

# The injection resin technique: a novel concept for developing esthetic restorations

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The concept of using an injectable molding technique to manufacture various parts has been around for over a century.<sup>1,2</sup> The first injection-molding machine was developed and patented by John and Isaiah Hyatt in 1872 for producing celluloid plastic parts.<sup>1,3</sup> The next half-century saw the adoption of this process for the manufacture of items such as collar stays, buttons, and hair combs.<sup>3</sup> Over the course of its development, injection molding has been used by designers and engineers for myriad applications with a host of materials, including glass, metals, confections, elastomers, and thermoplastic and thermosetting polymers, to fabricate a variety of complex shapes with high dimensional precision. It has been used in a variety of manufacturing industries, including aerospace, automotive, jewelry, avionics, biomedical, orthodontics, pharmaceutical, scientific, electronic, and computer technology. In dentistry, this technique has been used in the laboratory fabrication of prosthetic appliances such as complete dentures, partial dentures, laboratory-processed acrylic and composite provisional restorations, and ceramic restorations.<sup>1,2</sup>

Continued developments in adhesive technologies, the design of resin composite formulations, and innovative application techniques have revolutionized the delivery of minimally invasive direct resin composite restorations while improving the practice of dentistry. In some cases, complicated layering techniques are required that are dependent on the clinician's skill and artistic ability. The injectable resin composite technique provides a simplified, precise, and predictable method for developing natural esthetic composite restorations while reducing chair time. 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 diagnostic wax-up or the anatomical form of the natural dentition of a preexisting diagnostic model into composite restorations. There are myriad applications for this technique using a highly filled flowable (injectable) resin



*Figure 1: Preoperative facial view of the maxillary anterior segment of a 63-year-old who presented with incisal wear and fracture on the maxillary anterior teeth. The patient requested a conservative esthetic enhancement without orthodontic treatment. Clinical evaluation revealed multiple diastemas and cervical corrosion on the central incisors from lemon sucking.*



*Figure 2: Development of a diagnostic wax-up that established new parameters (ie, esthetic, functional) for the final restorations.*

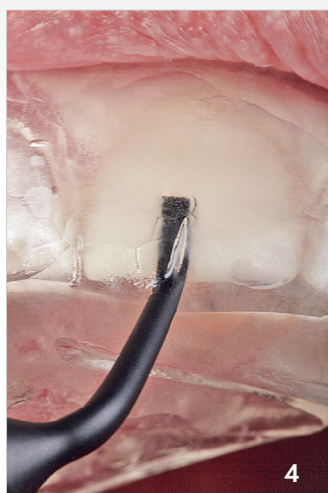


*Figure 3: A clear polyvinyl siloxane matrix was fabricated to replicate the diagnostic wax-up.*

composite, including emergency repair of fractured teeth and restorations; modification and repair of prototypes and provisional restorations, composite restorations (Class III, IV, and V; veneers), and pediatric composite crowns; resurfacing of occlusal wear on posterior composite restorations; establishment of incisal edge length prior to esthetic crown lengthening; orthodontic space management; development of composite prototypes for copy milling; fabrication of an implant-supported composite provisional restoration; and repair of fractured or missing denture teeth.<sup>1,4-6</sup> In addition, this technique can be used to establish vertical dimension and to alter occlusal schemes (anterior guidance and posterior

disocclusion) prior to definitive restoration.<sup>1-3</sup> Furthermore, this noninvasive technique is an integral tool for enhancing communication between the patient and the restorative team during treatment planning.<sup>1,2,4</sup>

