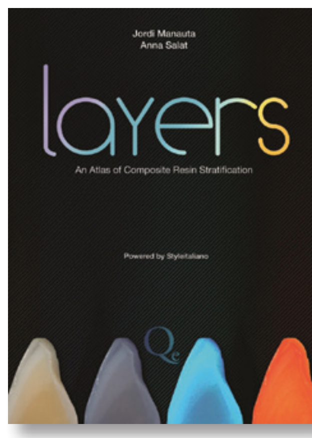
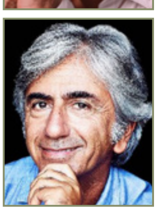
IN & OUT: A new concept in composite stratification



By Dr Jordi Manauta, Dr Walter Devoto and Prof. Angelo Putignano



Every single time we face a tooth to restore, a challenge comes to mind - probably the most disturbing one is dealing with colour. In this article, we're proposing a new method for colour matching and clinical stratification thru simple procedures and based on two beautiful tissues, dentin and enamel, studying their characteristics and applying them to our dental materials.

Enamel is the skin of the tooth, while dentin is the muscle... one protects and the other gives strength. Separately, they are two susceptible structures, useless for everyday function, as in the example.

To imitate the tooth correctly, we must know very well the properties of dentin and enamel separately and together.

The IN layer

We call the dentin the *In layer*, because it is located on the inside and is the deepest in the stratification.

The base Chroma (Hue and Chroma) is given by the dentin, which dominates the chromatic nature of teeth.

Dentin is the most abundant tissue in the tooth; it provides resistance and elasticity to the dental complex. Despite its apparent similarity to enamel, dentin is completely different physically and optically. Generally, dentin is a reddish yellow and has a high chromaticity and a remarkable opacity. It is also a highly fluorescent tissue, because of the presence of certain proteins, such as photochrome.

It is commonly stated that dentin is opaque; in fact, dentin is more opaque than enamel, but it is also translucent.

To achieve faultless restorations, one of the most important features we must consider is the appropriate level of translucency and opacity. The dentin acts as a very efficient opaquer: It hides dark colours but can let light pass through efficiently.

Several studies have reported numeric data for the translucency and opacity of several restorative materials. Therefore it is relevant to become acquainted with the translucency parameters of natural enamel and dentin. In this way, we will be able to choose the appropriate composite resin in each clinical situation. For example, if we are fabricating a small restoration that will be placed

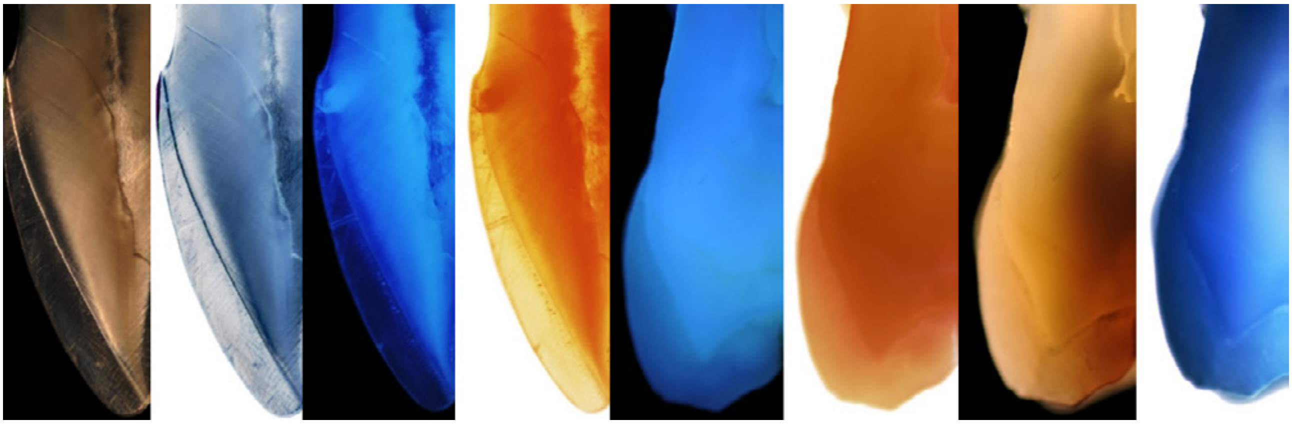


Figure 1. Natural teeth are our role model, but because dental materials are so different from natural tissues, some strategy needs to be employed when trying to imitate them.

in healthy surrounding tissue, we would be interested in a more translucent material to display and reflect the underlying tooth structure. For a large restoration, we would suggest an opaque material for buildup, because if it were too translucent, it would be unable to mask the black background of the oral cavity.

Studies have determined the translucency of 1 mm of human dentin and human enamel to range between 16.4. and 18.7. For comparison, the same thickness of several composites was between 6.3 and 17.2. Higher numbers correspond to a higher translucency; in a completely opaque material, the translucency would be 0.0.

There are significant differences in the opacity of the dentin composites available from various composite manufacturers. Understanding the opacity and translucency of the different brands is mandatory in order for the professional to select the correct composite resin (Figures 1-10).

Selection of dentin shades for stratification

One of the most important parameters in shade matching is determination of the correct saturation and Chroma for the natural dentin. Most teeth have a Hue in the A range. Some authors have estimated that this is the case in 80% of teeth. Other authors have measured the Hue to be around 580 nm, meaning a red-orange Hue that corresponds to shades A2, A3 and A3.5 (Figures 11-12).

Many modern aesthetic composites only include shade A dentins in their systems.

Figure 2 (Above). Composite discs of different brands, have a very similar appearance, but in the reality they behave completely different in every sense, in chromaticity, opacity and physical properties.

