

# The i3d Shade Matching Technique: A Case Report

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## Abstract

**Objectives:** In direct composite restorations, successful shade matching is considered as one of the most difficult task to accomplish. It is based on a subjective comparison between a shade tab and the natural tooth and as direct composite restorations are realized within one single appointment, no "try-in" is possible. Therefore the search for a reliable shade matching procedure is still going on.

**Materials and Methods:** Based on the fact that composite shade is thickness-dependent and that a natural tooth is built up of enamel and dentin with individual 3D thicknesses, a novel shade matching technique was developed respecting the natural three-dimensional structure of the tooth to be reproduced by the restorative composite material. CBCT data of an upper central incisor were converted into stl 3D files and a pair of 3D printed molds was acquired. One represented the negative of the root and the dentin core and the other one represented the negative of the enamel complex. By using these molds, an individual 3D shade tab perfectly reproducing the natural tooth morphology was fabricated out of pre-selected composite materials and used for shade comparison with a fractured upper central incisor.

**Results:** The preoperative  $\Delta E$  value of approximately 3.46 of the custom shade tab-tooth has decreased into a postoperative  $\Delta E$  value of 1.96. The vertical  $L^*$  axis represented by Lightness made a significant positive difference (-3.07 to -1.78) when dentin material was modified while maintaining the same initial three-dimensional structure of the tooth to be reproduced, in both the custom shade tab-tooth and in the final restoration.

**Conclusions:** The proposed method significantly improved the shade matching of a direct composite restoration within one appointment. In the future, the i3D technique may be also used for 3D printed composite restorations and for the development of more aesthetic composite materials as well.

**Keywords:** 3D shade matching; 3D shade analysis; Composite resin; Aesthetic dentistry; Adhesive Dentistry; Layering Technique; Stratification Technique

## Introduction

The successful outcome of direct composite restorations largely depends on the skills and abilities of the clinician [1,2]. Consequently, the application of predictable treatment protocols is mandatory to meet patients' expectations [3].

Shade matching is considered one of the fundamental restorative steps, which determines successful treatment outcome. By definition, it refers to the accurate shade assessment and reproduction of natural dentition with ceramic or composite restorative materials and applies to both direct and indirect restorations. After many years of clinical and laboratory research, shade matching between natural teeth and dental restorative materials still remains a challenging task [4]. Within indirect restorative procedures [5-7], three steps are implicated: The first step comprises two different aspects, shade mapping and shade matching. The second step consists of the communication of tooth color to the dental lab and the third step involves shade reproduction and verification with the restorative materials within a "try-in session". In the case of direct restorations [8-11], these three steps are reduced to one, omitting the communication with the dental technician and thus eliminating numerous subjective factors that influence shade determination but omitting also the try-in session, which allows for shade correction before the definitive incorporation of the restoration [12].

In direct restorations, the first stage of the overall shade matching-process aims the identification of shade distribution named 'shade mapping' and the second stage is matching or segmental correlation between natural tissues and composite materials, named 'shade matching' [13]. At this stage matching occurs between the prefabricated shade guide and the natural tooth. As direct restorations do not comprise the verification step within a "try-in" session, the final result can only be

verified with the definitive restoration several days postoperatively after tissue and material rehydration.

It is broadly agreed that contemporary composite systems include enamel, dentin and effect masses that closely mimic and should be able to reproduce the natural tissues. Unfortunately, a history of complaints about shade mismatching between teeth and composite restorations still exist due to a variety of causes [14]. One reason for this mismatch is the fact that a lot of prefabricated shade guides are not made of the same material as the final restoration [15,16]. In addition, short-term material changes are observed a few days after restorative session due to post-polymerization and water sorption [17-20]. Another issue is the fact that shade may be different before and after polymerization of the composite material [20,21].

