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CLINICAL ARTICLE

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Precision layering techniques: Integrating digital tools for accurate color matching and realistic try-ins in anterior composite restorations

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Abstract

Objective: This article aims to demonstrate the clinical application of a comprehensive workflow that integrates digital tools for accurate color matching, and its immediate implementation in the restoration of anterior teeth.

Clinical Considerations: Two patients demonstrating dissatisfaction regarding a maxillary central incisor had an old restoration replaced resorting to a digital workflow to enhance the predictability of the new direct restoration. OptiShade allowed the precise assessment of tooth color and the CompoShade application provided precise color and material selection, as well as the determination of a layering strategy. Precision and accuracy of the colorimeter and the composite layering application were demonstrated clinically in vivo.

Conclusions: Implementing a digital workflow with the integration of OptiShade measurements and the CompoShade layering recipe calculation, as well as the respective realistic try-in, enables the achievement of precise color matching for anterior composite restorations.

Clinical Significance: The employment of a digital colorimeter and layering recipes simplify shade matching, and optimizes composite resin clinical use and success. The implementation of a realistic try-in, previous to the definitive restoration, allows the clinician to perform any adjustments if needed.

KEYWORDS

Class IV restoration, composite resin, dental color matching, digital color matching, digital colorimeter, direct composite veneers, layering, layering recipes

1 | INTRODUCTION

Direct composite resin restorations are the most frequently employed type of rehabilitation in both anterior and posterior teeth,[1] primarily due to their aesthetics and for being a conservative treatment option.[2] Regarding the rehabilitation of anterior teeth, achieving a pleasing restorative result continues to pose a challenge to clinicians.[3] Patient satisfaction is profoundly influenced by perceived tooth color, with dissatisfaction often prompting individuals to seek aesthetic enhancements such as whitening or restorative treatments.[4–6] Thus, the endeavor for precise shade matching becomes pivotal to align treatment outcomes with patient expectations.[7–9]

The color of an object is a perception created by the human brain in response to the different wavelengths of light reflected by an object.[10] This perception is a nuanced interplay of physiological and psychological factors, intricately integrated into restorative dentistry. Human vision, facilitated by specialized cones in the retina sensitive to short (S), medium (M), and long (L) wavelengths, constructs a trichromatic color space essential for interpreting the spectral distribution of light.[11] Although the inherent color of a tooth arises from the differences between dental tissues, such as enamel, dentin, pulp and soft tissues, the most important factor to consider is the way light is scattered, reflected, and transmitted among them.[8]

The International Commission on Illumination (CIE) defined the L*a*b* scales, expressing color as three different axes: black-white (L*), red-green (a*), and yellow-blue (b*).[7,12] Therefore, color is recognized as a 3-dimensional space.[7,13] Additionally, the concept of color ΔE was introduced, a measure of color discrepancy, allowing the calculation of the difference between color measurements.[10,12,13] As shade matching is recognized as a factor of paramount importance to achieve aesthetic success, both accuracy and precision must be assessed.[3,14] While accuracy consists of the ability to match the desired shade, precision indicates the repeatability of the method.[3] The former usually appears as a result of systematic errors and the latter is mostly affected by random errors.[10]

Over the last few years, literature has been focusing on systems developed to avoid discrepancies and identify visual color thresholds.[10] Direct comparisons with a specific shade are considered inconsistent, as age, sex, operator fatigue, and experience can act as adverse variables.[3,10,13,15,16] Furthermore, the phenomenon of illuminant metamerism, in which restorative materials match under one lighting condition but appear different when the lighting condition changes, led to an increasing need to develop predictable color-measuring instruments to enhance the accuracy of individual measurements.[3,12]

Therefore, new instruments have been developed to overcome the underlying subjectivity of traditional methods, such as spectrophotometers and colorimeters.[3,10,13] While spectrophotometers measure the spectral reflectance of an object along visible wavelengths, colorimeters identify a color triplet directly, like the amount of red, green, and blue light, reflected by the object.[3,10,12] In addition to these contact-based instruments, the introduction of digital images allows for better capture of color, form, and texture, not only from teeth but also from the adjacent soft tissue.[3,12] Furthermore, technological innovations, such as intraoral scanners and 3D printers, continue to refine shade-matching practices.[17,18]

Despite the fact that these new tools aim to standardize color evaluation, clinician training and experience remain pivotal determinants of success.[14,15,19,20] Direct restorations require the clinician to apply the layering concept in an attempt to emulate the tooth's tissue, enamel, and dentin, as much as possible.[21] To achieve this, clinicians must fully understand anatomy and the multidimensional nature of color.[21] Heterogeneity among patients should be considered regarding the amount of dentin and enamel, their respective thickness, translucency, opacity, and texture.[22] Additionally, the several composite resin systems available in the market are associated with different optical results,[21] as nowadays there is a diverse range of shades and effects, which enable various combinations to obtain the desired result.[2]

Successful color matching requires compliance with standardized protocols, reliable instruments, and ongoing research-driven practices.[8,10,23–26] Until now, the utilization of colorimeters and spectrophotometers in dentistry was limited due to the lack of standardized methodologies for directly translating the measurements into clinical steps.[3,27] Thus, the aim of this article is to demonstrate the clinical application of a comprehensive workflow that integrates digital tools for accurate color matching, and its immediate implementation in the restoration of anterior teeth.

2 | CLINICAL PRESENTATION

Two female patients sought dental care, demonstrating dissatisfaction regarding preexistent Class IV restorations in the right maxillary central incisor. Clinical examination was complemented with a comprehensive anamnesis and an initial photographic record. Prior to any procedure, both patients provided written informed consent. The diagnostic process indicated that the replacement of the previous restoration with a new direct composite resin restoration was the most adequate treatment option. Because of the high aesthetic demands of the clinical situations, both cases were managed using the OptiShade–CompoShade system, aiming for an accurate and reproducible color match for the composite restorations.

2.1 | OptiShade–CompoShade system

The OptiShade–CompoShade system allows the precise assessment of tooth translucency, facilitating a seamless integration of dental restorations. OptiShade (Smile Line SA, Saint-Imier, Switzerland) is a high-precision dental colorimeter, which relies on the use of uncontextual images (UI) that focus on the tooth's analysis in specific areas, particularly in the incisal edge and the central portion of the tooth. OptiShade is able to remove the influence of the gingival tissue and the adjacent teeth, allowing color not to be affected by the additional reflection of those tissues (Figure 1A). Furthermore, the colorimeter provides information based on color coordinates, resorting to the L*a*b* scales, which consider lightness, red-green, and yellow-blue scale positions.

