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An Improved Direct Injection Technique With Flowable Composites. A Digital Workflow Case Report

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Clinical Relevance

Anterior dental restorations often involve difficult and time-consuming procedures. An improved direct injection technique using a digital workflow in the restoration of anterior teeth can be an alternative to save clinical time and yield a predictable and esthetic outcome.

SUMMARY

This article presents a clinical technique based on a case report for restoring the contours and shape of the upper teeth involved in the smile display of a young patient. After planning the treatment for the patient using digital tools (Digital pictures, Digital Smile Design, digital waxup, three-dimensional [3D] printed models, mockup), the upper teeth were restored using an improved injection technique. This improved technique involves the direct injection of flowable composite resin using clear polyvinyl siloxane molds made from 3D-printed models of the patient. The details and benefits of this new technique are described in the article.

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INTRODUCTION

State-of-the-art oral rehabilitation techniques aim for both esthetic and functional outcomes. Contemporary dental materials, clinical techniques such as Digital Smile Design (DSD), mockups, and integrated treatment planning enables the clinician to both virtually and/or clinically view and assess the treatment plan beforehand. Nevertheless, the process of making direct or indirect final restorations is still very tedious and time-consuming, demanding highly specific skills and attention to meticulous details from the clinician. The traditional process of placing direct anterior restorations is clinically demanding to complete, often involving a tedious layering process, which limits the ideal indication of them to only a few restorations at a time.[1] Furthermore, traditional direct restorations are not made using preestablished tooth shapes or contours, making the procedure operator dependent and less predictable. When multiple anterior restorations or a smile change is required, indirect restorations are preferred by clinicians. However, fabrication of indirect restorations is often externalized to a dental technician, which increases delivery time and costs.

A clinician's preference for composite resin selection should be based on reported survivability, the composite resins' esthetic ability, and adaptability/handling. Since the 1990s, composite resins have improved vastly both in optical and mechanical properties, making them more versatile within their limitations.[1] Moreover, new techniques for applying composite resins have been introduced, enhancing their application. Mockups using bis-acryl or injecting flowable composite via transparent matrices have become more popular for provisionalizing anterior teeth.[2-5]

The early 1990s hallmarked the use of composite resins in dentistry, especially with the advancements in adhesive bonding. The initial composite resins were usually filled with large quartz particles, resulting in restorations that were rough and difficult to polish. With polishability being a major esthetic concern, newer composite resins emerged in response to the needs expressed by dental practitioners. Most contemporary composite resins fall into one of the following categories: hybrid, nano-filled, microfill, packable, and flowable composite.[6] Composite resins obtain their physical properties/handling characteristics from filler particles' relative amount, size, and shape. As a general rule, the more filler content and the smaller the filler particle, the better. Increasing filler load improves the resistance to functional wear and enhances physical properties. Also, composite resins with smaller particles are inherently more polishable, retain their polish for longer periods of time, and are more resistant to wear. Most composite resins have a putty-like consistency, which is desirable for clinical situations when packing composite resin into cavities. However, there was a need to have a composite resin with lower viscosity for better proximity with the cavity walls. For this reason, a new class of "flowable composite resins" was introduced in late 1996.[7]

Flowable resin-based composites are conventional composites with filler loading reduced to 37%-53% (volume) compared with 50%-70% (volume) for conventional minifilled hybrid composite resin. This altered filler loading modifies the viscosity of these materials. Most manufacturers package flowable composites in small syringes that allow for easy dispensing with very-small-gauge needles. This makes them ideal for use in small preparations or in situations where it would be difficult to fill otherwise. However, the main drawback of flowable composite resins is reduced physical properties and increased polymerization shrinkage compared with conventional composite resin attributed to its low filler content.[8]

A number of studies were conducted to improve the mechanical properties of flowable composite resins by adding nano-filled particles. This addition improved mechanical properties without affecting handling characteristics of the composite.[9] However, laboratory abrasion wear tests have produced contradictory results concerning wear resistance,[10-12] but the clinical wear resistance of flowable composites has yet to be determined. Other studies have concluded that flowable composite resins may have good polishability but less wear resistance, more potential to be eroded under acidic conditions, and more surface roughness over time due to reduced filler loading.[13-15] Therefore, based on the previous studies and due to the decreased filler content, reduced physical properties, and poor wear resistance, it is recommended that flowable composites should only be used in low stress-bearing areas, as liners or in small cavities.