Developing transitional resin composite restorations using the injectable technique is an excellent method for increasing the patient's understanding of the planned clinical procedure and anticipated final result.<sup>7</sup> Transitional composite prototypes establish parameters for occlusal function,<sup>8</sup> tooth position and alignment,<sup>9</sup> restoration shape and physiologic contour,<sup>10</sup> restorative material color and texture, lip profile, phonetics, incisal edge position, and gingival orientation. This process also eliminates confusion and misunderstanding between the patient and the restorative team during the treatment-planning stage.<sup>7</sup> It can reduce the potential for patient dissatisfaction and litigation because the process is reversible, can be performed without preparation, and allows the patient to accept the visual and functional result before the definitive restorations are fabricated. In addition, this simple procedure helps to regulate the dimensions of the preparation design, ensures uniform spatial parameters for the restorative material, and increases the potential for a more conservative preparation design.<sup>4</sup> This injectable technique can also be used in the development and management of soft tissue profiles and in the design of the definitive restoration.<sup>11-14</sup> The clinician and technician can use this technique as a guide for developing a preapproved functional and esthetic definitive restoration.<sup>15</sup> In some cases,



**Figure 4:** Upon completion of the adhesive protocol, the clear silicone matrix was placed over the arch and an opacous shade A2 flowable resin composite (G-aenial Universal Flo, GC America) was initially injected through a small opening above each tooth, followed by mixing with a shade B1 flowable resin composite (inverse injection layering technique). The resin composite was cured through the clear resin matrix for 40 seconds.

**Figure 5:** Completed composite veneer restorations with optimal anatomical form. The inverse injection layering technique allowed the establishment of harmonious proportions of the transitional restorations and the surrounding biologic framework.

these transitional restorations can be worn for months or even years during long-term interdisciplinary rehabilitation.<sup>2,4</sup> However, this material technique should not be utilized as a final material for full-mouth rehabilitation.

In certain clinical situations, this technique can be performed intraorally without anesthesia. A clear polyvinyl siloxane (PVS) impression material is used to replicate the diagnostic wax-up or the anatomical form of the natural dentition of a preexisting diagnostic model. The clear matrix can be placed intraorally over the prepared or unprepared teeth and used as a transfer vehicle for the flowable resin composite to be injected and cured.<sup>1,2</sup> (Figs 1 to 5)

### Empirical Data

Flowable composite materials have been evaluated in numerous studies<sup>16-40</sup> since their inception. Although early flowable formulations demonstrated poor clinical performance,<sup>1,16</sup> some of the more recent studies<sup>34,37,38</sup> indicate that the clinical performance of specifically tested next-generation flowable (injectable) resin composites have similar or improved performance to specifically tested universal resin composites. Attar and others<sup>23</sup> showed that different flowable composites possessed a wide range of

mechanical and physical properties. Earlier studies by Gallo et al.<sup>24</sup> on specific flowable resin composites suggested that these materials should be limited to small-and moderate-sized restorations having isthmus widths of one-quarter or less of the intercusp distance.<sup>31</sup> However, Torres et al.<sup>38</sup> reported that, after 2 years of clinical service, no significant differences were found between Class II restorations restored with GrandioSO (VOCO) conventional nanocomposites and those restored with GrandioSO Heavy Flow (VOCO) flowable hybrid nanocomposites. A study by Karaman et al.<sup>34</sup> showed similar clinical performance over 24 months in restorations of noncarious cervical lesions restored with the conventional nanocomposites (Grandio, VOCO) and those restored with the flowable material (Grandio Flow, VOCO). A more recent study by Sumino et al.<sup>37</sup> indicated that the flowable (injectable) materials G-aenial Universal Flo (GC America), G-aenial Flo (GC America) and Clearfil Majesty Flo (Kuraray Noritake) had significantly greater flexural strength and a higher elastic modulus than the corresponding conventional nanocomposite materials, Kalore (GC America) and Clearfil Majesty Esthetic (Kuraray Noritake). The wear and mechanical properties of these specific universal injectable resin composites suggested an

improved clinical performance compared with that of the universal composites. Several *in vitro* studies conducted at GC Research and Development comparing specific flowable material properties of several conventional composites found results similar to those of Sumino et al. Of the next-generation flowable systems studied, G-aenial Universal Flo (GC America) and Clearfil Majesty ES Flo (Kuraray Noritake) showed superior gloss retention and similar wear resistance to the conventional nanocomposites tested, which included Filtek Supreme Ultra (3M ESPE), Herculite Ultra (Kerr), Clearfil Majesty ES-2 (Kuraray Noritake) and G-aenial Sculpt (GC America).