In order to identify the different behavior of dental tissues, OptiShade UI are obtained with a specific composite adapter in the tip and can be captured with two different types of backgrounds by opening and closing a colored flap (Figure 1B). The open flap provides an empty background, catching the darkness of the mouth, therefore simulating an open mouth. On the other hand, a closed flap simulates the clinical situation of a closed mouth with an overlapping antagonist with the same color, so that the system is able to perform easier calculations (Figure 1C). Additionally to OptiShade UI, the clinician is

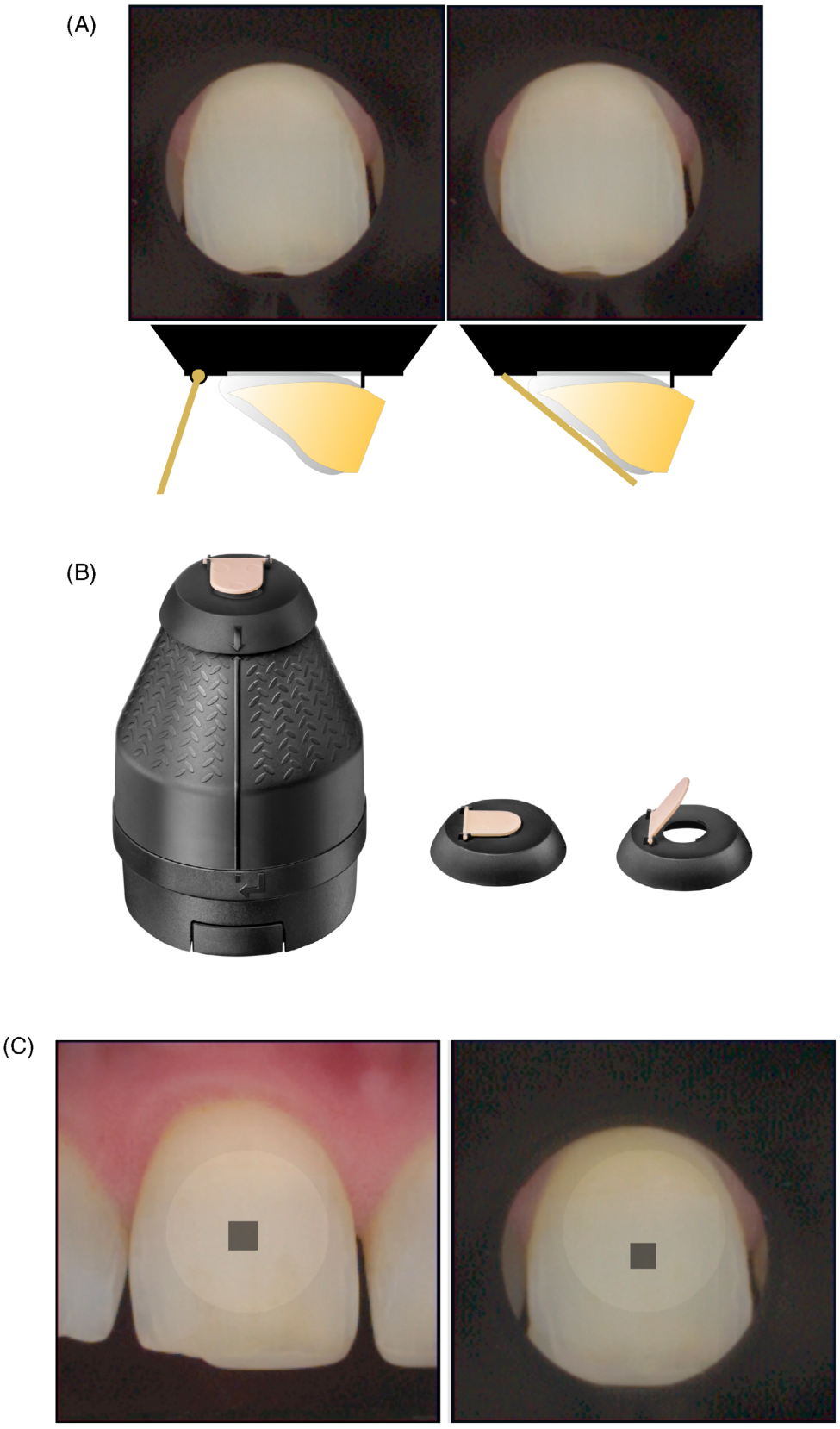

FIGURE 1 OptiShade: (A) different positions of the colored flap, (B) the open flap (left) simulating an open mouth and a closed flap (right) simulating a close mouth, and (C) difference between an image with (left) or without (right) additional reflections.

required to measure the tooth's thickness in both the incisal edge and the central portion, as variations in thickness can influence light transmission and reflection due to translucency.

Subsequently, the OptiShade measurements must be exported to the CompoShade application (StyleItaliano, Genoa, Italy). The application provides a platform for precise color spot selection, material

TABLE 1 Association between the ΔE94 and restorative thresholds.

ΔE94	Restorative thresholds
0	Identical perceived colors
<0.67	Excellent match
0.67–1	Very good match
1–1.6	Good match
1.6–2.7	Acceptable mismatch
2.7–4.7	Evident mismatch
>4.7	Unacceptable mismatch

FIGURE 2 Initial intraoral photograph.

selection, and layering strategy for the composite restoration determination, based on the acquired data. The software compares the measured color to a comprehensive database of commercial shade guides and calculates the closest correspondence. The color difference formula developed by the International Commission on Illumination in 1994 (ΔE94) can be associated with different restorative thresholds, as depicted in Table 1. Therefore, detailed recipes are provided, considering factors such as layer order and thickness, which lead to a perfectly integrated anterior restoration.

The use of the OptiShade–CompoShade system simplifies communication with the patients, as realistic try-ins can be conducted using nonadhered composite in the prepared tooth and feedback on color, shape, and overall aesthetic appearance can be provided.

2.2 | Case 1

A 24-year-old female patient with the desire to replace an unaesthetic restoration (Figure 2) was submitted to the previously mentioned technique. Data collection from the sound adjacent tooth, specifically two OptiShade UI and the thickness of the tooth in the incisal and middle area, was collected.

Considering the OptiShade UI with the open flap (Figure 3A), the colorimeter displayed the L*a*b* values, as well as a comparison database which the showed Vita 3D-Master (Vita Zahnfabrik, Bad Säckingen, Germany) correspondence. In this case, a 0M3 (bleach color) was

FIGURE 3 OptiShade uncontextual images with different backgrounds: (A) open flap and (B) closed flap.

the closest match. Furthermore, regarding the OptiShade UI with the closed flap (Figure 3B), the colorimeter also displayed the L*a*b* values and the Vita 3D-Master correspondence. It is noteworthy that although the L*a*b* values were similar to the previous OptiShade UI, the minimal difference was crucial for the system to analyze the opacity/translucency of the tooth. Clinicians are recommended to label the images, as "open" or "closed," as these become difficult to distinguish along the process. Subsequently, both OptiShade UI were selected in the patients' folder and shared in the first displayed modality to the CompoShade application.

Once the images were available in CompoShade, in the "open" OptiShade UI, the options "Mid Opn" (Figure 4A) and "Inc Opn" (Figure 4B) were selected, which represent the point in the middle (colored in brown) and the point in the incisal (colored in blue), respectively. The same procedure was repeated for the "closed" OptiShade UI, with these points presenting a different colored frame, as a way to distinguish them from the "open" image (Figure 4C). Concurrently, a metal caliper was used to measure the thickness of the tooth in the same specific spots where the color was selected (Figure 5).