Recently, newer and improved versions of flowable composites have been introduced that may extend their application to be considered in restoring minimally invasive preparations and tooth discolorations.[16-18] No difference in clinical outcomes was concluded when a nanohybrid composite resin was compared with a flowable composite in restoring noncarious cervical lesions during a 24-month observation period.[14] Moreover, when analyzing surface roughness and wear of recent flowable composites compared with conventional nanohybrid composites after toothbrush simulation, similar results were found between the two types of composite resins.[15,19]

Based on these current findings, recent flowable composites imply promising outcomes for esthetic applications. However, due to their lower filler content, they are still considered to be contraindicated for stress-bearing areas. Therefore, it is ultimately the clinicians' responsibility to consider the application of flowable composites in cases where successful and durable outcomes can be anticipated. Direct restorations require attention to meticulous detail and skills to properly restore a tooth to its proper shape, function, and esthetics. Handling of conventional composites in restoring embrasures and contours can be challenging, and some composite resins' adaptability and sculptability can be complicated. As a result, certain clinical techniques have been introduced to facilitate the application of direct restorative material saving time with optimal esthetic and functional results.

The injection technique using flowable composite[20,21] is an example of a technique that suggests a quick and simple way to restore contours and shape of worn-out/defective teeth. After taking an impression and pouring it with stone, a waxup is made on the model replicating the desired outcome. An impression of this waxup is taken with a clear polyvinyl siloxane (PVS) material. Small access holes are made facially to the incisal edges of the teeth to be restored. Etching and bonding is done for every other tooth while isolating the other teeth with polytetrafluoroethylene tape. After inserting the PVS mold and checking its proper fit, flowable composite is injected through the access holes for the teeth that have been prepared and photopolymerized. This process is repeated for the other teeth that were isolated, and after removing the mold, the final restorations are finished and polished. Because the PVS mold replicates the complete waxup, the space between the mold and the natural tooth is inevitable, and injecting the flowable composite into one tooth space can cause the flowable composite to leak into this space and polymerize on the adjacent tooth. This can be difficult to clean and reshaping the teeth time-consuming, diminishing the very purpose of this technique: saving time with a favorable result.

A more accurate approach based on the injection technique is proposed by making a waxup on the cast of every other tooth, then taking an impression with the clear PVS. This will be the first mold. Then the waxup is completed for the other teeth, and a second PVS mold is made for the full waxup of the teeth. After isolation, etching, and bonding as previously described, the first PVS mold is secured in the patients' mouth. There should be a tight seal between the waxed and unwaxed teeth to seize the flowable composite from flowing into the embrasures and onto the adjacent teeth, accurately polymerizing the flowable composite into the confined space of the first waxup. The second PVS mold is placed, and the process is repeated. Accuracy and finishing time should be advantageous with this approach vs the conventional injection technique. However, it may be challenging to achieve symmetry, shape, and contouring of the teeth. Clinicians and technicians need to consider that it is very difficult to make two identical manual waxups, especially considering that one of them will have waxed every second tooth. Therefore, a digital workflow version of this procedure is introduced in the following clinical case, which can solve the drawbacks mentioned previously.

Computer-aided design and computer-aided manufacturing (CAD/CAM) technologies applied to dentistry have given the clinician a vast diversity of tools to handle clinical scenarios. Restorative dentistry is one of the fields that has benefited the most. The accuracy and consistency of intraoral scanners and milling units have allowed CAD/CAM restorations to be more predictable and durable. The CAD phase offers the clinician the ability to simulate the outcome without even changing a tooth intraorally. Based on an intraoral scan, a digital waxup can be made. Using the "adding tool" of the design software, the volume and shape of a tooth can be changed gradually on the screen and even corrected as many times as needed. Every step in the process can be reversible and modified as a single shape, making a digital waxup both versatile and retrievable. If a "digitally waxed" tooth is not looking according to the expectations, that tooth can be erased, and the process can start again from scratch. After the digital waxup is finished, each tooth can remain as a single shape as well. This means that each digitally waxed tooth can be later modified or visualized individually. This feature presents an incomparable advantage over traditional waxing techniques, where the waxed models are delicate and irreversible. Another advantage is that the digital workflow allows three-dimensional (3D) printing of the models, which is not only easy and inexpensive but also more durable. This sequential digital workflow is crucial to assure proper shape and ease the clinical procedures as described in the following case report.

