing into one network. This digital network allows all members of the interdisciplinary team to interact during the entire process from diagnosis to completion of treatment and maintenance. This process for more complex clinical cases can require interrelated interventions that can be coordinated sequentially throughout the various clinical stages of treatment. Furthermore, this visualization (virtually and/or clinically) of the final anticipated result by the entire team before treatment is initiated can eliminate errors and unnecessary treatment procedures and improve decision making.[7] Virtual visualization can be expanded because the digital workflow allows 3D printing of resin models.[8] This CAD/CAM software integration provides the capability to fabricate guides (ie, surgical and prosthetic), provisionals, and final restorations (ie, ceramic, composite). Furthermore, this concept allows the patient to be involved in the treatment planning and to visualize the anticipated result prior to initiation of treatment procedures.[9]

Patient digitization allows the creation of a virtual patient who can have smile design harmonized with the facial appearance.[10–13] Facially driven and interdisciplinary integrated software systems allow for the translation of 2D photographs into 3D digital models to develop esthetic parameters in three dimensions that can be completely integrated into the face.[7,14,15] Algorithm libraries of natural tooth and smile designs allow for superimposition for dynamic facial and lip analysis using esthetic reference lines. The addition of functional parameters can be incorporated with digital articulators and jaw-tracking devices that allow for designing of teeth and smiles with 3D simulation and real-time dynamic augmented simulations.[14]

In addition, correlation between the hard and soft tissue can be assessed by integrating CBCT imaging with intraoral scans.[10,16,17] The integration of these systems allows for a complete workflow that provides the interdisciplinary team with a method to translate various treatment options into 3D simulation. Furthermore, this digital design technology advances the clinician-patient relationship by facilitating patient awareness and involvement.[18] It is important to remember, however, that while this technology can provide algorithm data that allows the team to develop a smile, this information is generic and requires experienced technicians and clinicians to assimilate and refine the development.

Material selection and technique

Flowable composite materials have been evaluated in numerous studies since their inception.[19–30] Early flowable formulations demonstrated poor clinical performance, with inferior mechanical properties such as flexural strength and wear resistance compared with the conventional hybrid composites.[19,20] However, some of the more recent studies[28–30] indicate that the clinical performance of specifically tested flowable resin composites is similar to or better than that of specifically tested universal resin composites. Recent studies report that specific flowable composites have comparable shrinkage stress to conventional composites.[22,27,31] The wear and mechanical properties of these specific flowable materials suggest an improved clinical performance compared with that of the universal composites. With improved mechanical properties reported,[29] these highly filled formulations are indicated for use in anterior and posterior restorative applications.[32,33]

The injection technique using flowable composite provides a simplified, precise, and predictable method for developing natural esthetic composite restorations while reducing chair time.[33] Although not a panacea to all restorative challenges, this technique provides the patient and clinician with an alternative approach to various clinical situations. This technique is a unique and novel indirect-direct process of predictably translating a traditional diagnostic wax-up, digital wax-up, or the anatomical form of the natural dentition of a preexisting diagnostic model or digital model into composite restorations.

In certain clinical situations, this technique can be performed intraorally without anesthesia. A clear polyvinyl siloxane (PVS) impression material is used to replicate the traditional diagnostic wax-up or duplicated model of the diagnostic wax-up, printed resin model of the digital wax-up, or the anatomical form of the natural dentition of a preexisting traditional diagnostic model or printed resin model. The clear matrix can be placed intraorally over the prepared or unprepared teeth and used

Fig 1 Preoperative clinical views of a 31-year-old woman presenting with diastemas and limited tooth visibility. (top) Portrait. (center row) Intraoral views. (bottom row) Smile.

as a transfer vehicle for the flowable resin composite to be injected and cured.[33] The complete technique is demonstrated later in this article.

Surgical considerations

New parameters of restorative therapy require consideration of esthetic results that might require both periodontal and operative procedures to restore a harmonious integration and an esthetic balance of gingiva and tooth.[34] Thus, periodontal plastic surgery procedures should be part of the clinician's recipe for restoring the dentogingival complex. Traditionally, restorative therapy of teeth with gingival recession and carious or noncarious lesions has been achieved through operative procedures, with little attention given to the overall esthetic picture. In contrast, the perioesthetic approach considers the harmonious integration and interrelationship of the gingiva and tooth complex.[35]