Once the thickness value was introduced in the layering section, both the composite system and the layering strategy should be chosen. CompoShade was then able to provide a recipe containing the order, layer sensitivity, thickness of each layer, and progressive thickness (Figure 6). Additionally, the system allowed the elimination of colors from the composite system selected, leading the software to calculate without computing a color which is not desired by

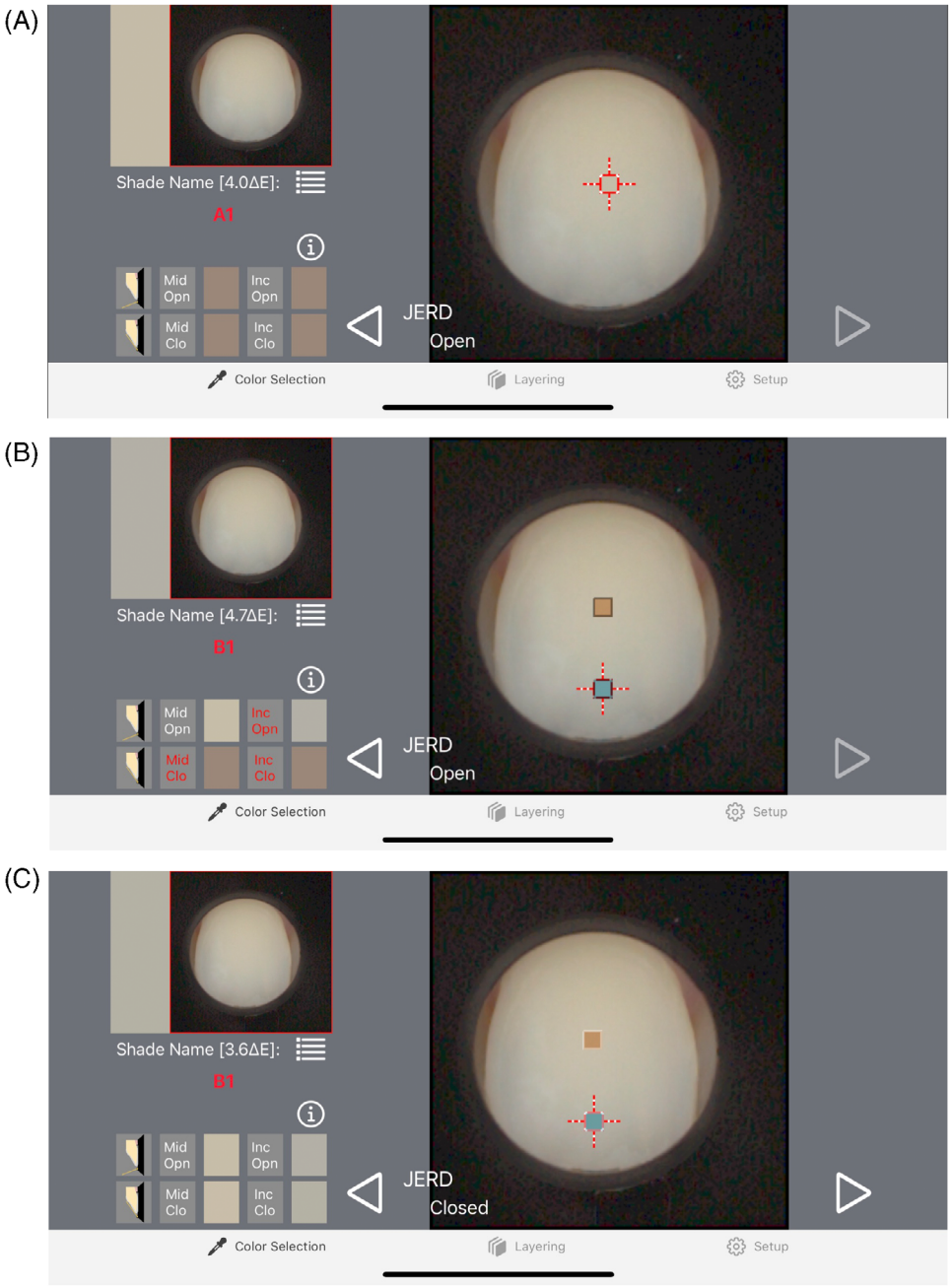

FIGURE 4 CompoShade points: (A) "Mid Opn" point, (B) "Inc Opn" point, and (C) "closed" OptiShade uncontextual images points.

the clinician (Figure 7A) and adapting the recipe accordingly (Figure 7B).

The clinical procedure started with the removal of the old restoration and bevel preparation (Figure 8A) on the right maxillary central incisor. Furthermore, the margins were polished with a Sof-Lex disc (3M, Seefeld, Germany) (Figure 8B). Subsequently, a realistic try-in of the two shades strategy proposed by the system (BioFunction Enamel 2 and Universal Dentin 1, HRi, Micerium, Genoa, Italy) was executed with nonadhered composite. The color integration of the try-in allowed the visualization of the final result, apart from the incisal edge where no characterization was completed at this stage (Figure 9).

The restorative procedures were performed under rubber dam isolation (Nic Tone, MDC Dental, Jalisco, Mexico). Proximal matrices (QuickmatFlex, Polydentia, Switzerland) were placed facing outwards in order to protect the adjacent teeth during the etching (37.5% phosphoric acid, Kerr Corporation, United States) and bonding procedures (Scotchbond Universal, 3M ESPE, United States) (Figure 10A). The same matrices were used later on but facing inwards. The internal dentin structure (Universal Dentin 1, HRi, Micerium, Genoa, Italy) (Figure 10B), and the incisal characterizations (Opalescent Blue Natural, HRi, Micerium, Genoa, Italy) (Figure 10C), were added according to the CompoShade instructions. Finally, the enamel layer was placed (BioFunction Enamel 2, HRI, Micerium, Genoa, Italy) (Figure 10D). It is noteworthy that the correct thickness is easier to achieve when the underlying layers are correctly measured. The entire polymerization process was conducted with Elipar (3M ESPE, United States).

Polishing procedures were carried out with ShapeGuard medium grit (Coltene, Altstätten, Switzerland) (Figure 11A) and lucida paste (Diashine, Lynnwood, USA) and felt wheel (Figure 11B). A photographic record was performed immediately after rubber dam removal (Figure 12A) and at 2-month follow-up (Figure 12B), showing perfect integration of the restoration.