According to these studies, these recently developed specific nanohybrid flowable resin (or universal injectable) composite systems (ie, Clearfil Majesty ES Flow and G-aenial Universal Flo) may possess properties that meet the aforementioned mechanical, physical, and optical requisites. These properties and the clinical behavior of the biomaterial formulations are contingent upon their structure. New resin filler technology allows higher filler loading because of the surface treatment of the particles and increase in the distribution of particle sizes. The unique resin filler matrix allows the particles to be situated very closely to each other, and this reduced interparticle spacing and homogeneous dispersion of the particles in the resin matrix increases the reinforcement and protects the matrix.<sup>41-43</sup> In addition, the proprietary chemical treatment of the filler particles allows proper wettability of the filler surface by the monomer and thus an improved dispersion and a stable and stronger bond between the filler and resin.

Studies<sup>43-47</sup> clearly indicate the importance that filler content and coupling agents represent in determining characteristics such as strength and wear resistance. Recent studies<sup>19,31,48</sup> report that specific flowable (universal injectable) composites have comparable shrinkage stress to conventional composites. According to the manufacturers, these next-generation flowable (universal injectable) composite formulations are purported to offer mechanical, physical and esthetic properties similar to or better than those of many universal composites.<sup>49</sup> The clinical attributes of universal flowable composites include easier insertion and manipulation, improved adaptation to the internal cavity wall<sup>50</sup>, increased wear resistance, greater elasticity, color stability, enhanced polishability and retention of polish, and radiopacity similar to enamel. Furthermore, the clinical indications for these next-generation flowable resin composites are increasing as the properties of the materials and the bond strength of adhesives to dental

tissues improve. With improved mechanical properties reported,<sup>37</sup> these highly filled formulations are indicated for use in anterior and posterior restorative applications.<sup>5</sup> The clinical applications of these specific next-generation universal injectable composites include sealants and preventative resin restorations; emergency repair of fractured teeth and restorations; fabrication, modification and repair of composite prototypes and provisional restorations<sup>4</sup>; anterior and posterior composite restorations; composite tooth splinting;<sup>51</sup> and intraoral repair of fractured ceramic and composite restorations.<sup>51</sup> In addition, these composites can be used to repair denture teeth,<sup>51</sup> establish vertical dimension, alter occlusal schemes before definitive restoration,<sup>5</sup> manage spatial parameters during orthodontic treatment, eliminate cervical sensitivity,<sup>51</sup> resurface occlusal wear on posterior composite restorations,<sup>51</sup> establish incisal edge length before esthetic crown lengthening,<sup>51</sup> develop composite prototypes for copy milling,<sup>5</sup> and place pediatric composite crowns.<sup>6</sup>

Since the past provides information to improve the future, the lack of evidence-based research and clinical trial data on flowable biomaterials requires clinicians to evaluate the individual mechanical properties of these materials to determine whether their properties are equal or superior to those of existing materials. As the clinical performance of these next-generation flowable materials has improved over time, the research data have concurred. Although no direct correlation has been found between a material's mechanical and physical properties and its clinical performance, such a correlation might suggest the potential success of a restorative biomaterial for a specific clinical situation.<sup>16</sup> However, clinical longevity for restorations developed with these biomaterials remains to be determined through clinical studies for each specific clinical application.

Future clinical applications of this novel technique with these next-generation flowable materials may provide clinicians and technicians with alternative approaches to various clinical situations while allowing them to deliver improved and predictable dental treatment to their patients. Although the long-term benefits of this novel injectable composite technique remain to be determined, the clinical results achieved by the first author in the last 14 years and the aforementioned supporting empirical data for these next-generation nanocomposite flowables are extremely promising. Cases 1 to 5 illustrate some of the many clinical applications of the injectable resin composite technique using various highly filled formulations of flowable composite materials (Figs 6-49).



## Case 1 - Developing the Functional Composite Prototype (Figures 06-14)



Figure 6: Preoperative facial view of the maxillary anterior segment of a patient who presented with incisal wear and fracture on the maxillary anterior teeth.