To be able to reliably judge on the final shade of a direct composite restoration including the aspect of the dental morphology, a custom fabricated shade guide replicating the exact anatomy of the tooth to be restored is obviously the best choice [22-25]. An attempt has been made to follow this direction by the introduction of shade guides consisting of a standardized dentin and enamel layer [26], made of the same material, which is subsequently used for the restoration. However, this approach has several limitations: The interface between the dentin core and the enamel shelf is not continuous, which, according to our internal evaluations changes the light transmission and as a consequence

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modifies the shade in comparison to a monoblock of a real restoration. In addition to that, only one type of anatomy for enamel and dentin is available with this type of shade guide, which limits its transferability to the clinical situation. To cope with these limitations, an ideal shade guide should be fabricated out of the same batch of composite material, which will be used for the composite restoration, and it should perfectly reproduce the anatomical aspects of the tooth to be restored. An interval of several days of storage in 100% humidity in the dark between shade guide fabrication and restorative session might stabilize the final shade as post-polymerization and water sorption will be terminated.

One purpose of this study was to present and validate a novel individual 3D shade matching technique to improve the classic subjective shade matching procedure. Another purpose was to propose future indications beyond subjective shade matching based on the developed technology.

## Materials and Methods

A 28 years old female patient was included in this research study, according to two selection criteria. The first was to have a fractured upper central incisor, restored with composite material (Figure 1) based on a 4-sequence treatment protocol. The second was to have CBCT data of this patient available from another dental treatment (i.e. implant treatment, surgical extraction of wisdom teeth etc.). The patient was informed about the purpose of the study and signed an informed consent for the use of the data of the existing cone-beam computed tomography for the purpose of this study, as well as for the photographic analysis and polyvinylsiloxane impressions that were necessary for the fabrication of stone models, which were used in this study.

The tomographic acquisition was performed using a Cone Beam Computer Tomography Device (Planmeca, Promax 3D Max, Finland) with the following acquisition parameters: All scans were output with  $512 \times 512$  pixels per slice and 8 bits per pixel. Resultant voxels were isotropic having identical length, width and depth of 0.16 mm. The acquisition time for each slice was 12s and the reconstruction time was 60 s at an angular increment of 0 degrees.

CBCT Dicom data were examined following by applying methodologies. The first one consisted in converting Dicom data into .stl files. To this purpose, DICOM datasets were imported to Simpleware ScanIP version 7.0 to produce a volumetric image. The teeth were examined and the image volume then cropped to surround the tooth of interest for each dataset. Filtering and segmentation tools were then used to select the dentine and enamel regions of interest. Finally, after 3D editing the teeth to improve accuracy with respect to the scan images, the models were converted to surface .stl models ready for 3D printing.

The three-dimensional tooth prints were performed with ProJet 1200 3D printer (3D Systems Corporation, Rock Hill, South Carolina, USA) and micro-SLA technology. UV curable resin was used to create the model of the tooth layer by layer. Due to the very high resolution of the printer of 585 dpi, accurate and detailed models were obtained. Following printing procedure and initial curing, 3D print works were additionally cured in an appropriate UV curing device. In this way, a pair of three-dimensional print outs of the natural central incisor to be reproduced was acquired: One 3D print represented the dentinal core consisting of the root and the dentin core of the crown and the other 3D print represented the entire tooth (enamel and dentin) (Figure 2). Both 3D prints were duplicated which generated molds for the accurate reconstruction of dentin and enamel with appropriate dentin- and enamel shades.



**Figure 1:** Preoperative situation of a previously restored central incisor with composite resin (tooth 21). Patient complained for an unpleasant greyish appearance of the composite restoration. This discomfort was considered an indication for restoration replacement.



**Figure 2:** The 3D printed central incisor to be reproduced, was fabricated by converting Dicom into STL files. Thus the three-dimensional structure of the natural tooth and as a consequence of the composite restoration was accomplished.