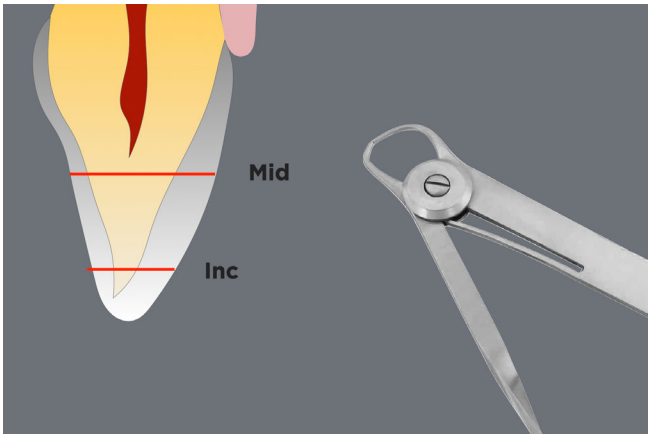

FIGURE 5 Thickness measure.

2.3 | Case 2

A 36-year-old female patient sought medical care due to the desire to replace an unaesthetic restoration in the right maxillary central incisor (Figure 13). Following the previously described procedure, two OptiShade UI were collected from the adjacent tooth. In this clinical scenario, only one thickness measurement was done, in the incisal area. CompoShade (StyleItaliano, Genoa, Italy) then provided a recipe containing the order and thickness of each layer, as well as their progressive thickness (Figure 14).

Once again the previous restoration was removed, a bevel was prepared and the margins were polished with Sof-Lex discs (3M, Seefeld, Germany). Subsequently, a realistic try-in of the proposed recipe was conducted, showing adequate color integration and evidencing the need of incisal characterizations (Figure 15).

Restorative procedures were conducted under rubber dam isolation (Nic Tone, MDC Dental, Jalisco, Mexico), (Figure 16A), and proximal matrices (QuickmatFlex, Polydentia, Switzerland) were placed facing outwards to ensure full visibility (Figure 16B). Then, selective

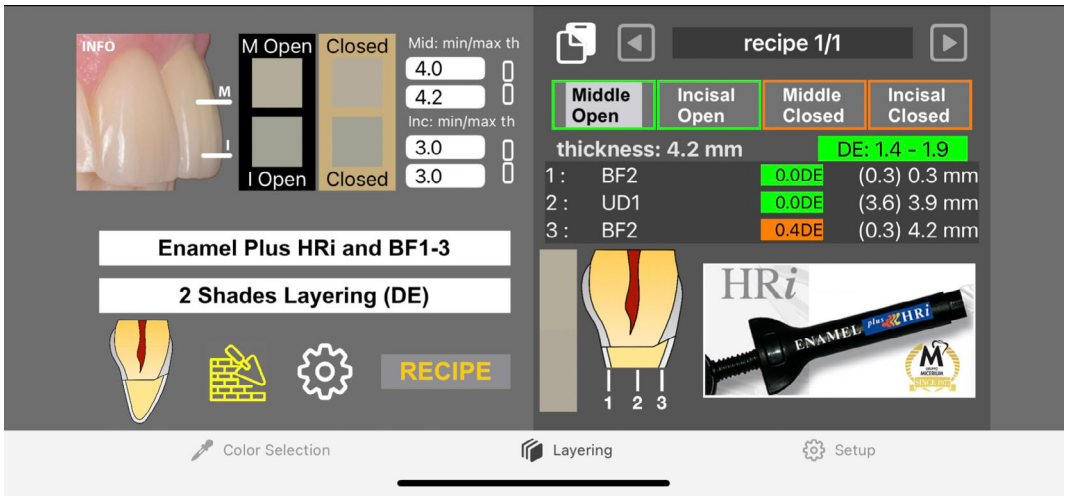

FIGURE 6 Recipe provided by CompoShade.

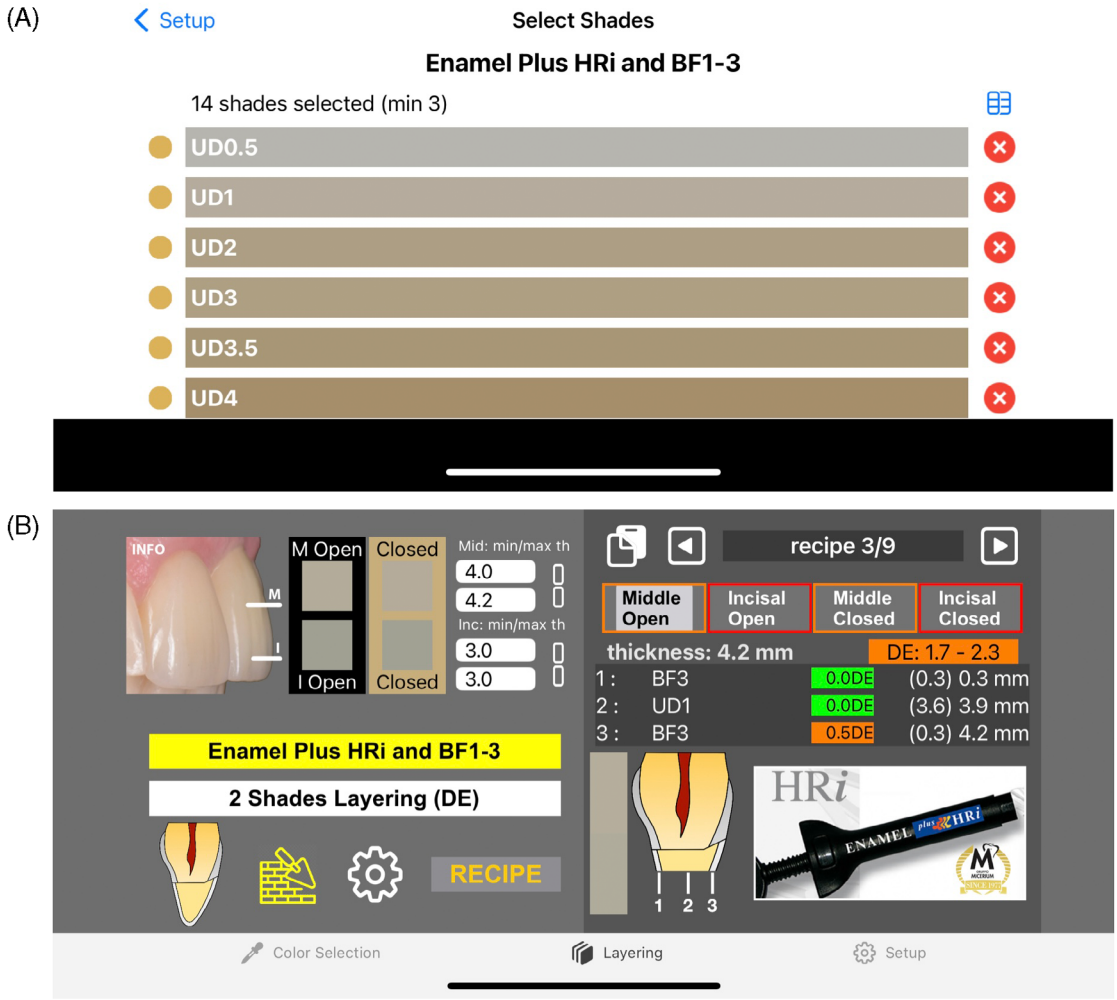

FIGURE 7 Alternative recipe provided by CompoShade.

acid etching was performed with 37.5% phosphoric acid (Kerr Corporation, United States) (Figure 16C) and bonding procedures with Scotchbond universal (3M ESPE, United States) according to the manufacturer's instructions.