In general, most clinical situations that present with gingival recession also involve a deficiency of keratinized attached gingiva, which requires mucogingival surgery.[35] The periodontal plastic surgery procedures available for the treatment and correction of gingival recession include free gingival autografts, subepithelial connective tissue grafts, coronally positioned flaps, guided tissue regeneration, and acellular matrix grafts.[36–41] These soft tissue grafts are indicated for the restoration of noncarious and carious cervical radicular lesions and for previously placed restorations associated with gingival recession. Recent advances in periodontal plastic surgery procedures have stimulated reassessment of the envelope technique and its modified version, the tunnel technique, for root coverage of single and multiple adjacent gingival recessions.[36,42,43]

The envelope technique originated in 1985 for single gingival recession defects.[36,44] This procedure involved vertical incisions on either side of a tunnel preparation that enabled placement of a subepithelial connective tissue graft within the tunnel to cover the gingival recession. The modified microsurgical technique eliminates the vertical incisions and allows the construction of a tunnel under the gingival tissue by means of a sulcular incision beyond the mucogingival line without raising a flap. This alteration of technique by using newly developed microsurgical instruments allows an undermining split-flap preparation of the facial tissues, ensuring improved blood supply, early wound healing, predictable root coverage, and esthetic postoperative results.[45–53] This modified microsurgical approach simplifies the technique and allows for the treatment of multiple adjacent gingival recession defects in one surgical visit.

Clinical concepts demonstrated

The following clinical procedure illustrates the aforementioned clinical concepts using a methodologic approach for planning and restoring the maxillary anterior dentition.

A 31-year-old woman presented with cosmetic concerns regarding her smile and requested a conservative enhancement. After clinical and radiographic analysis, digital 35mm photographs were taken and reviewed by the restorative clinician, technician, and surgeon (Fig 1). A digital impression was taken of the maxillary and mandibular arches using an intraoral scanner (Trios 3, 3Shape; Fig 2), and a smile design was developed with NemoSmile Design 3D software (Nemotec; Fig 3a). This allows for a facially driven smile frame to be created using reference lines of facial and smile proportions and natural teeth shapes and textures from the digital library (Fig 3b).

After developing the simulated mock-up, a 3D-printed resin model was created using CAD software (Fig 4a), and a clear PVS matrix (Exaclear, GC America) was fabricated to replicate the printed diagnostic wax-up using a nonperforated tray (Fig

4b). This matrix was used to create an intraoral motivational mock-up with bis-acryl composite (Luxatemp Ultra, DMG). This additive mock-up provides the interdisciplinary team with an intraoral translation for evaluation (Fig 5). Upon evaluation of the digital smile frame and the clinical translation, it was determined that multiple esthetic and restorative requirements were necessary for an optimal biologic framework, and the interdisciplinary team determined the best sequence for these procedures. The patient was presented with the interdisciplinary treatment possibilities that included restoring the maxillary anterior teeth and premolars with a minimally invasive preparationless procedure or with less conservative veneer preparations. The restorative materials discussed included injectable resin composites and ceramic (ie, feldspathic, pressable, machinable). For an optimal biologic framework and health, it was determined that connective tissue grafting would be necessary for treatment of the recession-type defects on the maxillary left central and lateral incisors, canine, and premolars. The patient opted for the conservative preparationless composite veneers using the injectable resin technique followed by a connective tissue surgical procedure using the tunneling technique.

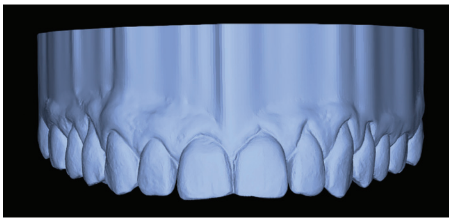

Fig 2 Digital scan of the preoperative maxillary arch.

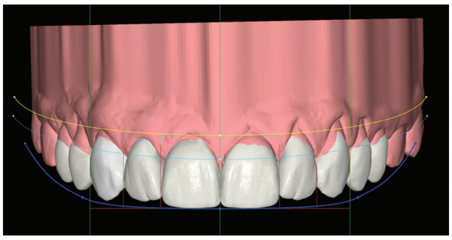

Fig 3 (above) Simulated smile developed with NemoSmile Design 3D software. (left) A facially driven smile frame was created using reference lines of facial and smile proportions and natural teeth shapes and textures from the digital library.

