

Original Article

Advancements in Orthodontic Appearance: Exploring Injectable Resin Approaches for Transformative Smile Design

Nawal Hamid Mohammed Hamed¹, Mohamed Siyam Elamin Bushara^{2*}

¹ Private Practice, Abu Dhabi, United Arab Emirates.

² Department of Oral Health Science, Faculty of Dentistry, University of British Columbia, Vancouver, Canada.

*E-mail ✉ msiyambushra@gmail.com

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ABSTRACT

The injection moulding technique (IMT) offers a non-invasive method for dental restoration by using flowable composite materials within a transparent silicone index, which serves as a mould. This technique capitalizes on the fluid properties of the composite to seamlessly integrate with the natural tooth structure, often avoiding the need for tooth alteration and preserving tooth integrity. The etch-and-rinse process ensures that the procedure is both consistent and reproducible. This minimally invasive technique is particularly useful following orthodontic procedures, where slight changes in tooth shape or alignment are often necessary to achieve optimal aesthetic and functional results. The integration of orthodontic and restorative treatments is essential for optimal patient outcomes, especially in complex cases requiring multiple disciplines. This retrospective study examines the use of IMT for restoring maxillary lateral incisors in two pediatric patients (ages 12.6 and 12.3). The technique provides a temporary restoration until the patient is ready for permanent ceramic veneers, offering a conservative solution for orthodontic treatment completion. The IMT technique works best for addressing minor gaps or slight tooth misalignments. The cases presented show that the method is effective for treating irregular tooth sizes or shapes, especially when an additive approach is necessary without the need for invasive preparation. The IMT is a helpful tool for pediatric patients at various stages of orthodontic treatment. It aids in correcting discrepancies such as Bolton index variations and enhances tooth morphology. The addition of a digital workflow enables thermo-formed retainers to be created and delivered in the same visit as the IMT, resulting in cost and time efficiency. This technique simplifies the overall treatment process, improving clinical efficiency and outcomes in interdisciplinary orthodontic-restorative care.

Keywords: Injection moulding, Flowable composite, Silicone index, Digital workflows, Bolton discrepancy, Orthodontics, Restorative dentistry.

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Introduction

In today's dental practice, aesthetic considerations have become increasingly important for patient care [1]. The focus of restorative dentistry is to restore not only the functional aspects of the occlusion but also enhance the aesthetic appearance, which can significantly improve the patient's self-esteem and overall quality of life [2]. The chosen method of

rehabilitation often depends on the patient's age, specific clinical needs, and individual preferences. Ceramic veneers, known for their excellent biomechanical properties and aesthetic appeal, are widely regarded as one of the best options in many clinical scenarios [3-5].

In addition to ceramic restorations, composite fillings have gained popularity in aesthetic and operative dentistry [6] due to their cost-effectiveness and reduced treatment time compared to traditional methods [7-11].

Freehand bonding, an approach commonly used in aesthetic dentistry, involves layering composite materials with varying opacity levels to achieve a natural look. However, this method demands high technical skill and substantial time commitment in the dental chair [12].

The integration of digital technologies such as CAD/CAM has provided clinicians with more precise and efficient tools for managing complex clinical situations [13]. Digital techniques like intraoral scanning, cone-beam computed tomography (CBCT), and digital smile design (DSD) offer a more streamlined approach to treatment planning, especially when multiple disciplines are involved [14]. DSD is particularly useful in the early phases of treatment, helping guide the final restorative phases by clearly defining desired tooth aesthetics and functional goals [15]. Moreover, the use of open-source software (e.g., Digital Smile Design—Keynote) has made digital planning more accessible and cost-effective [16, 17]. IMT offers a simplified alternative to freehand bonding by using a transparent silicone mould filled with flowable composite material. This method ensures an efficient integration with the natural tooth and eliminates the need for extensive tooth preparation, preserving the overall tooth structure. The use of an etch-and-rinse protocol further ensures reliable, repeatable outcomes [7–10].

Following orthodontic treatment, minimally invasive restorative techniques can help fine-tune tooth shapes, ensuring both functional and aesthetic perfection. For the best patient outcomes, combining restorative and orthodontic procedures is key, especially in multidisciplinary cases. Conservative methods are beneficial for correcting issues like tooth wear, incisal margin damage, irregular tooth shapes, and discrepancies in the Bolton index [7].