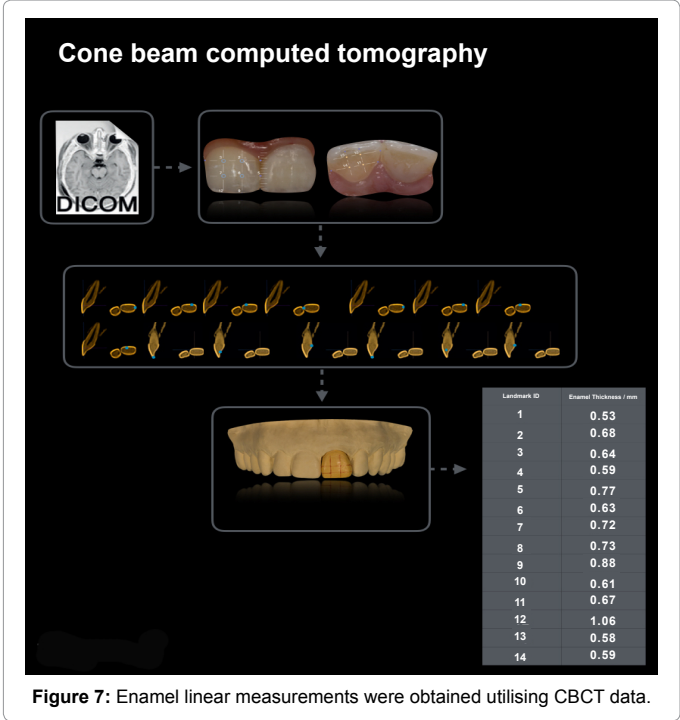
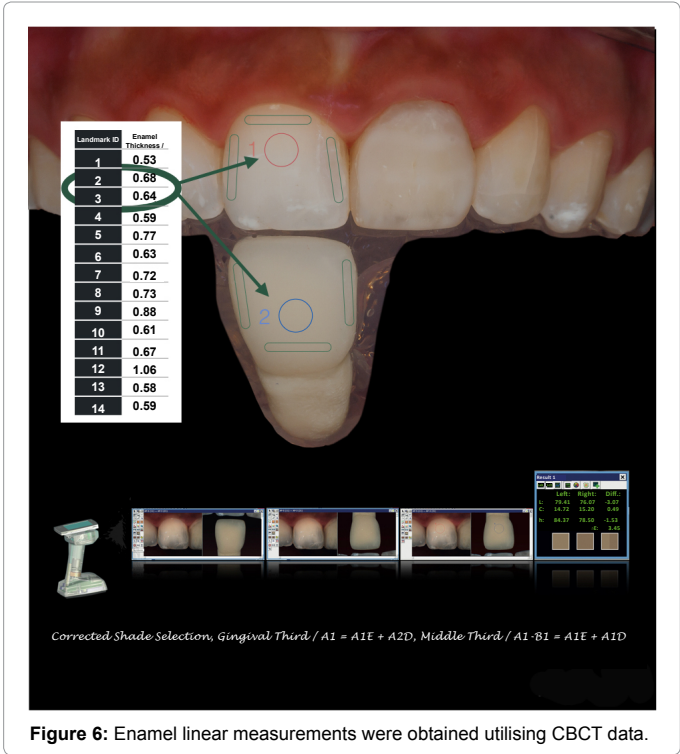
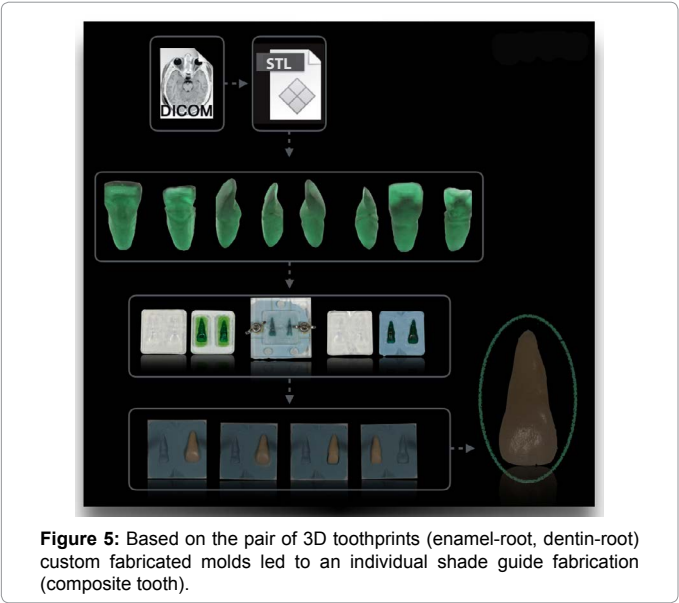
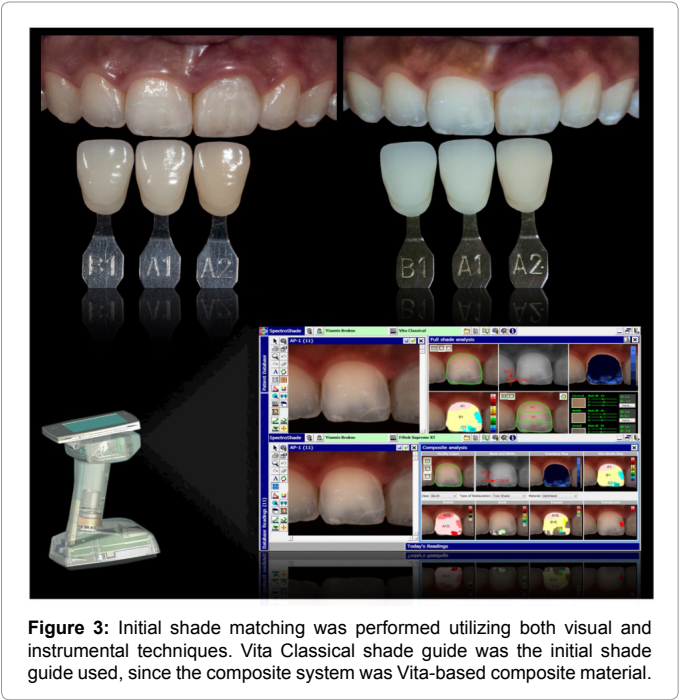
To avoid the fabrication of all combinations of the available enamel and dentin shades with the individual 3D shade guide a preselection of the most appropriate shades for enamel and dentin was performed by comparing 3 most closest commercial Vitapan shade tabs with the tooth subjectively and by using Spectroshade (MHT, Handy Dental Type 71,3000, S/N: HDL0438, MHT, Verona, Italy) (Figure 3). The goal of both methods was to narrow the choice of the shades based on the commercial Vitapan Shade guide.