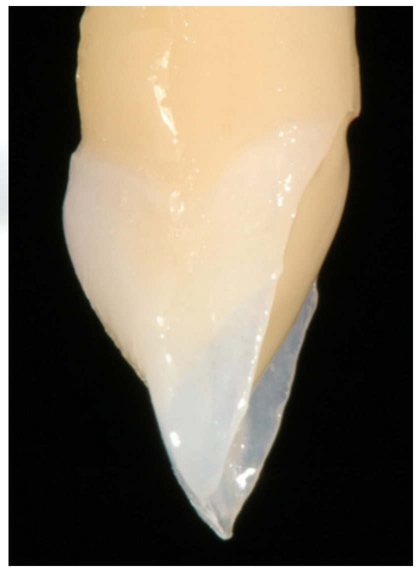


Figure 3 (Right). A stratified tooth, displaying the different layers of enamel and dentin, the key to success is the layer thickness accuracy.

Ideal properties of a composite dentin

The ideal properties of a composite dentin include:

- High Young modulus;
- High elasticity;
- Fluorescence;
- Low refraction index;
- Optimal opacity-translucency;
- Orange-red hue;
- Ability to opacify;
- High iridescence;
- Efficient light transmission; and
- Compression resistance.

A material with all these features would be an exact copy of the human dentin, which at present is not technically possible.

Where composite resins, acrylic resins, and ceramics fail currently is on the efficiency of light transmission; the composite is not able to opacify effectively without losing its translucence and light transmission properties.

Nonetheless, physical properties are improving as materials evolve. Fluorescence of materials has been calibrated to natural teeth and colour properties have improved considerably over the last decade.

The choice of dentin composite currently is limited to the following properties:

- High fluorescence;
- Adequate opacity;
- Correct hue and chroma; and
- Favourable physical properties.

Figure 4. Dentin disks arranged from thinnest to thickest (left to right) under direct light. The thicker the sample is, the better it masks the black line.

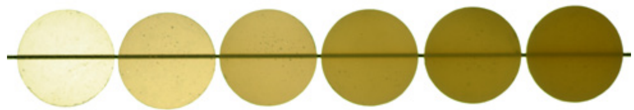


Figure 5. Dentin disks arranged from thinnest to thickest (left to right) under transmitted light. The thicker the sample is, the less light goes through.

Figure 6. Different brands of composite resin, shown in the same thickness of A3 dentin, under direct light. The differences in Chroma and Hue are obvious.

Figure 7. Different brands of composite resin, shown in the same thickness of A3 dentin, under indirect light. The differences between their opacity and light transmission are revealed.

Figure 8. Different brands of A3 dentin composite have been photographed under direct light. Differences in Chroma and Hue are obvious.

Figure 9. The same samples are shown under transmitted light. There are obvious differences in opacity, although all samples were calibrated to have the same thickness.

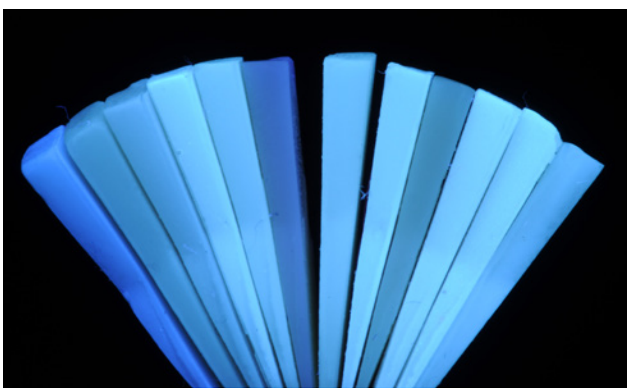


Figure 10. The fluorescence of the different samples from different companies is quite variable.

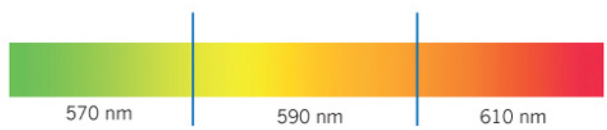


Figure 11. Part of the color spectrum which comprises the dentin colours, very close to the "A" colour of the Vita shade guide.
Figure 12. The average Hue of incisors and canines is 580 nm (red-orange), which corresponds to the tones A2, A3, and A3.5 in the Vita shade guide.

Figure 13. Optical features of the enamel include opalescence, iridescence, reflection, refraction, diffusion and scattering among others.

Figure 14. The most common failure resides in an incorrect layer thickness and arbitrary material selection, many times misguided by company instructions.

Figure 15. A well hydrated tooth displays all the features of the enamel and dentin.

Figure 16. Different degrees of translucency and opacity, when one lacks the other increases.

The "OUT" layer

We call the masses that are used to reproduce the enamel Out layers.

The enamel is primarily responsible for regulating the Value, or tooth brightness, and is characterized by a high degree of translucency (compared with the dentin) and unique light effects (Figure 13).

Enamel is composed mainly of hydroxyapatite and a lesser percentage of organic matter and water. The crystal structure of enamel prisms allows light to pass with little restraint, while the organic interprismatic substance shows high opacity. Without this interprismatic substance, enamel would appear gray or blue. The composition of the enamel makes it a unique complex of reflection, transmission, and absorption of light. The enamel acts as an advanced system of optical fibers; it helps to transmit light into the dentin, which is then responsible for spreading light and consequently generating a complex combination of light effects. The combination of the highly translucent enamel prismatic structure with the more opaque interprismatic matter, makes enamel both translucent and a high-Value substance at the same time. Industrially it is still not possible to align two components so different with the same disposition and nanometric dimensions as the enamel prisms.

Hence, there is a difference in behavior between dental materials and natural enamel. The goal, of course, is to make light travel on the materials in a way that is similar to the way it travels in natural teeth. To do this we measure the refractive index of the enamel and try to find the same in the composites. The refractive index is the way the light travels through an object, that is, its speed and direction. The vast majority of composite masses do not have the same refractive index as natural enamel, so if the composite is placed in the same thickness as the enamel, optical integration will not be achieved. Clinicians try to solve the problem through layering, placing enamel composite layers that are thinner than those of the natural teeth.