This paper discusses the IMT applied to pediatric patients undergoing orthodontic treatment, specifically for the restoration of maxillary lateral incisors. This method provides a temporary solution before permanent all-ceramic veneers are possible. By using a digital workflow, orthodontists can design the necessary tooth adjustments quickly, and thermoformed retainers can be created during the same session. This integration optimizes the patient experience and reduces the number of clinical visits. Compared to 3D printing, which offers customizable results, the IMT provides a faster, time-efficient approach, achieving similar aesthetic outcomes. Its simplicity and cost-effectiveness make it an ideal choice for pediatric patients, where non-invasive methods are preferred. Furthermore, the IMT integrates

seamlessly with standard orthodontic practices, making it a practical and accessible tool in daily clinical procedures.

Case Presentation

The following case reports were conducted in accordance with the 2013 CARE checklist [18]. All participants provided informed consent, and the study was approved by the University of L'Aquila Ethics Committee (L'Aquila, Italy) (Project ID: 12/2020; approval date: May 11, 2020). The research adhered to the Declaration of Helsinki.

Case 1

Patient overview

A 12.6-year-old female patient presented to an orthodontist for aesthetic concerns regarding her smile. Examination revealed the upper lateral incisors (teeth 12 and 22) were undersized and exhibited irregular shapes.

The patient's medical history was clear, and she followed a healthy lifestyle. A dietary evaluation revealed that the patient had a balanced diet with no increased caries risk.

Clinical evaluation

Upon evaluation, the patient exhibited a Class I skeletal relationship, with a symmetrical oval face and a slightly convex profile. The molars and canines were well-aligned in a Class I relationship, and the dental midlines were centered. There were no signs of caries in either the anterior or posterior teeth. Mild misalignment was present in the lower arch.

Diagnosis and digital analysis

Conventional orthodontic records were obtained, including clinical photos, radiographs, and impressions. These were analyzed using Digital Smile Design (DSD) software for comprehensive planning and tooth modification (**Figure 1**).





Figure 1. (a) Frontal view showing conical teeth 12 and 22. (b) Occlusal view of the maxillary arch. (c,d) Radiographic images

Treatment options considered

Two treatment approaches were proposed:

1. Extraction of the lower incisor (tooth 42) to relieve crowding, with restorations for teeth 12 and 22 in the upper arch. This plan involved placing fixed retainers on both the upper and lower arches (from tooth 33 to tooth 43).
2. A non-extractive option, where interproximal enamel reduction would create space in the lower arch, followed by restoration of teeth 12 and 22 **using the Injection Moulding Technique (IMT)**. Fixed lower retainers and removable upper retainers would also be used. The patient preferred this second approach, which was less invasive.

Treatment approach

After finalizing the tooth shape digitally, a resin mock-up was temporarily placed in the patient's mouth to assess the aesthetic and functional outcomes. Once the mock-up met both the patient's and clinician's expectations, a final silicone mould was created. This was based on a thermoformed tray that aligned with the final wax-up. The subsequent phase involved fabricating both a thermoformed retainer and a triple-layer silicone index, created through digital design (**Figure 2**).

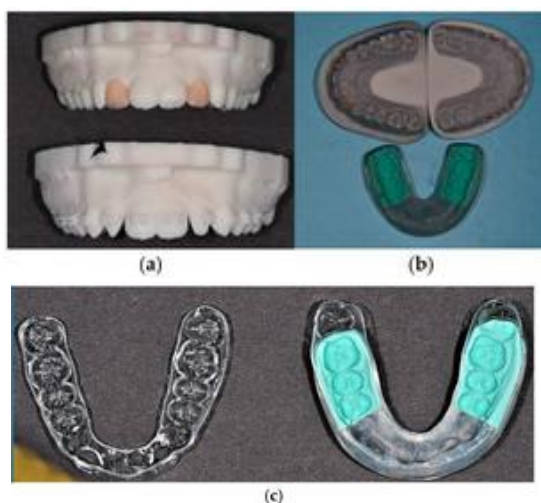


Figure 2. (a) Wax-up model of teeth 12 and 22. (b) Thermoformed retainer on the upper left model,

with the final orthodontic model and silicone index shown. (c) Comparison of the thermoformed retainer and silicone index

A three-layer silicone index was utilized for precise replication of the wax-up during composite restoration. The layers were specifically designed for different functions:

Layer 1: Provides posterior stability.