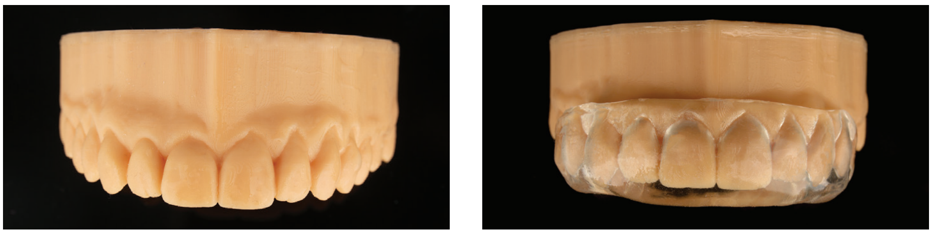

Fig 4 (left) A 3D-printed resin model was created using CAD software. (right) A clear PVS matrix (Exaclear, GC America) was fabricated to replicate the printed diagnostic wax-up using a nonperforated tray.

Fig 5 (left) The clear PVS matrix was used as a transfer vehicle for the bis-acryl composite (Luxatemp Ultra). (center and right) This additive mock-up provides the interdisciplinary team with an intraoral translation for evaluation; this is an excellent method for increasing the patient's understanding of the planned clinical procedure and the anticipated final result.

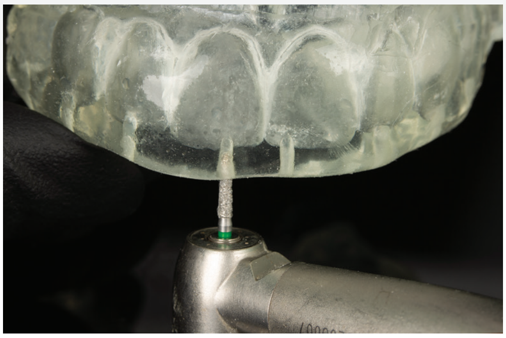

Fig 6 Using the same matrix, a small opening was made above each tooth to be restored using a tapered diamond bur (6847). It is important to clean the internal surfaces with a microbrush to prevent silicone debris from incorporating into the flowable material.

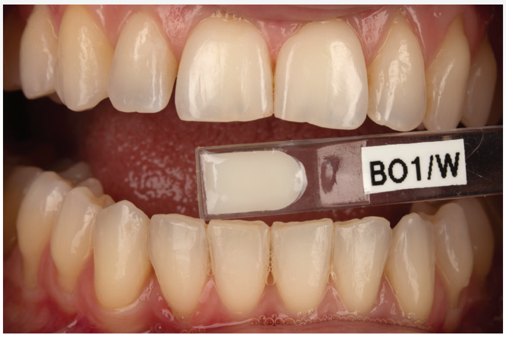

Fig 7 An improved restorative recipe was developed using the clear shade tab (Venus 2-Layer Shade System, Heraeus Kulzer). An opacious B1-shaded flowable (BO1 G-aenial Universal Flo, GC America) was selected for the artificial dentin layer, and a translucent white-shaded flowable (White, Clearfil Majesty ES Flow, Kuraray Noritake) was utilized for the artificial enamel layer.

The clear PVS matrix was used in the development of the final restorations. A small opening was made above each tooth to be restored with a Brasseler 6847 diamond bur (Fig 6). The optimal development of multiple restorations requires completion and finishing of each restoration prior to initiation of the next restoration. The injection process for unprepared teeth involves isolation with Teflon tape and a total etch technique prior to placement of the matrix. The injection of a combination of flowable materials can allow mixing of colors for a polychromatic integration. Figures 7 to 22 provide a detailed description of this adhesive procedure.

Fig 8 Before the adhesive surface preparation, each tooth was separated by applying sterilized Teflon tape on the adjacent teeth. A 37.5% phosphoric acid semigel (Gel Etchant, Kerr) was then applied to the tooth surface for 15 seconds, rinsed for 5 seconds, and gently air dried.

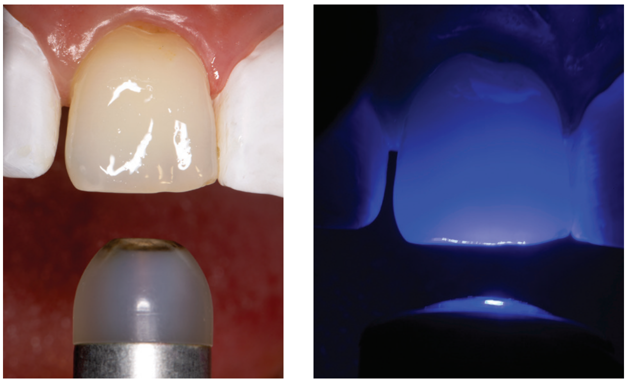

Fig 9 A two-component light-cured universal adhesive (G2-Bond Universal, GC America) was applied to the enamel surface. The primer was applied, allowed to dwell for 10 seconds, and dried before the adhesive was applied, air thinned, and light cured for 10 seconds.