It is vital to design layering techniques for each specific composite because each one has different formulation and properties. The final composite thickness has a particular importance for integration of the restoration, because it regulates the light and colour in the tooth.

Natural enamel is translucent and luminous at the same time, while composites act as a vitreous material; this makes it difficult to maintain preferred levels of luminosity and translucency at the same time, because opacity increases when luminosity does and vice versa. This fact has hampered clinical practice. Usually the level of translucency we would wish for enamel composite would force the material to lose brightness, thus decreasing the Value of the restoration (creating a grayish appearance) (Figures 13-15).

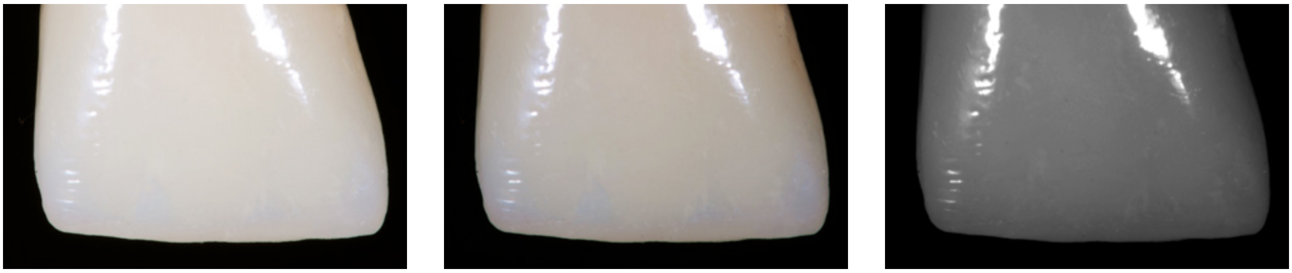


Figure 17. Dental materials are only able to generate a minimum quantity of opalescence in a single mass. Advances are getting closer to these features. On the image, a composite tooth photographed, digitally enhanced and in grayscale to see the features of the material.

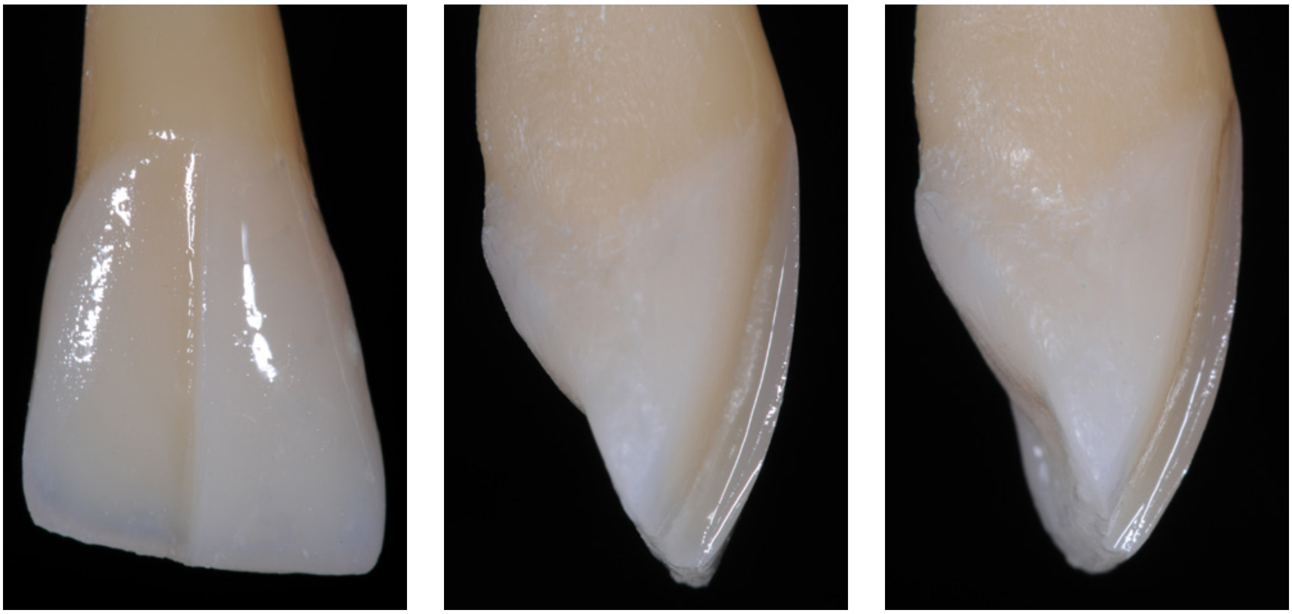


Figure 18. Value decreases dramatically when enamel is removed.

Figure 19. An effective composite enamel must increase its opalescence while increasing its thickness.

Glass Effect

A disadvantage of transparent and translucent materials is that they lose Value as their thickness increases. They become gray or blue, representative of a violent light absorption (“killing light”).

Composites behave similarly to glass; they lose brightness as they increase in thickness. In contrast, in natural tooth enamel, thickness is directly proportional to the total luminosity of the tooth. Therefore, when enamel composite is used in high thicknesses, it develops the so-called glass effect and the restoration becomes gray.

This difference in behavior is essentially the result of the difference in the refractive indices of composite resin and enamel.

Translucency is a main feature of natural enamel. There are very translucent enamels, almost transparent, as in abraded and fine teeth at the incisal edge, but they never become completely transparent. Transparency is the maximum expression of light transmission through materials, allowing a clear vision through them, while translucent materials blur the background and opaque materials totally block the passage of light. Transparent materials do not exist in dentistry.