Digital photographs were used for high quality photo-documentation of the teeth. The digital equipment included an SLR camera body (Canon EOS 550D) with macro lens (Canon EF 100mm) and a macro twin-light flash (Canon MT-24EX). Canine-to-canine aspects of the upper anterior dentition together with 3 Vitapan shade tabs were documented with normal and polarized photographs. The best shade match was identified and further refined by using a digital reflectance spectrophotometer (SpectroShade). The shade tab selected by this procedure was assigned to the composite system's shade guide for enamel and dentine (Figure 4).

A composite tooth with the anatomically correct 3D representation of enamel and dentin was fabricated with the selected enamel and dentin composite masses by using the individual 3D molds for dentin and enamel (Figure 5). The final comparison between the natural and the composite tooth was done subjectively on intraoral polarized pictures objectively by using the spectrophotometer (Figure 6).

The second methodology of fabricating a custom shade tab was performed after obtaining linear enamel measurements from the Dicom data (Figure 7) used for the working model (Figure 8). The final comparison between the natural and composite tooth (shade tab) was evaluated with intraoral polarized pictures (Figure 9).

Any shade mismatches of  $L^*$ ,  $a^*$ ,  $b^*$  values were recorded prior to the restorative phase and refined in course of the layering technique



of enamel and materials (Figure 10) and finally evaluated one week postoperatively (Figure 11), always meticulously respecting the three dimensions of the natural tooth (Figure 12).