CLINICAL CASE REPORT

A 28-year-old female patient presented for a screening appointment with concerns about spacing and malaligned and discolored teeth. Tooth #7 was slightly retruded with a lower gingival zenith, lateral incisors were smaller in proportion to central incisors, tooth #10 had a mesial and distal diastema, and the tooth shade of the maxillary teeth was unequal in chroma. She was also dissatisfied with her smile display, complaining about having an uneven gingival line (Figure 1). To begin the

Figure 1. *Pre-operative portrait picture of the patient.*

Figure 2. *DSD photographic protocol of the patient and occlusal scan of upper model.*

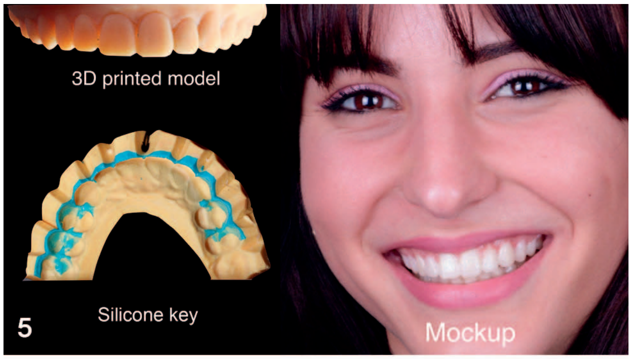
Figure 3. *Digital 2D simulation of the new smile with proposed tooth shape.*

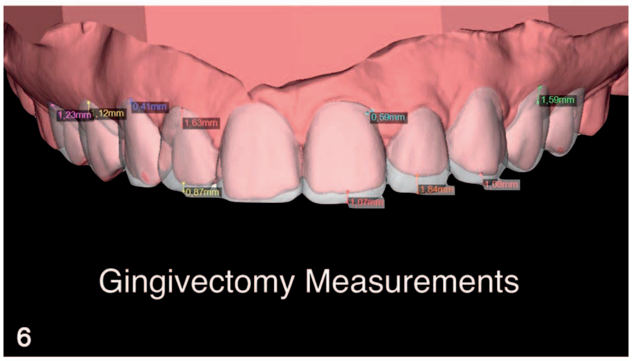
Figure 4. *Digital 3D wax-up design on the digital model and overlapped in the portrait picture of the patient.*

documentation of the findings, the DSD photographic protocol[22] was used, consisting of frontal portrait pictures with and without lip retraction; profile pictures in resting position and full smile; 12-hour picture (picture is taken from the back of the patient, angled from the overhead toward the anterior portion of the chin, focusing on the anterior maxillary flare of the incisors; and occlusal picture (in this case, the digital scan of the model; Figure 2).

A new smile proposition was simulated digitally with the DSD application, which provided the clinician and the patient with a helpful insight of treatment possibilities (Figure 3). Subsequently, the 3D design was created with the NEMO Smile design 3D software (Nemotec Company, Madrid, Spain) and overlapped with the patient's smile (Figure 4). From this simulated mockup, a 3D-printed model was created, and a PVS impression was made as a mold. A traditional additive mockup was made with a bis-acryl temporary material to visualize how the digitally designed teeth appear in the patients' mouth and determine whether the patients' expectations were met (Figure 5). Another aim of this mockup was to check if the occlusal function was kept with the proposed design. The goals were to provide protrusive guidance with all incisors participating in it and to keep canine guidance as lateral excursion pattern toward both sides.

Subsequently, after the occlusion was checked and the viability of the design confirmed, the digital scan of the model and the digital waxup were overlapped revealing tooth shape, alignment, and contours (Figure 6). After the final design was approved, a surgical stent for guiding the gingivectomy procedure was fabricated (Figures 6 and 7) The anticipated outcome of gingival zenith height, alignment, and contour were achieved (Figure 8). After four months of soft tissue healing, the teeth were bleached (Figure 9). Two models were 3D printed: the first was based on a waxup of every other tooth, and the second model was based on the complete waxup. As previously mentioned, this first design can be achieved using the design software by activating or deactivating the superimposed tooth with the digital waxup, because each tooth is an individual overlapped image (Figure 10). A translucent custom tray was used with a clear PVS impression material to take an impression of the models and then placed in a 1.5-bar pressure pot. This process ensured the optimum fit, accuracy of surface details, and contours (Figure 11). Access holes the size of the flowable composite tip were made through the tray and impression material slightly facial to the incisal