Figure 7: Development of a diagnostic wax-up that establishes new parameters (ie, esthetic, functional) for the final restorations.



Figure 8: Clear PVS matrix (Memosil 2, Heraeus Kulzer) was fabricated to replicate the diagnostic wax-up.

Figure 9: Flowable composite resin material (Filtek Supreme Ultra, 3M ESPE) was injected through a portal in the matrix, allowing the material to completely cover the conditioned unprepared enamel surface.



Figures 10, 11, 12: Functional resin composite prototype was completed and inspected in centric relation and protrusive and lateral excursions.



Figure 13: Functional resin composite prototype established the optimal esthetic parameters for a natural smile.



Figure 14: Facial view at 6-year follow-up.



**Case 2 - Orthodontic Space Management (Figures 15 - 22)**

Figure 15, 16: Preoperative facial view prior to interdisciplinary orthodontic treatment of 11-years-old, who presented with a tooth size discrepancy on the maxillary anterior segment and caries present on the proximal surfaces of the maxillary lateral incisors. During orthodontic and restorative evaluation, the patient and parent were explained the significance of achieving specific space requirements so the orthodontist could position the teeth in the most optimal restorative position that will require a minimal preparation design. It is important that the appropriate and anticipated result be decided prior to the placement of the orthodontic appliances.



Figure 17: After review with the patient, parent, and orthodontist, a diagnostic wax-up was designed to modify the size and shape of the maxillary lateral incisors. This wax-up allowed the restorative team to evaluate form and function.

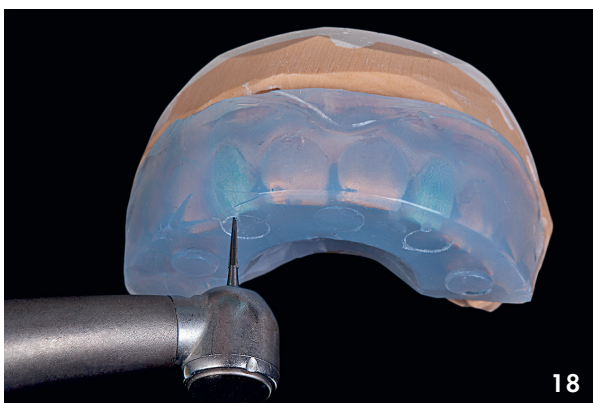


Figure 18: A clear PVS matrix was fabricated to replicate the diagnostic wax-up. A small opening was made above each tooth that was to be restored using a needle-shaped finishing bur (ET Series bur, Brasseler USA).

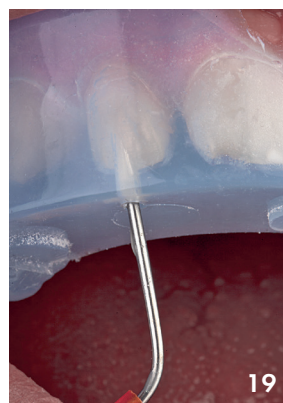


Figure 19: After the adhesive protocol is completed, the clear silicone matrix was placed over the arch and shade A-1 flowable resin composite (G-aenial Universal Flo, GC America) was injected through a small opening above each tooth. The resin composite was cured through the clear resin matrix on the incisal, facial and lingual aspect for 40 seconds.

**Case 2 - Orthodontic Space Management (Figures 15 - 22) contd.**



Figure 20, 21: Completed resin composite restorations with optimal anatomical form for the 11-year-old patient. The composite injection technique allowed the establishment of harmonious proportions of the transitional restorations and the surrounding biologic framework. Use of the technique for tooth size discrepancies in the preorthodontic treatment-planning stages simplifies technique the understanding and management of this restorative dilemma for the patient and the interdisciplinary team.



Figure 22: Seven-year follow-up of composite transitional restorations after orthodontic treatment. Note the minimal wear.