Enamel opacity

Compared with dentinal tissues, enamel structure has a highly translucent appearance. Actually, enamel has a high degree of opacity, especially in areas with thicker enamel and only allows partial passage of light.

In areas such as the incisal edge, enamel allows light to pass through very efficiently, providing translucent and opalescent effects despite the fact that no tooth structure is transparent. The incisal edge is where less dentin is found and the translucency of enamel is best appreciated.

The synergy between the enamel and dentin makes the tooth an object that plays with light in a unique way that allows light to pass through enamel, where it is stopped by dentin. Both enamel and dentin have a completely different appearance when analyzed separately or together (Figure 15).

Translucency

Colour has three dimensions: Hue, Chroma, and Value. Translucency, which also must be taken into account, is often forgotten. Translucency is defined as the degree to which a semi-transparent object allows light to diffuse through it. A semi-transparent body can be defined as an object that blocks between 0.1% and 99.9% of light; consequently there are numerous degrees of translucency.

In dentistry, to simulate the enamel, we combine two phenomena, translucency and Value. Increasing the Value of composites is commonly done by increasing its whiteness, but when Value is changed, translucency becomes altered. As a rule, an increase in Value increases the opacity. Investigations are still underway to develop composite resins that will transmit light in the same way as natural enamel. The secret will be to increase the Value without losing translucency.

With high-translucency composite resins, restorations gain colour depth and the illusion of a natural and vital tooth. If the outside layer has little translucency, it will mask underlying dentin, its characterizations and effects. If enamel composite is excessively translucent, however, there will be excessive absorption of light and minor reflection of it, which means loss of light and Value and a gray restoration.

In dental tissues, this occurs but in a less significant degree, because the enamel optically transmits light very efficiently, so it achieves both proper translucency and a high Value. The Value and brightness of enamel are closely related to the degree of mineralisation and hydration.

Spontaneous opalescence

One complex task in dentistry is to appreciate the degree of translucency of the natural tooth and correctly pair it with its corresponding composite. We must learn to perceive the different opacities, carefully look at teeth and develop an appreciation of the diverse patient enamels. We can achieve this proficiency by becoming expert observers, developing the ability to perceive slight differences among enamel translucencies.

Materials that try to simulate enamel and have the best optical properties share one common characteristic: opalescence, an attribute of natural enamel, characterised by its optimal light transmission and unique colour effects. With the currently available composites, we can reproduce some highly opalescent restorations.

To appreciate the opalescence of a material, it is necessary to observe at different angles of incidence and transmission (eg, move the sample and look at it under direct light and transmitted light. Opalescent enamels alter the passage of light; they look blue and white under direct light and show amber and orange effects when observed under transmitted light.

The ideal combination would be an enamel that has the property of being white under direct light and amber and orange under transmitted light or, in other words, the ability to look like an opaque material but allow the very efficient passage of light.

Enamel thickness

The natural tooth enamel acts as an efficient mask for the dentin and increases the tooth Value. In areas where enamel is removed, the overall tooth chromaticity increases dramatically and thus the Value decreases. When the tooth is observed in the area where enamel has not been removed, dentin is blocked and we can compare the enamel Value with the Value of the rest of the tooth (Figure 18).

The thickness of enamel changes across the tooth. In the incisal third we can see increased translucency; however, in the middle and cervical thirds, there is a boost of opacity due to the proximity of the dentin.

With increasing thickness of enamel, the Value rises and properties of the underlying strata fade.

The blue opalescence of the incisal edge is more difficult to obtain when enamel thickness is increased. With thinner enamel, this blue effect is more intense. In aesthetic enamel composite restorations, this effect should be strengthened with the use of specific masses especially designed for the incisal and interproximal areas. Although the final enamel layer has opalescence, this intrinsic feature has to be enhanced with special colours.

Enamel thickness is different in every tooth; the thickness does not correlate with the tooth size or shape but correlates somehow with the type of tooth. Enamel also becomes thinner over time, as a result of wear caused by the action of the different elements in contact with the enamel throughout life.

Few materials have properties that will increase the restoration's Value and preserve its transparency when we increase the thickness.

Properties of an ideal enamel composite

- High opalescence and translucency;
- Refractive index equal to natural enamel;
- Calibrated luminosity for each situation;
- Hardness after polymerisation;
- High polishing;
- Smooth and stable handling;
- Reflectivity;
- Stability in the oral environment; and
- Able to add value by increasing thickness.

Composites for enamel reproduction

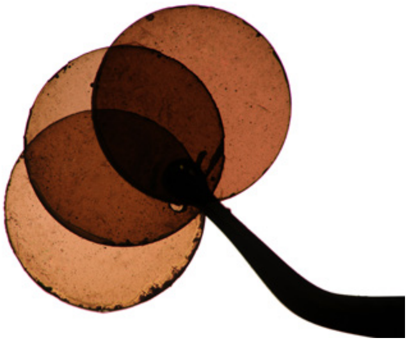


Figure 20. The best materials for enamel are the ones that imitate the opalescence and translucency of natural enamel.

Because of current improvements in composite formulations, it's important to understand that many classifications of composite resins exist, according to their particles (microfilled, hybrids, nanohybrids, nanofilled, etc), the degree of translucency (body, incisal, opaque, enamel, dentin, etc), or their location in the restoration (opalescent, cervical, liner, etc).

Composites for enamel reproduction are more translucent than are those for dentin and have opalescent features.

Enamels, when classified in a system, can have a numerical designation (1, 2, or 3), a shade guide designation (A1, 2B, 3M3), an alphabetical designation (XL, L, D) a qualifying designation (light, medium, dark), or even a name (pearl, ivory white, facial enamel). Most enamel composites are paired with a corresponding dentin composite (e.g., A1 dentin and A1 enamel), while in other systems the materials are sorted by Value.