Layer 2: Prevents flexing.

Layer 3: Allows for optimal light transmission.

Holes in the incisal regions were strategically placed to guide the application of composite materials (**Figure 3**).

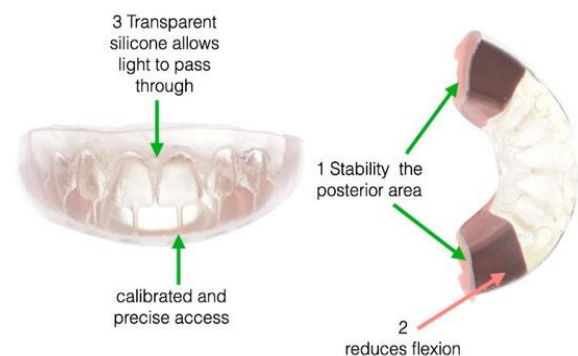


Figure 3. Diagram showing the structure of the silicone index

After etching and bonding, the A1 shade flowable composite was applied using the silicone index to sculpt the teeth. Once light curing was completed (with a wavelength of 430–480 nm and 1470 mW/cm² intensity), excess material was carefully removed to avoid overhangs and plaque accumulation. A polishing protocol, including fine-grit burs and 3M finishing discs, was used to ensure a smooth and glossy surface (**Figure 4**).

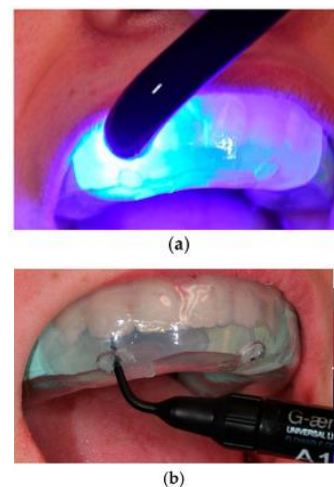


Figure 4. (a) Flowable composite being applied. (b) Curing process

The entire procedure lasted 22 months, after which the patient expressed satisfaction with the improved aesthetics of her smile (**Figure 5**). The digital workflow also allowed for the delivery of the final retainer at the end of the restorative phase.

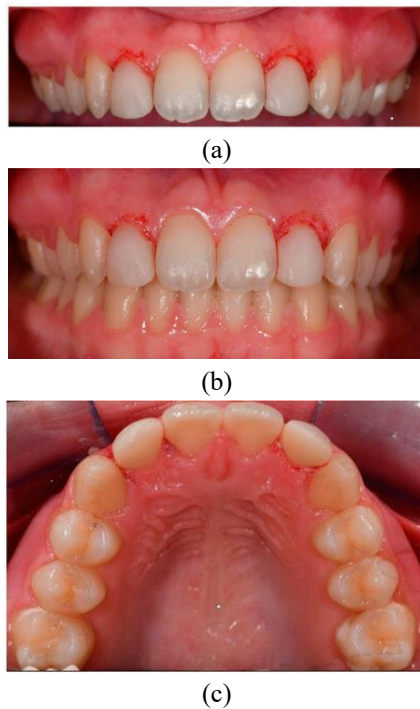


Figure 5. (a) Detailed reshaping of teeth 12 and 22. (b) Final frontal occlusion. (c) Occlusal view showing the palatal aspects of the reconstructions on 12 and 22

At a six-month follow-up, there were no signs of gingival inflammation, the periodontal health was stable, and the colour of teeth 12 and 22 remained consistent. The patient reported high satisfaction and showed no adverse reactions to the procedure. After six years, a follow-up revealed healthy periodontal conditions, normal probing depths, and excellent oral hygiene (**Figure 6**).