### Results

The  $\Delta E$  value and the  $L^*$ ,  $a^*$ , and  $b^*$  values of the natural central incisor and the 3D shade tab tooth are presented in Figure 13. The

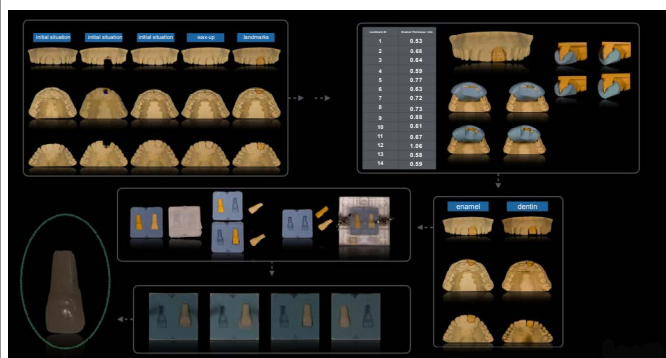


**Figure 8:** Enamel measurements from the clinical crown of the tooth, were applied on the working model to form similar samples, such as the pair of 3D toothprints for an individual shade guide fabrication (second option).



**Figure 11:** A few days after tissue and material rehydration, composite restoration was verified visually and instrumentally.

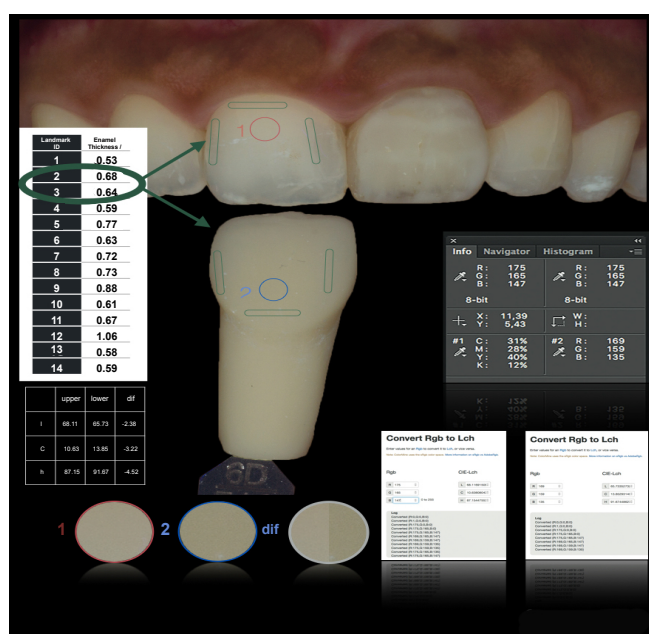


**Figure 9:** An accurate clinical crown was fabricated from the selected enamel and dentin composite materials and used as a custom shade guide. Prior to any restorative procedure, shade assessment was performed between two identical structured samples, natural and composite tooth. The parameter of thickness was again eliminated from the shade matching process. Numerical data acquisition was performed using Adobe photoshop.



**Figure 10:** Custom made measuring instruments with tips of 0.25 mm, 0.5 mm, 0.75 mm, 1 mm, were used intraorally during the layering of enamel and dentin materials, for accurate thickness reproduction.