Combining the In and Out layers as nature does

So far, after learning that Dentin composites (In) and Enamel composites (Out), regardless of the brand or its alleged characteristics, behave differently from natural tissues, we can see that it creates a big challenge when restoring teeth.

The good news is that dental materials can be strategically stratified to achieve similar optic features than those on natural teeth (Figures 21-25).

Personalised shade guides

So knowing that dental composites behave differently from the natural tissues and that single blocks of composite do not perform as a reliable shade guide, it leaves the dentist in a very awkward position when figuring out the colour masses to select.

The purpose of personalising a generic shade guide is to get a system as close as possible to reality when we create layers. To do this, we must take into account the following parameters.

First, it is essential to know the material in detail. It is ideal to perform the colour match with a shade guide prepared from the SAME restorative material that will be used, because each material has different physical and optical properties. Even the same colour (e.g., A3) in different brands can be very dissimilar. However, it is mandatory that the dental laboratory relies on the same material that will be used in the dental clinic to ensure consistency.

Second, to design a reliable shade guide, each tab should provide a sample of enamel and dentin in overlapped layers of different thicknesses. It is mandatory to superimpose the layers because the final colour of the tooth results from the interaction of dentin (In) and enamel (Out).

A simple method for fabricating personalised generic shade guides will be described. This technique quickly produces two-layer samples and provides a preview of a simple stratification, which is one of the most helpful things in a clinical case (Figures 26-38).

Figure 21. A natural tooth displays amazing light effects from the enamel-dentin complex. Its thickness, unfortunately, cannot be reproduced yet with current materials.

Figure 22. A composite tooth built by layers, shows that similar characteristics can be achieved by an adequate selection of masses and decreasing slightly the thickness of the enamel layer.

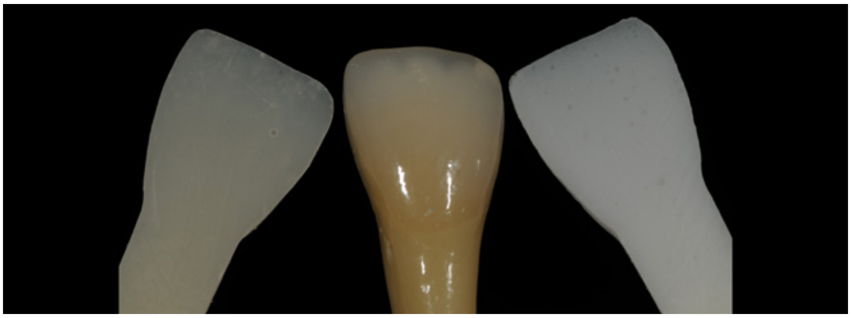


Figure 23. Composite by itself may look monochromatic, but when stratifying a tooth shaped restoration, colour gains depth.

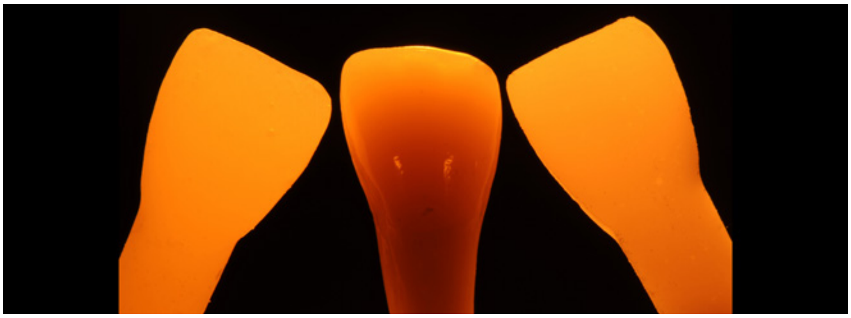


Figure 24. While looking under transmitted light, the thicker areas block light passage, while the blocks of composite behave as plastic.

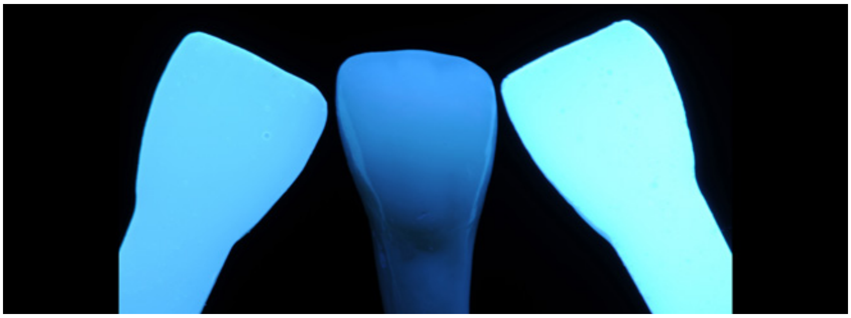


Figure 25. Thickness and enamel affect the fluorescence as well, making it more similar to that on the natural tooth.

Figure 26. A specially designed system allows a quick construction of a personalized shade guide in overlapped layers.

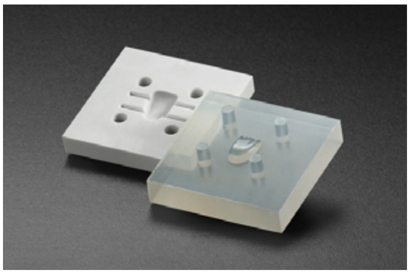


Figure 27. With this flask, an inverse layering technique is used, with he white part for the enamel and the transparent for the dentin.

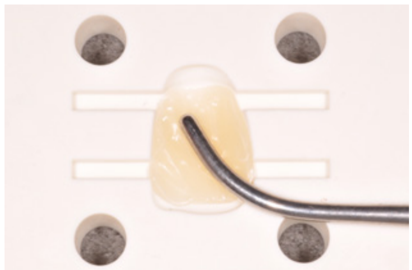


Figure 28. A layer of composite enamel is placed on the white part of the flask.