Figure 6. View of the final bite alignment observed during the follow-up assessment, six years post-treatment

Case 2

Initial consultation

A 12.3-year-old male sought orthodontic advice, feeling dissatisfied with the cosmetic appearance of his teeth. Upon examination, it was noted that his lateral incisors were unusually small, and his canines (teeth 13 and 23) had not yet emerged (**Figure 7**).

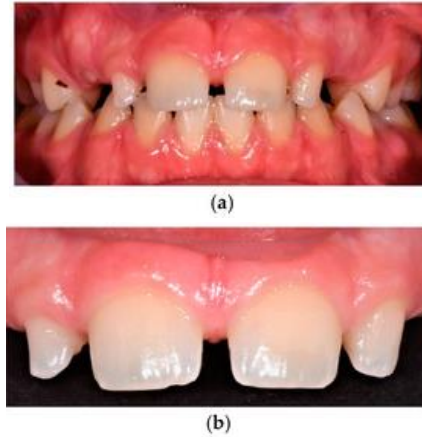


Figure 7. (a) Frontal view showing the occlusion in complete intercuspation. (b) Close-up highlighting the dental irregularities of teeth 12 and 22

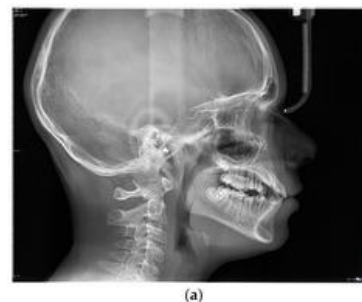
The patient's health was unremarkable, and he maintained a balanced diet with no apparent health concerns. A risk assessment of potential cavities showed a low likelihood of dental caries.

Observed findings

The patient exhibited a skeletal relationship classified as Class I, but with a slight tendency toward a Class III occlusion. His face had an oval shape, with symmetrical proportions and a slightly convex profile. The canine and molar relationships were in harmony with a well-aligned dental midline (**Figure 7**). The dental arches showed no crowding, and there were no cavities in any area of the mouth.

Diagnostic evaluation

Comprehensive diagnostic data, including clinical photographs, X-rays, and dental casts, were gathered (**Figure 8**). These were then analyzed using specialized software to adjust the teeth's size and shape digitally.



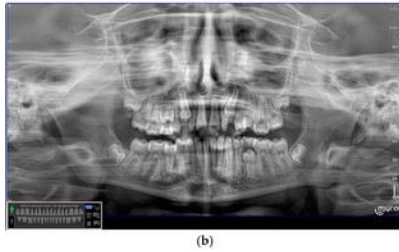


Figure 8. (a,b) Radiographic images used for analysis

Considered treatment plans

Two treatment strategies were evaluated:

1. Space closure along with the correction of the Class III tendency.
2. A direct restoration of the lateral incisors (teeth 12 and 22) before starting the orthodontic treatment, followed by a treatment course lasting 24 months, including space closure and fitting retainers at the end. The patient chose the second plan, favoring the restoration prior to the full orthodontic phase.

Treatment execution

After finalizing the digital design of the desired tooth structure, a provisional mock-up was created and placed in the patient's mouth. The shape and aesthetic were adjusted to meet his expectations. Once satisfactory results were confirmed, the final mould was created using a thermoformed plastic tray around a silicone stent that matched the wax-up (**Figure 9**). Teflon strips were applied to shield the central incisors from excess composite during the procedure.

A bonding agent was applied to the lateral incisors, followed by the gradual injection of a flowable composite material into the silicone index to shape the teeth. After light-curing, any excess composite was carefully removed to prevent plaque buildup and gum irritation. A polishing routine ensured the restoration's longevity and visual appeal. The methodology and materials used mirrored the process in Case 1 (**Figure 10**).



Figure 9. Thermo-formed retainer placed on the silicone tray (upper left). The lower left shows the

wax-up used to create the triple-layer silicone mould. The image on the left represents the model for the lower teeth

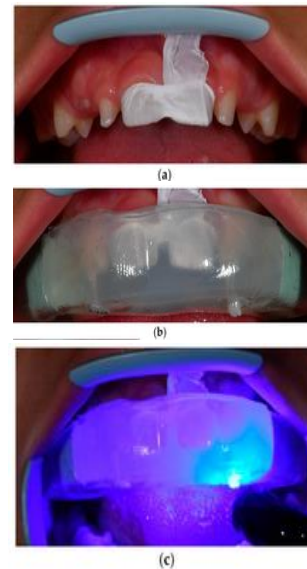


Figure 10. (a) Teflon strips isolating the central incisors from the composite. (b) The silicone index in position during the treatment, showing how the material flows into the mould. (c) Light-curing of the injected composite

At the same appointment, retainers were fabricated digitally and delivered to the patient.