Once the surface was conditioned and bonding procedures were carried out, the layer of dentin (Universal Dentin 1, HRI, Micerium, Genoa, Italy) was restored using the finger index technique (Figure 17A,B). It is noteworthy that thickness should only be assessed once the composite is polymerized (Figure 17C), so that the clinician can proceed accordingly, adding more composite or removing the excess if needed. In order to achieve the desired result regarding the incisal characterization, an Opalescent Blue Natural composite (HRi, Micerium, Genoa, Italy) was employed (Figure 17D,E). Then, a proximal matrix was used for distal wall construction (Figure 17F,G). Subsequently, a final layer of composite was applied (Universal Enamel 1, HRI, Micerium, Genoa, Italy) (Figure 17H).

Once the desired layering was obtained (Figure 18A), polishing procedures were conducted, resorting to ShapeGuard medium grit (Coltene, Altstätten, Switzerland) (Figure 18B) and Lucida paste (Diashine, Lynnwood, USA) and felt wheel (Figure 18C). The final integration of the restoration was confirmed before (Figure 19A) and after rubber dam removal (Figure 19B).

3 | DISCUSSION

The two presented case reports leverage advancements in color science, technology, and clinical expertise to elevate patient satisfaction and deliver aesthetic restorations that seamlessly harmonize with natural dentition.

The pursuit of accurate tooth color matching transcends mere optics, intersecting with patient expectations, functional outcomes, and aesthetic preferences. Clinicians are required to understand the importance of harmoniously aligning direct composite resin restorations with the original tooth tissues, without compromising functional and aesthetic standards.[21,28] Accordingly, it is important to acknowledge different materials' optical and physical properties, as well as tooth anatomy and color.[21]

It should be taken into account that dentin is the main responsible for the tooth's shade,[8] as enamel is highly translucent and believed to

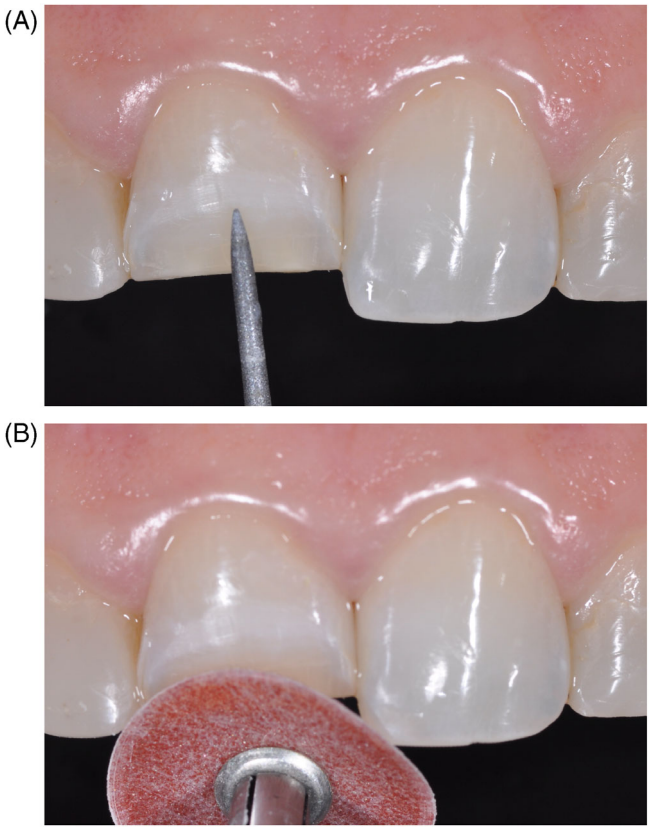

FIGURE 8 Tooth preparation: (A) bevel preparation and (B) margin polishing.

FIGURE 9 Try-in.

act as a color modifier for the dentin layer placed underneath.[28] While enamel can present either a chromatic or an achromatic translucency, dentin has usually chromatic translucency.[28] Variability among individuals should also be considered, with enamel translucency oscillating with age and among different ethnic groups.[29]

The perception of color can be affected by numerous factors, either intrinsic or extrinsic.[3] Illumination conditions,[3] the predominant background color,[7] and the level of surface hydration should be

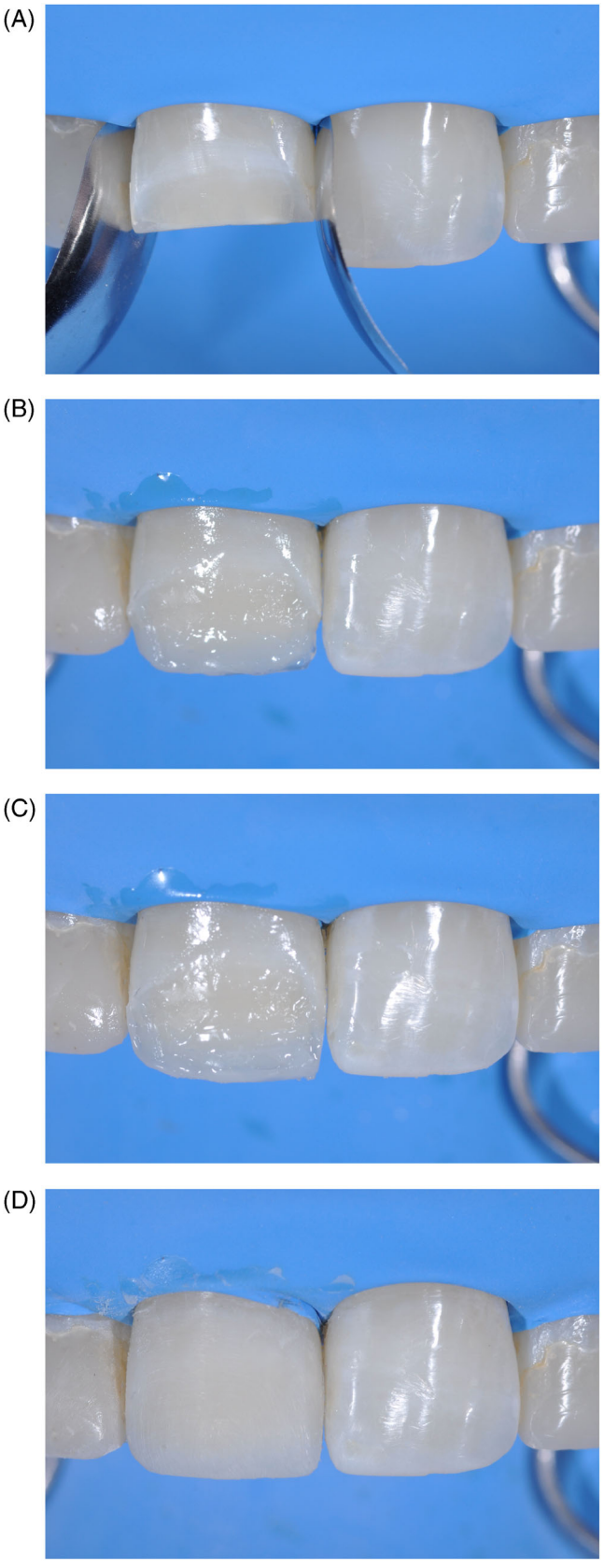

FIGURE 10 Restorative procedure: (A) proximal matrices colocation, (B) internal dentin layer, (C) incisal edge, and (D) enamel layer.