### Case 3 - Restoring Posterior Primary Tooth with an Injectable Composite Crown (Figures 23-30)



Figure 23, 24: Preoperative occlusal view and radiograph of the primary mandibular second molar of 78-year-old patient with an existing Class II composite restoration and caries on the distoproximal surface of the tooth. Upon initial consultation with periodontist, the recommended treatment included an implant and bone graft, and the patient needed to temporarily discontinue his warfarin regimen. After subsequent medical history and radiographic review and discussion with the patient and periodontist, it was decided that the injectable resin technique would be a viable alternative treatment for this clinical situation, and the patient agreed.

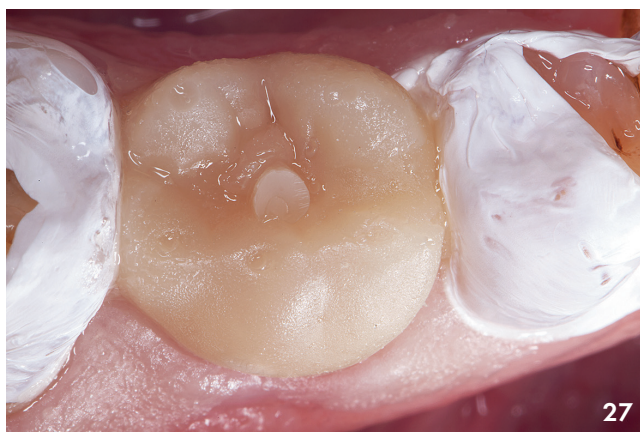


Figure 25: A clear PVS (ExaClear, GC America) matrix was fabricated to replicate the preoperative diagnostic model, and an opening was made above the primary mandibular second molar with a tapered diamond bur (6847, Brasseler USA).



Figure 26: Adhesive preparation design included removal of preexisting defective composite restoration and carious dentin and enamel; occlusal reduction of 1.5 to 2 mm; a circumferential chamfer 0.3 mm in depth; vertical proximal, buccal and lingual walls with slight convergence toward the occlusal; all internal and external line angles rounded and cavity walls smoothed; and unsupported enamel walls removed to improve the path of material flow.

Figure 27: After the injection process was completed, the matrix was removed and the excess polymerized resin composite was scoured on the facial, lingual and interproximal regions with a scalpel blade (#12 BD Bard-Parker, BD Medical) and removed with a scaler. The occlusal composite sprue was removed using an 8-fluted pyramidal-shaped finishing bur (H274, Brasseler USA).





**Case 3 - Restoring Posterior Primary Tooth with an Injectable Composite Crown (Figures 23-30) contd.**



Figure 28, 29: Completed primary composite crown. The radiograph reveals ideal proximal contours and contacts with an optimal marginal integrity at the restorative interface.



Figure 30: Clinical follow-up at 18 months. The patient was pleased with the results achieved using this minimally invasive injection technique.

#### Case 4 - The Single Anterior Implant- Immediate Placement Technique (Figures 31-36)



Figure 31: Facial view of the maxillary anterior segment and surrounding tissue of a 28-year-old patient.



Figure 32: Diagnostic wax-up was used for presurgical planning of the interrelationship between the definitive restoration and the oral structures and to fabricate the provisional restoration.



Figure 33: Prefabricated zirconia abutment was placed and secured in position, and the access opening was sealed. Sterilized Teflon tape was applied on the adjacent teeth to separate the abutment, and glycerin was applied to the entire surface of the abutment.



Figure 34: A clear silicone matrix was placed over the anterior segment of the maxillary arch, and an opacious shade A3 flowable resin composite (G-aenial Universal Flo, GC America) was injected through the small opening above the abutment, followed by a translucent A3 flowable resin composite. The resin composite mix was cured through the clear matrix on the occlusal, buccal, and lingual aspects for 40 seconds each using an LED curing light.



Figure 35: Biointegration of the provisional composite crown with the peri-implant architecture after 3 months.



Figure 36: Final results after placement of the implant-supported restoration, revealing optimal hard and soft tissue integration.



**Case 5 - Restoring Anatomical Form and Color (Figures 37-49)**

Figure 37: Preoperative facial view of the maxillary anterior segment of a 47-year-old patient who presented with cosmetic concerns regarding his smile. The patient requested a conservative esthetic enhancement without orthodontic treatment.