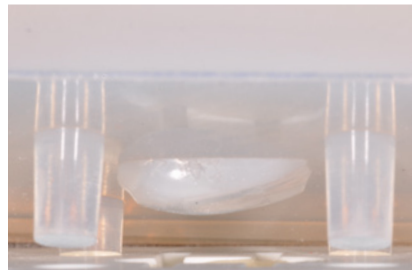


Figure 29. The transparent part of the flask is inserted and it will push and calibrate the enamel composite to have a perfect thickness. Polymerization is followed through the transparent silicone.

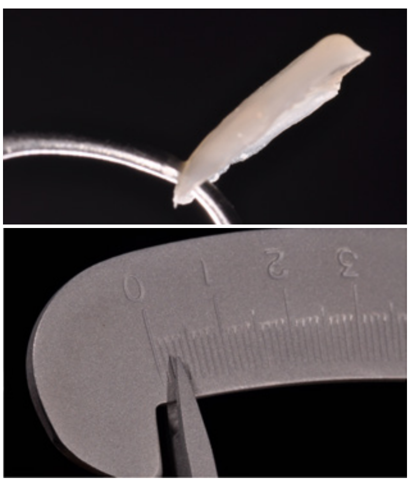


Figure 30. The enamel shape developed is measured to verify that an adequate thickness has been achieved, 0.2 mm on the cervical area.

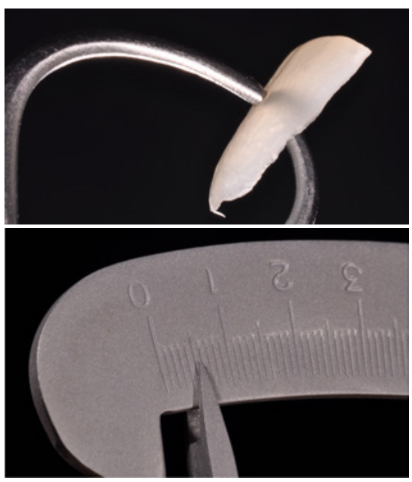


Figure 31. 0.5 mm on the middle third.

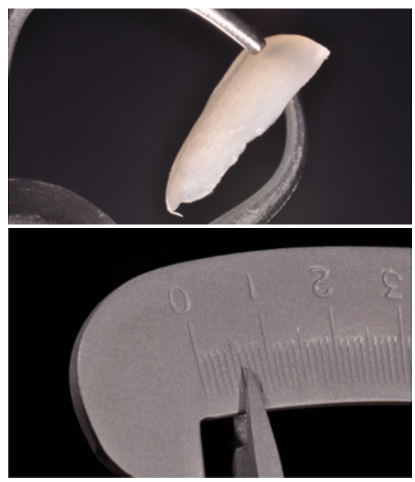


Figure 32. 0,7 mm on the incisal third.

The 0.5 layer in dentistry

Wide clinical experience has demonstrated that different thicknesses of composite can affect or benefit the restoration (Figure 39).

- 0.3 mm minimally modifies the underlying layer (result too opaque as dentin displays too much);
- 0.5 mm correctly modifies without dramatic value loss;
- 0.7 mm modifies but lowers the value too much (result too translucent and becomes easily a gray restoration); and
- 0.9 mm completely hides the dentin (acts as a unique mass).

The meaning of this statement is that with only one dentin (In) and one enamel (Out) shade, we can obtain many different colours, making our restorative treatment unpredictable and dangerous in terms of integration.

A common practice is to stratify what the manufacturer suggested and if there is a failure, to repeat the restoration until it matches, making it frustrating for both the patient and the practitioner and economically unrealistic.

Many composite systems include colour recipes and shade guides which are not reliable. A colour recipe must be developed from our restorative material in order to have a reliable colour comparison when facing a clinical challenge.

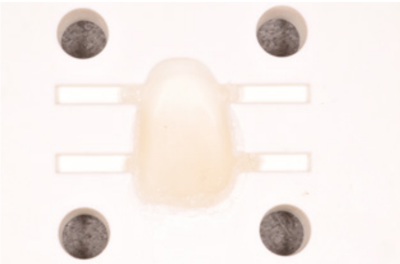


Figure 33. the enamel shell once polymerised.

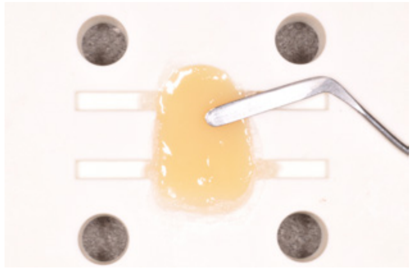


Figure 34. The shell is filled up with the desired dentin color and polymerised.

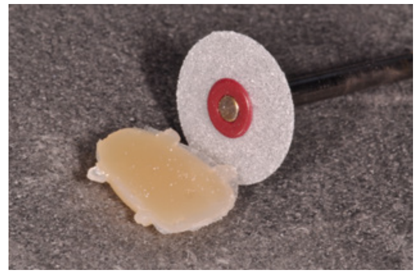


Figure 35. The sample is removed from the silicone and the excess of the flow channels is trimmed with rotatory instruments.

Until now, it has been clinically impossible to calibrate a perfect 0,5 mm thickness in an intraoral restoration without magnificent skills from the operator. For this purpose, a special instrument was designed (Misura, LM Instruments). This instrument consists of a conical end, which has a thinner tip which is upheld against the sound enamel; the thicker conical part will push the uncured dentin composite in order to have the right thickness (Figures 40-55).

Conclusions

Because most natural dentin belongs to shade group A, focusing on selection of the correct chromaticity will be the key to success.