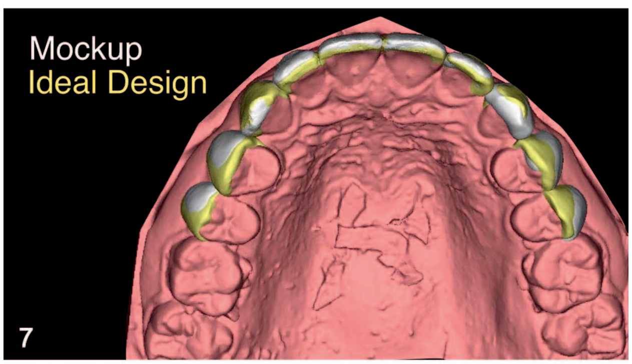


Figure 5. *Traditional additive mock-up on the patient based on a 3D printed model of the digital wax-up.*

Figure 6. *Estimated measurements planned for the gingivectomy procedure.*

Figure 7. *Occlusal view of the ideal mock-up design, which led to the fabrication of a surgical stent.*

Figure 8. *Clinical picture after the gingivectomy was completed.*

edge of each tooth that was to be restored (Figures 12 and 13). Isolation of every other tooth that was not included in the first waxup design was achieved with polytetrafluoroethylene tape due to its minimal thickness, it would not interfere with the seating of the clear PVS mold. However, care was taken when placing the tape around the teeth, because it folds very easily and can leave undesired wrinkles in the contour of the restored teeth. The teeth to be restored were etched with 38% phosphoric acid and rinsed, and the adhesive was applied according to manufacturer's instructions (Adhese Universal, Ivoclar Vivadent, Schaan, Liechtenstein) (Figure 14). The first mold was placed and checked for proper fit. The flowable composite (Tetric Evoflow Bleach L, Ivoclar Vivadent) was injected through the holes filling the entire facial surface, followed by photopolymerization using a Bluephase G2 device (Ivoclar Vivadent) (Figures 15 and 16) with an output of 1200 mW/cm^2. Considering the thickness of the tray and the PVS material, it was favorable to double the polymerization time recommended by the manufacturer to ensure sufficient delivery of energy to achieve optimal polymerization.[23,24] Other authors even suggest applying three times the recommended curing time when the distance between the composite resin and the light tip is more than 4 mm, because of LED design and light scattering.[25]

After light polymerization of the first set of teeth, finishing and polishing were performed. Finalizing contours and embrasures were completed with a #12 blade. Finishing and polishing were achieved with finishing burs, rubber cups, Sof-Lex discs (3M ESPE, St Paul, MN, USA), and polishing wheels and pastes (Figure 19). Subsequently, the second mold of the full waxup design was placed, and the same procedure was repeated for the remaining teeth (Figures 17 and 18). In this case, no changes in the occlusion were made. Protrusive, lateral movements, and occlusal contacts in maximum intercuspation remained intact. The final portrait pictures can be seen in Figure 20.

The improved version of the injection technique presented in this case report depicts a real treatment option, especially for patients that cannot afford traditional full-mouth indirect restorations and are seeking esthetic improvements. However, careful treatment planning and occlusal considerations have to be taken into account to assure good prognosis and long-term success of the restorations. The use of a flowable composite will make these restorations last for a couple of years and will make them more prone to degradation than traditional composites. The longevity of the treatment needs to be addressed with the

Figure 9. *Portrait picture after whitening of teeth and gingivectomy were performed.*

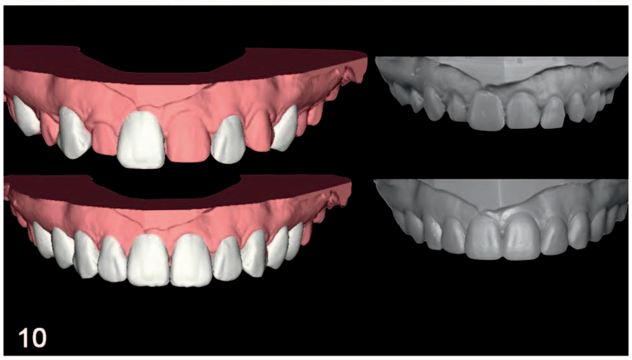


Figure 10. *First digital wax-up and 3D printed model created with the software after the deactivation of every other tooth from the complete wax-up.*