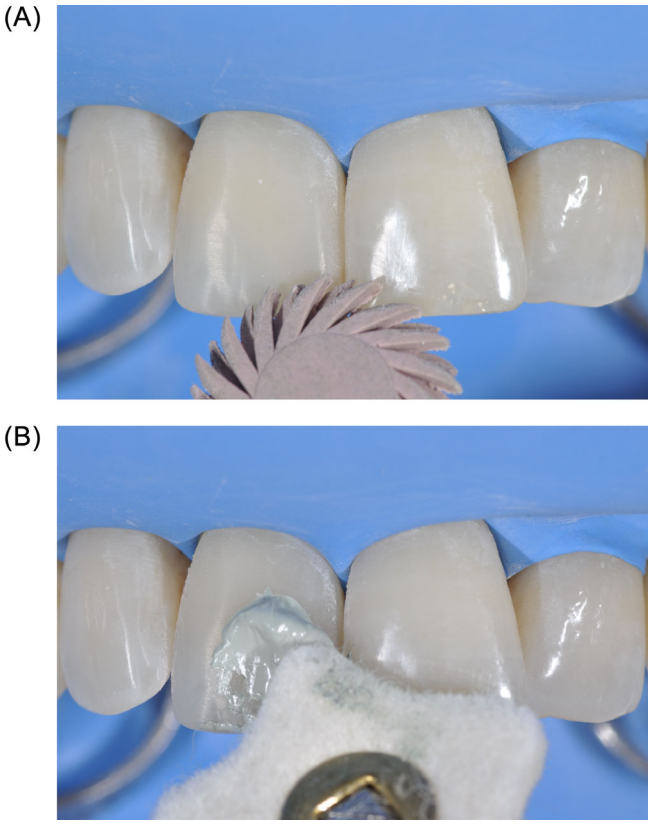

FIGURE 11 Polishing procedures: (A) ShapeGuard medium grit and (B) lucida paste.

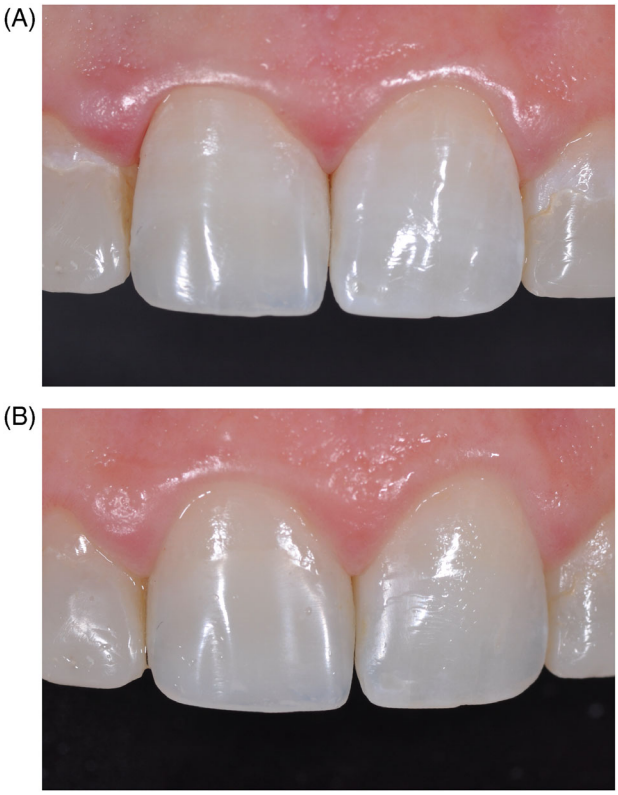

FIGURE 12 Final restoration: (A) immediate post-restorative procedure and (B) 2-month follow-up.

FIGURE 13 Initial intraoral photograph.

accounted for. It is important to take into account that surface dehydration can lead to a decrease in translucency up to 82%, therefore interfering with the color choice.[2]

Shade-matching instruments were introduced with the purpose of minimizing the existent inconsistencies in daily clinical practice,[10] as they can precisely collect a specific shade and cross-reference it to an existing database of fixed shade thicknesses.[10] Although every scale is paramount in color analyses, the L* scale should always be assessed carefully since the human eye is more discerning of value compared with chroma and hue.[23]

Regarding color differences, the authors considered the formula introduced in 1994 (ΔE94) to define the thresholds which have been instrumental in refining the approval process for the OptiShade colorimeter and the CompoShade dental recipes and restorations,[18] since literature has reported its superior homogeneity in the dental color sub-space.[8] By establishing clear acceptability thresholds, clinicians can objectively choose the desired color for anterior restorations, ensuring that the perceptual expectations of both clinicians and patients are met. It is important to note that literature considers 50% of individuals to display a tolerance of approximately 2.6 ΔE regarding color perceptibility.[13]

Composite stratification techniques rely mostly on subjective visual assessment, shade guides, and clinicians' subjective judgment, rather than objective data from color measurement devices.[19,30] One of the most important parameters to take into account is the thickness of the polychromatic layers as this has a direct influence on the optical properties of the restoration.[21] However, clinicians are not accustomed to precisely quantifying this when performing a direct composite restoration. Consequently, the existing gap between the potential of instrumental color measurement devices and their practical application in daily clinical practice has limited their use for many years.[31,32]

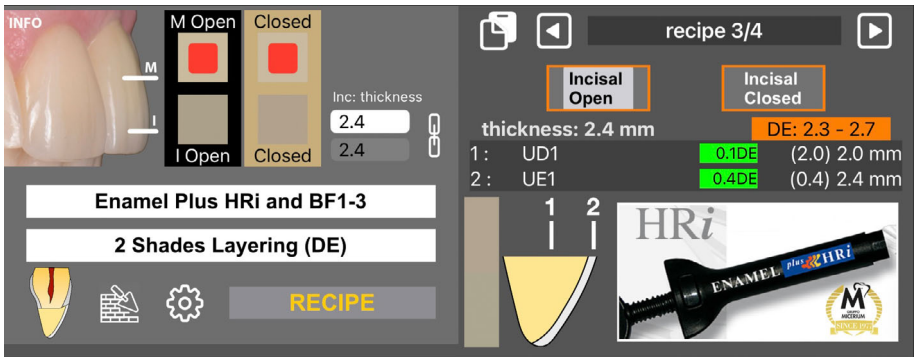

FIGURE 14 CompoShade recipe.