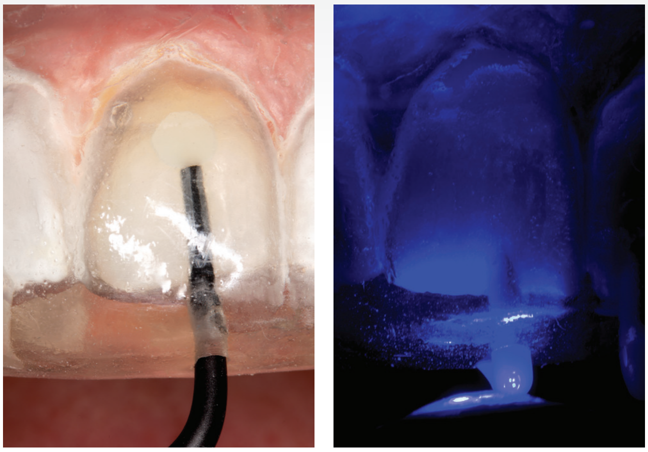

Fig 10 (left) The clear silicone matrix was placed over the arch, and a BO1- shaded flowable resin composite (G-aenial Universal Flo) followed by a translucent white-shaded flowable resin composite (White, Clearfil Majesty ES Flow) were injected through a small opening above each tooth. (right) The resin composite was cured through the clear resin matrix on the incisal, facial, and lingual aspects for 40 seconds each.

Fig 11 Upon removal of the matrix, the excess polymerized composite resin was removed from each restored tooth with a scalpel blade (#12 BD Bard-Parker).

Fig 12 The gingival tissue was retracted with a gingival protector (8A, Hu-Friedy), and the tooth–resin composite interface was finished using a tapered finishing diamond (DET Series, Brasseler).

Fig 13 Finishing strips (Hawe Finishing and Polishing Strips) were used sequentially according to grit and range (from fine to extrafine) to smooth interproximal regions.

Fig 14 After tooth isolation of the maxillary right lateral incisor, a 37.5% phosphoric acid semigel (Gel Etchant) was applied to the enamel surface for 30 seconds, rinsed with water for 5 seconds, and gently air dried. Note the characteristic frosty white, chalky appearance of the enamel after acid etching.

Fig 15 A two-component light-cured universal adhesive (G2-Bond Universal) was applied to the enamel surface. The primer was allowed to dwell for 10 seconds and dried before the adhesive was applied, air thinned, and light cured for 10 seconds.

Fig 16 The clear silicone matrix was placed over the maxillary arch, and the same restorative recipe was injected through a small opening above the maxillary right lateral incisor.

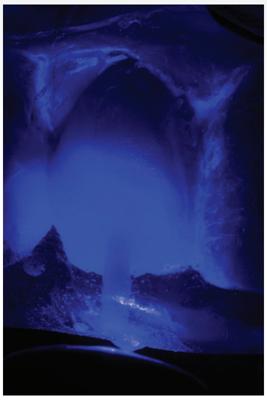

Fig 17 The resin composite mix was cured through the clear resin matrix on the incisal, facial, and lingual aspects for 40 econds each.

Fig 18 Upon removal of the matrix, the incisal composite sprue was removed using a tapered diamond finishing bur (DET Series).

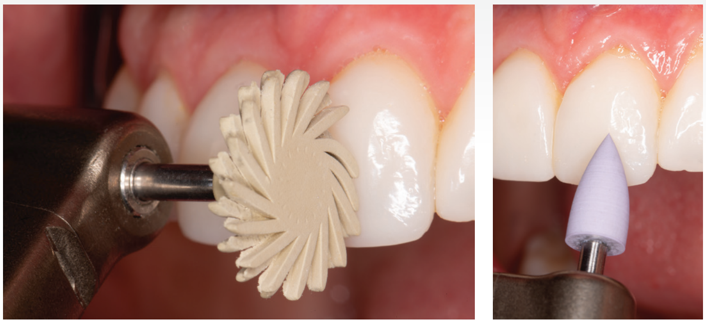

Fig 19 A series of prepolishing and high-shine silicone wheels (Diacomp Feather Lite) and points (ET Illustra) were used to increase the smoothness of the resin composite veneers.