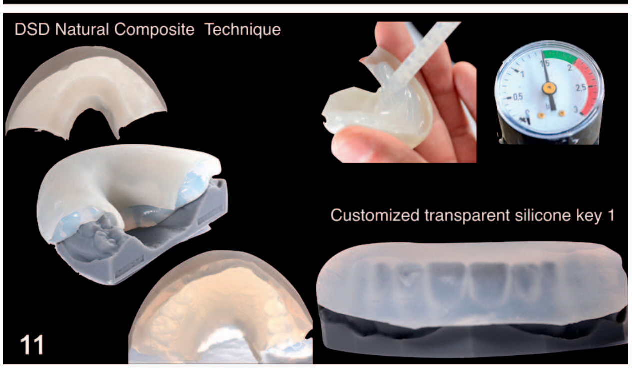


Figure 11. *Fabrication process of the first transparent silicone key.*

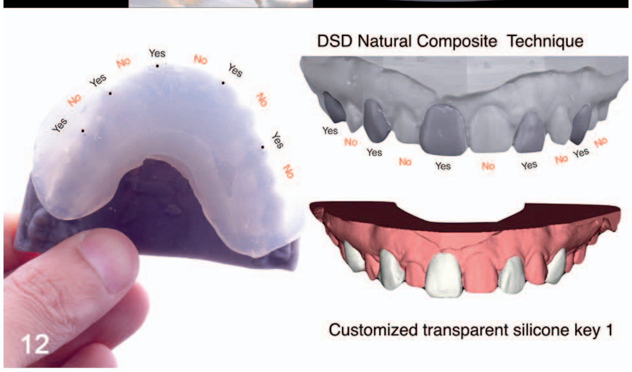


Figure 12. *Detail of the partial digital wax-up, 3D printed model and first silicone key fabricated.*

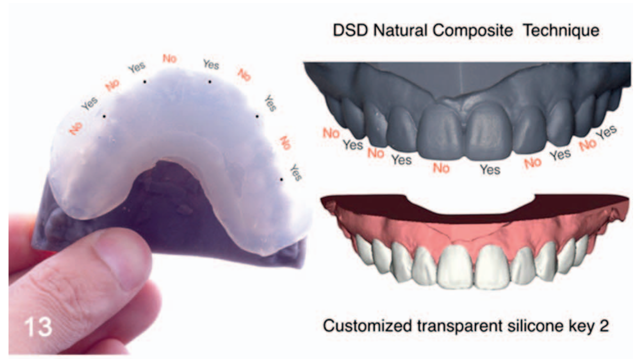


Figure 13. *Detail of the complete digital wax-up, 3D printed model and second silicone key fabricated.*

Figure 14. *Etching and bonding procedures for the first set of teeth to be restored.*

Figure 15. *Injection of flowable composite resin for the restoration of the first set of teeth through the first silicone key.*

Figure 16. *Photopolymerization of the composite resin through the silicone key.*

Figure 17. *Clinical picture after the first set of teeth are restored, finished and polished.*

Figure 18. *Injection of flowable composite resin for the restoration of the second set of teeth through the second silicone key.*

Figure 19. *Detail of the texture created after finishing and polishing of the restored teeth.*

patient, informing them about its semipermanent characteristics. This technique, unlike restoring anterior teeth directly and manually, might be more cost-effective and does not require high-end clinical skills, making it more predictable and affordable. The digital workflow, however, has a learning curve and requires state-of-the-art hardware/software. It will appear daunting at the beginning, but after the workflow is assimilated by the working team, it might become more convenient to complete a treatment plan than a traditional approach. Similar digital attempts in the field of prosthodontics have been proven to be more

Figure 20. *Set of portrait pictures of the patient from the pre-operative view to the final post-operative view.*

Figure 21. *Informal portrait pictures showing the final outcome.*

cost-effective than the traditional approach.[26] The authors of this paper believe that scientific research should focus more on identifying which clinical situations can get the greatest benefits from applying a digital workflow and that esthetic dentistry might be one of them. This technique also allows for treating patients that need additive restorations without the necessity of preparing the teeth. In fact, a final intraoral impression or scan can be taken to save it for future purposes like converting those shapes to a more durable composite resin or to deliver indirect veneers/crowns. This technique can also be used for subtractive or additive/subtractive (mixed) restorations, but a preparation needs to be performed prior to the waxup and the delivery of the restorations. In summary, when applying this technique, patients may receive a predictable result with reduced cost, effort, and time and acceptable durability and viability for future treatments.

Regulatory Statement

This study was conducted in accordance with all the provisions of the local human subjects oversight committee guidelines and policies of the University of North Carolina at Chapel Hill.

Conflict of Interest

CC is the current CEO of DSD Company (Sao Paulo, Brazil). LDA is the head of DSD Education of Nemotec Company (Madrid, Spain).

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