Figure 38: A clear polyvinyl siloxane matrix was fabricated to replicate the diagnostic wax-up using a non-perforated tray. A small opening was made above the lateral incisor that was to be restored using a tapered diamond bur (6847, Brasseler USA). It is important to clean the internal surfaces with a microbrush to prevent silicone debris incorporating into the flowable material.

Figure 39: After intraenamel preparation and adhesive protocol, the clear silicone matrix was placed over the maxillary arch and an opacious shade A1 flowable resin composite (G-aenial Universal Flo, GC America) was initially injected through a small opening above the preparation, followed by mixing with a shade B1 flowable resin composite (injection layering technique). The resin composite was cured through the clear resin matrix on the incisal, facial, and lingual aspects for 40 seconds, respectively.

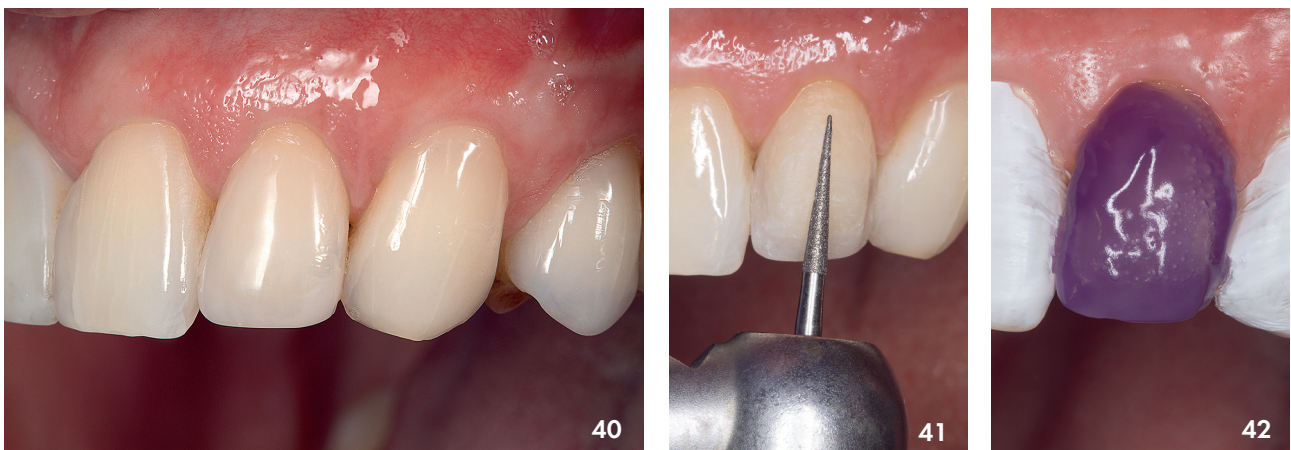


Figure 40: The completed resin composite veneer with optimal anatomical form.

Figure 41: At the following appointment, the final restoration was completed by using a composite cutback technique. The artificial enamel layer of the composite veneer was removed and a corrugated chamfer 0.3 mm in depth was placed around the entire margin with a long, tapered diamond.

Figure 42: The entire composite surface was etched with 37.5% phosphoric acid (Gel Etchant) for 15 seconds and rinsed for 5 seconds. Etching of the existing composite cleans the surface.



Figure 43: Silane was applied to the composite surface and lightly air dried. An adhesive was applied to the composite surface and allowed to dwell for 10 seconds, air dried for 5 seconds, and light cured for 10 seconds using an LED curing light.



Figure 44-46: Internal characterization was performed according to the appearance of the contralateral tooth and a shade-mapping diagram. A diluted gray tint (Renamel Creative Color, Cosmedent) was placed along the incisal edge and proximal regions with a size 08 endodontic file and light cured for 40 seconds. A diluted white tint (Renamel Creative Color, Cosmedent) was placed along the incisal edge, proximal regions, and in the body with a size 08 endodontic file, and light cured for 40 seconds to stabilize the color and prevent mixing of the tints. A diluted yellow tint (Renamel Creative Color, Cosmedent) was placed at the cervical and in the incisal third with a size 08 endodontic file, and light cured for 40 seconds. It is the color variation from these modifiers and tints that creates the three-dimensional effect and the nuances within the incisal edge.