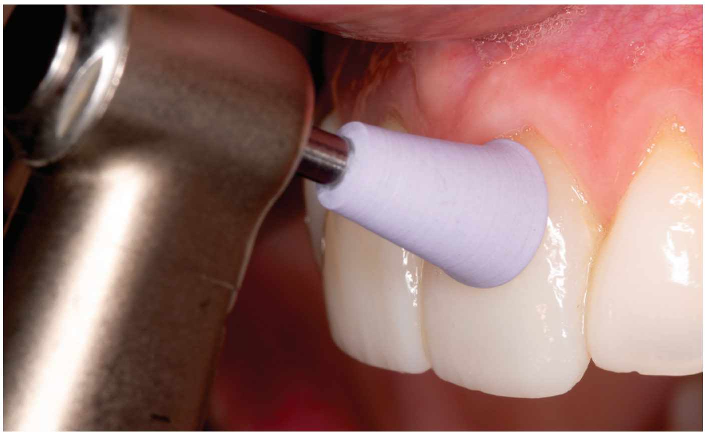

Fig 20 The gingival region was smoothed and polished with a silicone hollow cup (ET Illustra Polishing Cup). The cup provides an additional flexibility at the cervical curvature of the tooth.

Fig 21 A goat-hair wheel and diamond polishing paste were used to further refine the surface luster of the resin composite. High surface reflectivity was accomplished with a dry cotton buff applied with an intermittent staccato motion.

Fig 22 The posttreatment smile reflects a proper tooth proportion and incisal edge position relative to the patient's upper lip.

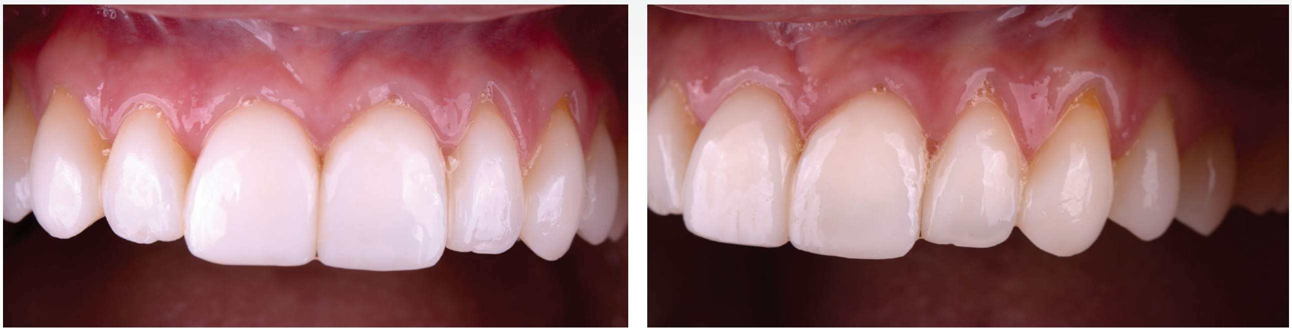

Fig 23 (left) Upon retraction, notice the incongruent dental and gingival esthetics with inadequate harmony and balance. For an optimal biologic framework and health, it was determined that connective tissue grafting would be necessary for treatment of the recession-type defects on the maxillary left central and lateral incisors, canine, and premolars (right).

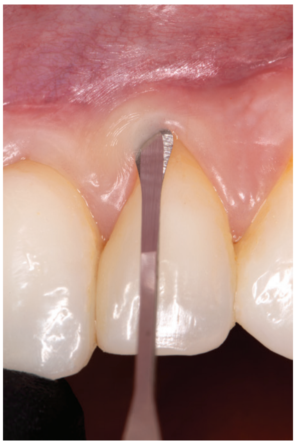

Fig 24 A dovetail-shaped bendable microblade (Keydent Micro Blade Tunnel, American Dental Systems) was used for the initial sulcular incision.