A two-year follow-up examination showed excellent results: no gum issues, proper tooth alignment, and no change in the teeth's color or shape. The patient experienced minimal discomfort throughout the treatment (**Figure 11**).



Figure 11. (a) Final occlusion view. (b) Close-up of reshaped lateral incisors (teeth 12 and 22). (c) Occlusal view, highlighting the palatal side of the reshaped teeth

Discussion

The injectable composite technique offers a practical and straightforward solution for enhancing tooth aesthetics, especially when only minor reshaping is required [19]. The cases presented illustrate how this technique can be effectively used to reshape teeth in younger patients. It serves as an affordable alternative to more invasive and costly treatments, such as ceramic veneers. A key benefit of composite materials is their ability to be easily repaired or replaced, and they can be polished during follow-up visits [20].

Recent innovations in flowable composites have significantly improved their performance, including enhanced durability, strength, wear resistance, and transparency [21, 22]. These advanced fluid resins demonstrate superior flexural strength, elasticity, and resilience compared to traditional composites [23, 24]. The inclusion of a high filler content (69 wt%) contributes to a more uniform distribution of particles, resulting in wear-resistant and longer-lasting restorations [25].

For the injectable moulding technique (IMT) to be effective, it's crucial to isolate the tooth surface carefully without the use of rubber dam clamps, as these could interfere with the thermo-formed tray. The tray should be 1 mm thick, with specific support areas for non-restored teeth, ensuring accurate mould formation.

Heating the composite material is essential for achieving the desired viscosity. A slight overflow of composite material at the gingival area ensures air is not trapped, and the material is evenly spread across interproximal and marginal areas. The light-curing process may need to be extended to ensure proper polymerization, especially when physical barriers obstruct the light [26]. After moulding, rubber polishers should be used to maintain the tooth's shape. The success of this procedure relies on patient-specific factors such as age, habits (like teeth grinding), and the size of the restoration.

The influence of light-curing on the durability of composite restorations has been extensively researched [27, 28]. Differences between resins from various manufacturers don't substantially affect the long-term performance, which allows clinicians the flexibility to choose based on personal preference [29, 30]. In this study, G-aenial Universal Injectable (GC Corporation) was used, following the manufacturer's recommendations, as it's backed by previous research [7, 31, 32]. This composite is particularly effective in reducing bacterial adherence due to its smoother

surface, which is further polished with Sof-Lex Spirals [33].

To avoid gum irritation or inflammation, it is crucial to place the composite material carefully within the gingival sulcus. A physical barrier is used to prevent subgingival flow, minimizing the risk of biological issues. By keeping the composite above the gum line in the wax-up stage, there's no need for retraction cords, which helps reduce the chance of irritation [10].

Choosing the right patients is critical for success. The injectable technique is best suited for those with minimal spacing, slight retrusion, or small diastemas [34]. The cases shown here, involving variations in tooth size and shape, demonstrate how the IMT works well in such situations, offering an additive solution without the need for invasive preparations.

Conclusions

- The IMT offers an effective, conservative solution when an additive approach is beneficial for the patient.
- Success is achieved through careful application, thorough pre-treatment planning, appropriate case selection, and strict adherence to procedural and polishing protocols.
- This method proves valuable for young patients, both at the beginning and the end of orthodontic treatment.
- The IMT is a useful tool for orthodontists in resolving Bolton index discrepancies and correcting tooth morphology.
- Functional and aesthetic improvements are attainable, resulting in better orthodontic outcomes and more attractive smiles for patients.
- Incorporating digital workflows improves clinical efficiency, as retainers or aligners can be delivered during the same appointment as the IMT, offering organizational and economic advantages.
- Further research is required to evaluate the long-term effectiveness of this technique.

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