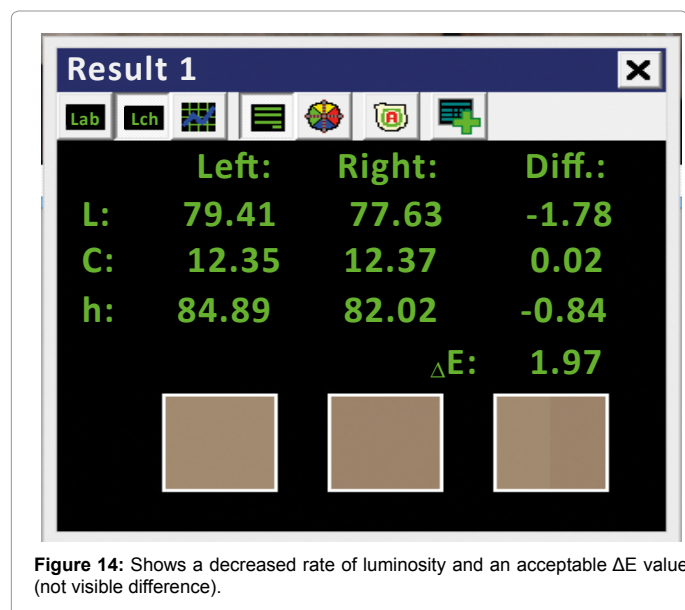


**Figure 12:** Postoperative situation 1 week later. The successful restorative replacement was performed predictably.



**Figure 13:** Shows significant difference mainly in luminosity (visible difference).

$\Delta E$  value and the  $L^*$ ,  $a^*$ , and  $b^*$  values of the natural central incisor and the final restoration are presented in Figure 14. The preoperative  $\Delta E$  value of 3.46 of the custom shade tab tooth, visible to the average person, has decreased into a postoperative  $\Delta E$  value of 1.96, detectable only by an experienced observer. The L number, representing lightness or value made a significant positive difference (-3.07 to -1.78) when dentin material was modified while maintaining the same initial three dimensional structure of the tooth to be reproduced, in both custom shade tab-tooth and in final restoration. Hue and chroma were not affected significantly having values relatively close to those of the natural tooth. The accuracy of Spectroshade was not affected by any conditions, because both natural tooth and composite restoration were



measured within patients' oral environment, 1 week postoperative thus after rehydration and post polymerization.

## Discussion

One of the main objectives in clinical restorative dentistry is to develop predictable direct and indirect adhesive techniques able to restore both anterior and posterior dental teeth in a natural and imperceptible way. Predictability refers to a straightforward procedure that aims to decrease the risks of failure. In the field of shade matching the risk of failure is particularly high for direct composite restorations, as they are usually realized within one single appointment [27-30], lacking the biscuit try-in usually preformed for indirect restorations.

Composite shades being heavily thickness dependent [31], predictable shade matching guides [32] must consider detailed and precise 3D morphology of the tooth. Even if attempts have been made to introduce the anatomical aspect into prefabricated shade guides [33], this approach is incomplete and has two major drawbacks which are the optically inappropriate connection between enamel and dentin and a standard anatomy which does not consider the individual situation. Recent research evaluated linear enamel measurements, *in vivo*, by using cone beam computed tomography [34]. It quantitatively revealed *in vivo* that enamel thickness was influenced by age, gender, type of tooth and area of measurement. Central and lateral incisors were statistically different from canines. Enamel was thinnest in the palatal areas and thickest on the incisal edge and decreased with age. As a consequence, shade guides, even if being composed of enamel and dentin layers cannot correctly represent the situation of an individual tooth. This was the main reason for the development of an accurate individual 3D shade matching procedure, which considers the exact anatomy of the individual tooth to be restored based on CBCT data. It is obvious that such an approach is only possible in the case of a pre-existing CBCT data of the patient because it is not reasonable to irradiate the patients just to improve shade matching. It is also obvious that the described, fabrication procedure of the individual 3D shade tab

based on the CBCT data, presents two disadvantages. It is time consuming and expensive.

Based on the results, a further development may take place which will use the latest technology: Instead of basing this technique on 3D CBCT data, 3D NIR reflection or transillumination data will be used which avoid the issue of irradiating the patient and in addition to this, significantly decreasing the costs of a 3D scan. Instead of 3D printing the model of the tooth based on the 3D data and fabricating molds for hand-made dentin and enamel layers, 3D printable composite materials will be used not only for printing a shade tab, but for the direct printing of the definitive restoration. Finally, the presented technique is intended to be used for reverse engineering allowing composite manufacturers to optimize their composite materials by 3D printing their existing shades to anatomically correct models, comparing them with real teeth which served as basis for the model and, based on this comparison, fine tuning the esthetic properties of their composite materials.

## Conclusion

The proposed individual three-dimensional layering technique (i3D layering technique) refines the shade matching procedure for a direct composite restoration by allowing for an initial preview of the chosen composite shades based on the real natural 3D anatomy of the respective tooth. In future, the described technique may be used for testing and development of more aesthetic composite materials as it allows for the direct comparison of the anatomically correct restorative copy to the original natural tooth.

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