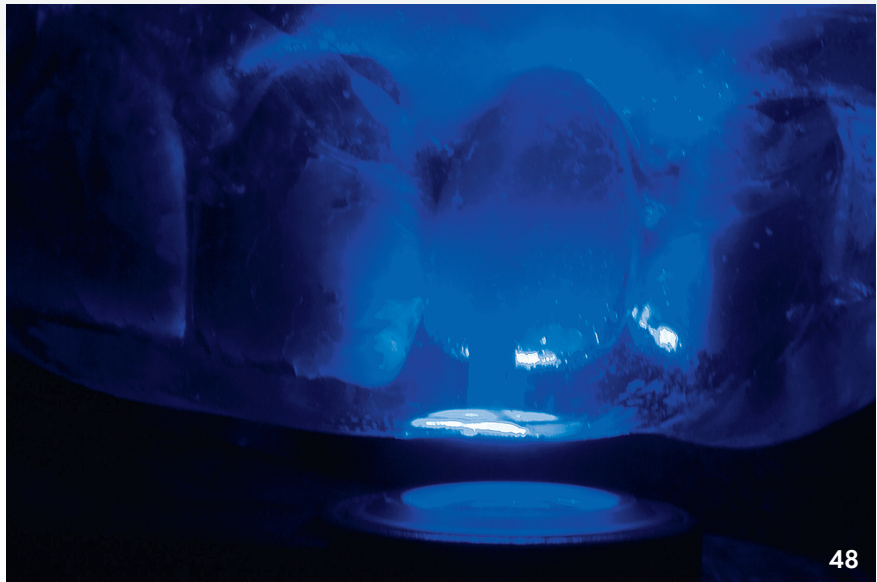


Figure 47, 48: A new clear silicone matrix fabricated after the connective tissue surgical procedure was placed over the anterior segment of the maxillary arch and a clear translucent flowable resin composite (Amaris Flow HT, VOCO) was injected through a small opening over the artificial dentin layer. The resin composite was cured through the clear resin matrix on the facial and incisal aspect for 40 seconds each.



Figure 49: Three-year follow-up of the composite resin veneer with an ideal anatomical form and color. Note the nuances in the incisal edge created by using the composite cutback technique.

### Conclusion

In the past, with the use of conventional resin composites and the direct bonding technique, the clinician had to combine the hybrid and the microfill because of the inequities of the materials of the time. However, polychromatism was

achieved from this early concept of anatomic stratification with successive layers of different restorative composites of varying refractive indexes, shades and opacities.<sup>52-57</sup> This development of the polychromatic restoration from the inequities of the different composite resin systems (hybrid

and microfill) stimulated scientists, researchers, clinicians and manufacturers to explore and develop restorative materials that are not only applied in relationship to the natural tissue anatomy, but that have similar physical, mechanical, and optical properties to that of tooth structure.<sup>53,58</sup> Today, these highly filled formulations of injectable composite materials can be used to improve adaption and color integration as a result of internal adaptation and the mixing of colors. As we compare the old and the new in history, only the material of time with the proper technique can provide optimal natural esthetic restorations. Knowledge of a concept of the past and a desire to create are limited by the materials clinicians have available to them for restorative procedures. Advancements in resin composite technology continue to improve the practice of dentistry. Continuing technological breakthroughs allow the clinician not only to comprehend the building blocks of the ideal composite restoration but also to implement and maximize the potential of new materials to attain more predictable and esthetic results.

Although new ideas and concepts continually flood the marketplace, one should not discount the power a new biomaterial may have on planning, design or procedure. These developments promise to simplify the clinical applications for esthetic and restorative techniques and ultimately improve the level of health care provided for the contemporary dental patient. Only the passage of time can determine the long-term benefits of these new flowable resin formulations.<sup>1</sup> The clinical applications provided in this article demonstrate the potential of these flowable nanoparticle composite formulations to expand treatment options for a wider range of clinical situations.

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