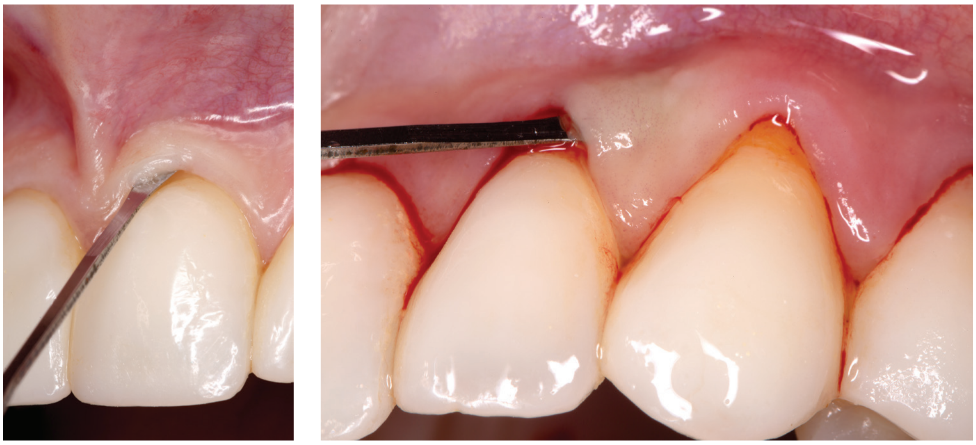

Fig 25 Subsequently, a tunneling knife (Hu-Friedy) was used to undermine a split-thickness tunnel. In circular movements, the knife was guided down beyond the mucogingival line until adequate flap mobility was achieved.

Fig 26 The papillae were fully detached with the periosteum using a periosteal elevator, while the integrity of the region was maintained with the lingual counterpart to avoid the loss of papillary tissue.

Fig 27 Measurement of the recipient site for optimal size and volume of the subepithelial connective tissue graft.

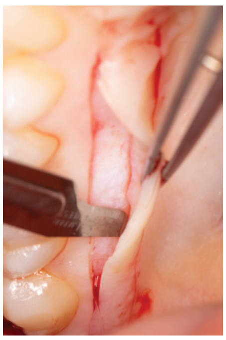

Fig 28 A subepithelial connective tissue graft was harvested from the palate using a parallel incision harvesting technique.

Fig 29 After the connective tissue graft was inspected and trimmed to size, the subepithelial connective tissue graft was measured for dimensional appropriateness in the areas of the defects. It is important that there are no glandular tissues or irregularities in this graft.

Fig 30 The exposed root surfaces of the maxillary left incisors, canine, and premolars were inspected for irregular or rough surfaces, mechanically scaled, and root planed with curettes.

Fig 31 The root surfaces were chemically treated with 24% ethylenediaminetetraacetic acid gel for 2 minutes to remove the smear layer from the dentinal tubules and to improve the coagulum adhesion to the root surface.

Fig 32 After thorough rinsing with water to remove the gel residue and drying, Emdogain (Straumann) was applied to the root surfaces. The surface must be free of blood and/or saliva in order to ensure protein deposition.

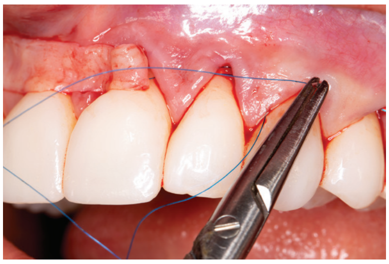

Fig 33 The connective tissue graft was introduced into the tunnel and oriented by placing sutures at each end of the graft.

Fig 34 After the grafts were in place, microsurgical instruments were used to suture and stabilize the grafts with the overlying gingival flap. In the papillary regions, vertical mattress sling monofilament sutures were used (60 polypropylene, Hu-Friedy).

Figs 35 and 36 The 1-year postoperative result reveals optimal root coverage with a harmonious gingival architecture and enhanced esthetics of the smile.

Fig 37 Final result possible with an interdisciplinary translation and integration of a facially driven smile design using the inverse injection layering technique and a modified microsurgical approach.

Conclusion

The evolution in digital technology has revolutionized the way we practice dentistry in our laboratories and operatories today. Future clinical applications of this injectable resin technique may provide clinicians and technicians with conservative alternative approaches to various clinical situations while allowing them to deliver improved and predictable dental treatment to their patients. By working together in proper sequence using a digital workflow, the clinician/ceramist team can develop restorations that are biologically and mechanically sound. Only through continued education, commitment to excellence, and communication (both quan-titative and qualitative) between clinical and laboratory colleagues can restorations be produced that reflect the continuous progress in esthetic and restorative dentistry. The proper transmission of information between clinician, ceramist, and patient allows the modern dental practice to progress beyond the antiquated practice of working on "stone models without faces"1 and to remain competitive and successful in this technologically advancing profession.

References

The full list of references 1-53 is available from:
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