FIGURE 15 Try-in.

The successful integration of the CompoShade app with OptiShade colorimeter measurements in both case reports allowed accurate color matching. By harnessing digital technology, the authors were able to overcome the limitations of traditional color matching methods, achieving superior aesthetic outcomes. The user-friendly interface of the CompoShade app streamlined the restoration process and enhanced clinical efficiency, while OptiShade colorimeter measurements provided objective data that improved the accuracy of shade selection and material manipulation, resulting in restorations that seamlessly blended with natural dentition.

Furthermore, the performed try-ins for the restorations act as a major advantage in anterior teeth, emphasizing the importance of incorporating patient expectations and preferences into the color validation process, and detecting potential errors before the definitive restorative procedure.[18] Try-ins play a crucial role in validating the selected shade and layering strategy, enabling clinicians to make informed adjustments and refinements as necessary. It is important to note that although shape mismatches can be hard to handle, patients tend to report higher dissatisfaction associated with shade discrepancy.[12] By involving patients in the decision-making process and transparently communicating with them, patient satisfaction is maximized.

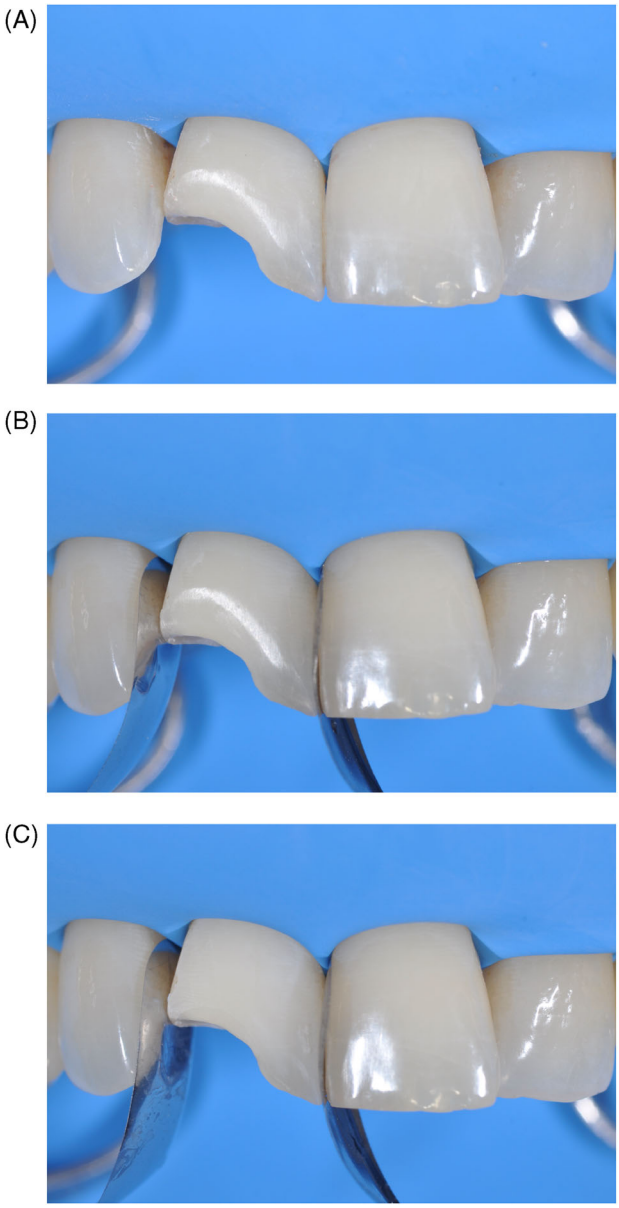

FIGURE 16 Surface conditioning: (A) absolute isolation under rubber dam, (B) matrices positioning, and (C) aspect after selective etching.

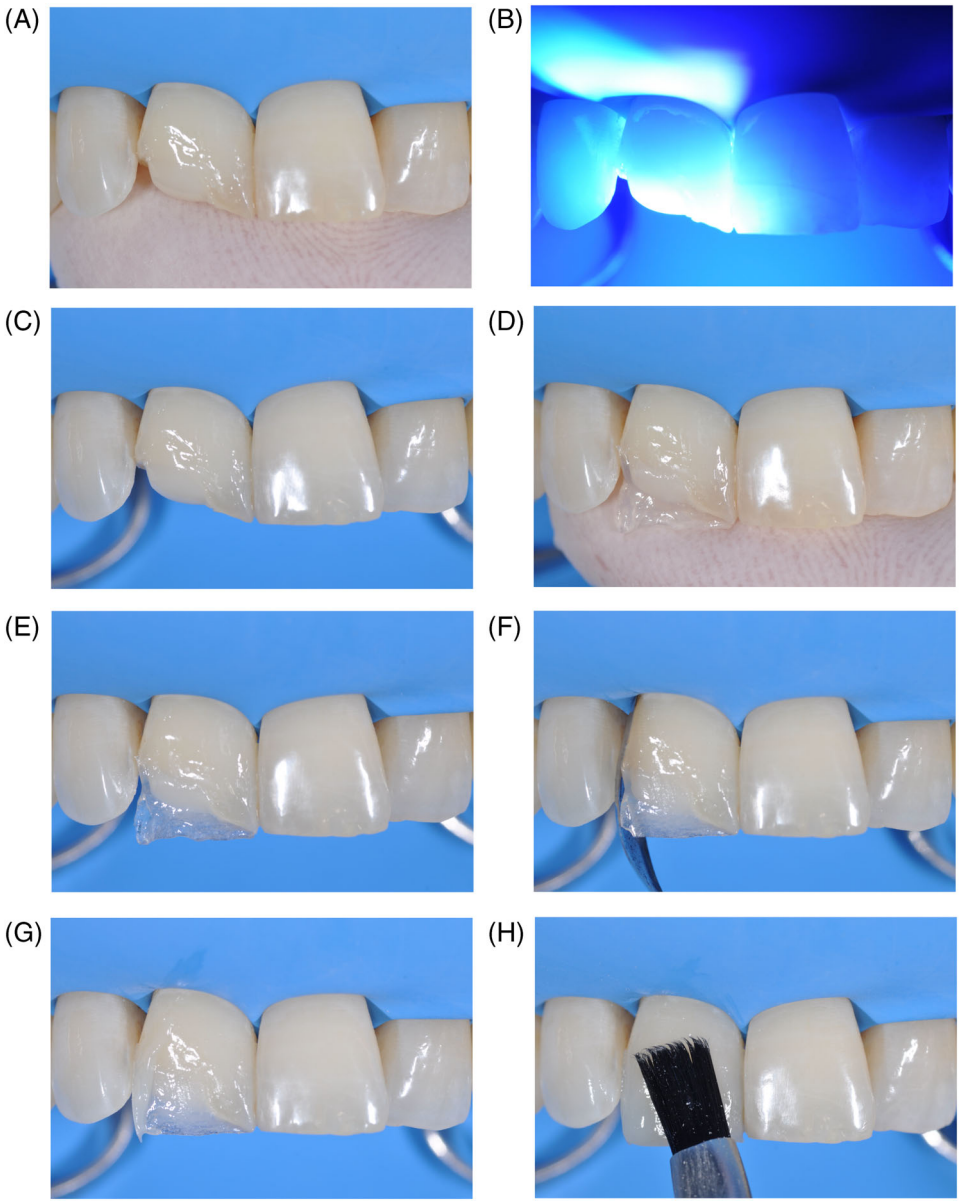

FIGURE 17 Restorative procedure: (A) finger index technique; (B) polymerization with Elipar (3M ESPE, United States), (C) polymerized composite, (D) placement of the Opalescent Blue Natural Composite, (E) incisal characterization after polymerization, (F) proximal matrix for distal wall construction, (G) polymerized distal wall with the matrix removed, and (H) final layer application.