Stratification in thin layers provides high accuracy during modeling.

Personalised shade guides together with high-quality pictures are the best means of communication between dentist and dental technician.

in most situations, enamel composite should be only half or less of the natural enamel thickness.

The nomenclature for enamel composite resins can be confusing in some systems. It is necessary to understand and analyse each system thoroughly before use to avoid absurd or serious mistakes.

Two masses are enough to find a right colour compromise.

A thickness of 0.5 mm enamel is right in the majority of cases for an optimal opacity-translucency appearance.

Acknowledgement

This article is composed mainly from contents of the book Layers by Jordi Manauta & Anna Salat (quintessence international, 2012) and by the clinical cases published in www.styleitaliano.org.


Figure 36. The appliances for placing the tooth into the stick are glued.


Figure 37. The sample is placed in a stick, where it can rotate and be used as a conventional shade guide.

Figure 38. Customized shade guides give us a quick color combination which is impossible to have with commercial shade guides.

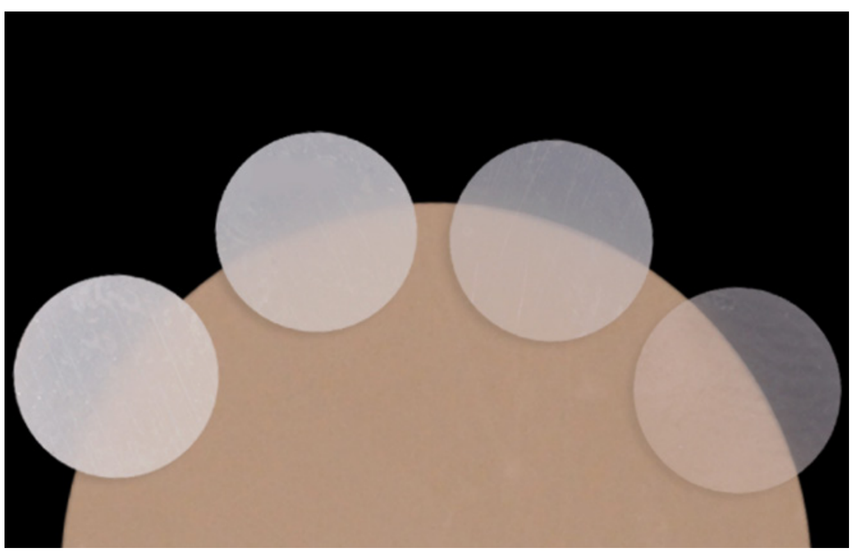


Figure 39. 0.3 mm, 0.5 mm, 0.7 mm and 0.9 mm discs placed over a high Chroma dentin disc, showing how a few tenths of millimeter can affect drastically the final outcome.

Figure 40. An special instrument (Misura) which helps modeling the dentinal body for a correct thickness of the final layer.

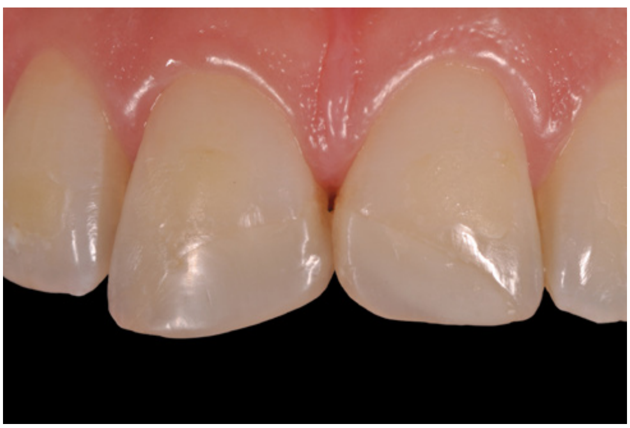


Figure 41. Two composite class IV restorations will be replaced.

Figure 42. The margin is located without harming the enamel with a zirconium round low speed bur (Styleitaliano all-prep'n polish, by Komet).

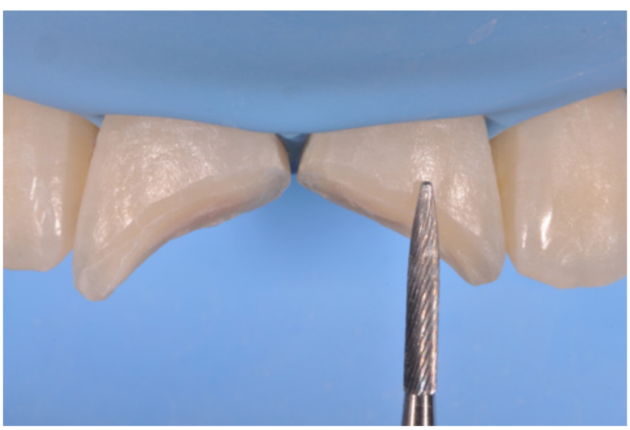


Figure 43. Once the restorations were removed, unsuported prisms are removed with a multiblade bur (Styleitaliano all-prep'n polish, by Komet)

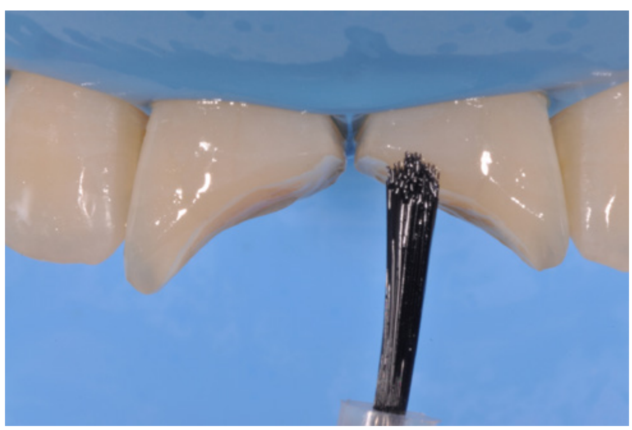


Figure 44. The bonding agents are meticulously applied, the most important step in the restoration.