Once the final adjustments are conducted, the clinician is able to perform the definitive treatment with complete tailored guidance. Nevertheless, knowledge of anatomy and adhesive dentistry remains necessary to achieve long-term clinical success. Thus, all restorative principles should be followed using the resins suggested by the software, including the proper use of matrices, adhesive system, and absolute isolation under rubber dam.[33]

The combination of the CompoShade app and OptiShade colorimeter measurements represents a powerful tool for achieving precise color matching and realistic try-ins in anterior composite restorations, being a clear example of leveraging digital technology to enhance clinical workflow and improve treatment outcomes. Further research and clinical validation will be crucial to fully explore the potential of these digital tools in aesthetic dentistry and refine digital protocols to increase color-matching accuracy and clinical predictability, benefiting both clinicians and patients.

4 | CONCLUSIONS

Within the limitations of these clinical cases, the following conclusions are drawn:

- The integration of OptiShade measurements with the CompoShade layering recipe calculation marks a significant advancement in achieving precise color matching for anterior composite restorations;
- The addition of a realistic try-in step before the direct restoration procedure ensures that both clinician and patient expectations are aligned, leading to enhanced patient satisfaction;
- Embracing the presented workflow empowers clinicians to deliver predictable and aesthetically pleasing results, minimizing the subjectivity associated with color assessment.

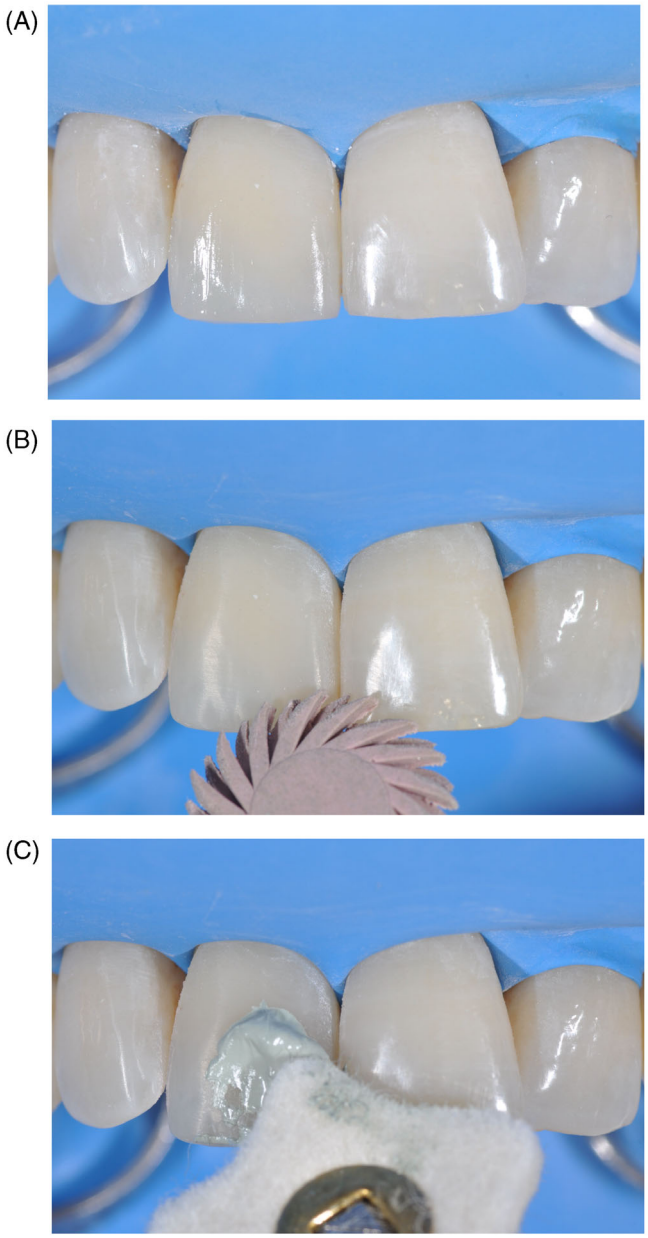

FIGURE 18 Finishing procedures: (A) tooth previously to finishing procedures, (B) ShapeGuard medium grit, and (C) lucida paste and felt wheel.

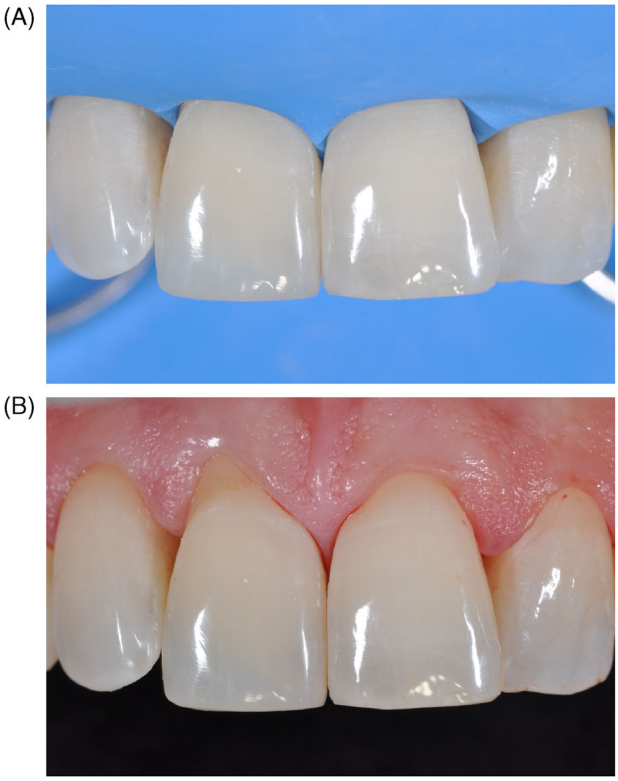

FIGURE 19 Immediate post-restorative procedure: (A) under absolute isolation and (B) after removing the rubber dam.

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CONFLICT OF INTEREST STATEMENT

The authors declare that they do not have any financial interest in the companies whose materials are included in this article.

DATA AVAILABILITY STATEMENT

The data that support the findings of this study are available on request from the corresponding author. The data are not publicly available due to privacy or ethical restrictions.

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