Figure 45. The silicon matrix obtained from a wax-up was used to build the palatal walls

Figure 46. Proximal walls are built one by one with the help of preformed matrices and wedges.

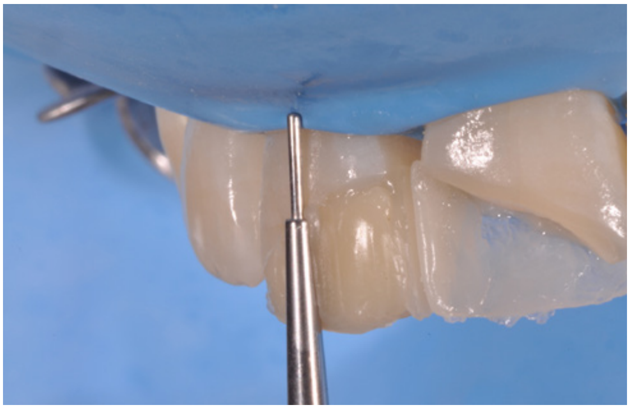


Figure 47. The chosen dentin is placed in bulk, the with the Misura instrument the excess of dentin will be removed allowing us to have the exact space needed for the enamel.

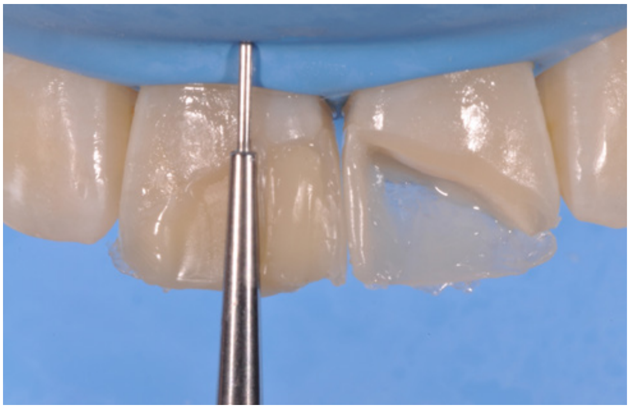


Figure 48. Frontal view of the Misura instrument working; notice how when operating from distal to mesial, an important amount of excess flows to the central part, allowing easy removal.

Figure 49. The same view, now working towards the mesial, this step facilitates the dentinal body modeling.

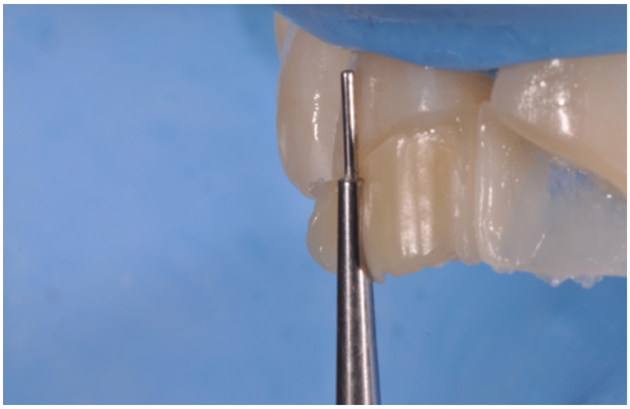


Figure 50. in a lateral view we can notice the space left by the instrument, according to the ideal thickness needed, 0.5 mm.

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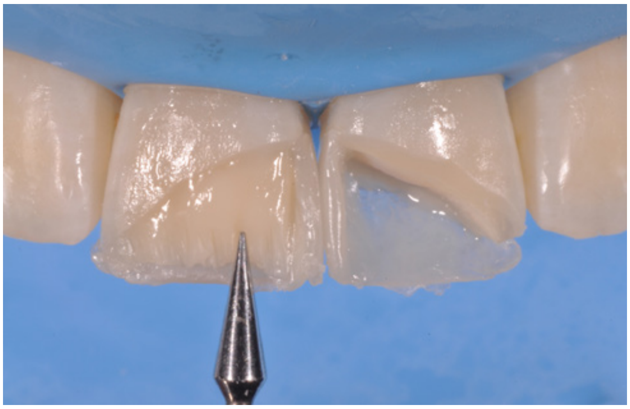

Figure 51. After removing all the excess, the dentinal body can be shaped in a desired way, making it as simple or as complex as wished, but with a right thickness.

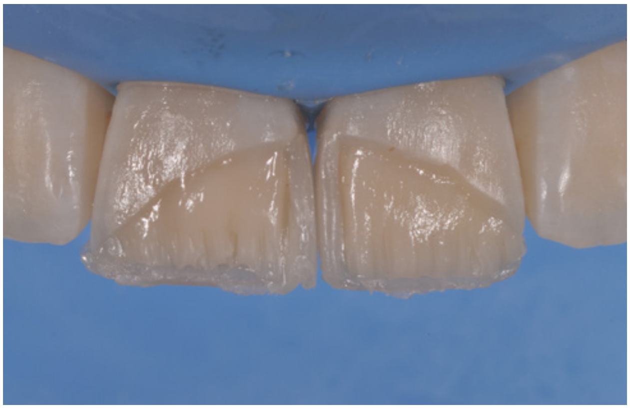

Figure 52. The dentinal body finished displaying multiple mammelons.

Figure 53. The enamel is placed in bulk as well, being confident that the outcome will be the desired one.

Figure 54. Many tricks can be use for smoothening the final layer, as a natural hair brus or silicone tips.

Figure 55. The final case showing good integration in the margin in a predictable way and lifelike polishing.

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