Achieving the predictable composite resin restoration: the nature of colour

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Although colour as an entity should be regarded as being only one of the many building blocks necessary in the achievement of an aesthetic restorative result, a discordant colour scheme can probably be more devastating to the overall effect than many of the other factors present. It is for this reason that so much time, research and expense has gone into the 'colour matching' properties of contemporary aesthetic restorative materials.

The manufacturers of aesthetic restorative materials have inadvertently added to the challenge of accurate colour matching. Although producing wonderful aesthetic materials, there still remains a lack of total standardisation within the productive process and separate batches of the same material often display completely different colour properties. The shade guide remains the traditional method of recording colour matching, and for the most part this is totally inadequate as the guide is not unique to the chosen material.

The objective of this paper is to present an understanding of the nature of colour and to provide a simple roadmap technique that eliminates much of the uncertainty of colour matching (Figures 1 & 2).

The nature of colour

The modern understanding of colour originated in the discovery of the spectral nature of light by Isaac Newton in the 1600s. Newton considered light to be a stream of particles. His experiments with prisms showed that white light can be split into individual colours. Newton's experiments demonstrated that light is made up of energy with differing wavelengths. The universe is considered to comprise a magnetic field of positive and negative charges, constantly vibrating and producing electromagnetic waves. Each of these has a different wavelength and speed of vibration and together they form the electromagnetic spectrum. We can see about 40% of the colours contained in sunlight. So although white light appears colourless and intangible, it is made up of distinct colour vibrations, which have not only wavelengths but also a 'corpuscular structure.'

The colours in light

One way colours in sunlight can be made visible to us is by passing white light through a prism. Because each of

Figures 1 and 2: Restoration of central incisor showing precise colour matching.

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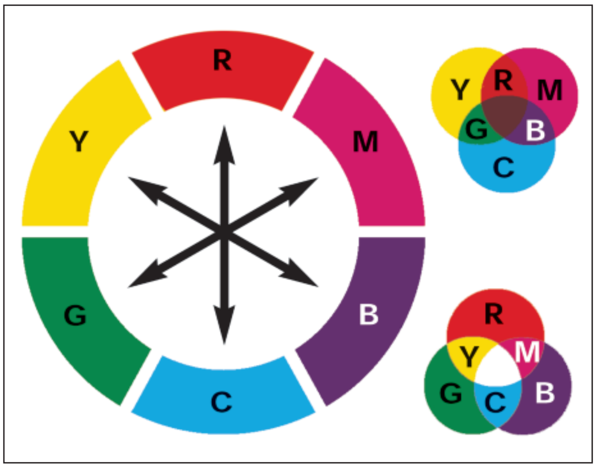


Figure 3: The colour wheel showing the primary hues red, green and blue. Opposite each primary hue is the corresponding complementary colour, cyan, magenta and yellow.

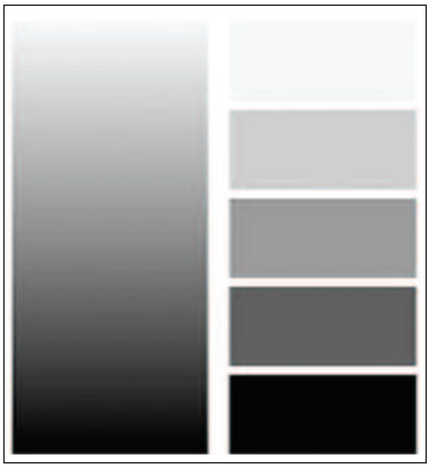


Figure 4: Value scale and chart graduated from 0 to 10. A black or low value is represented by 0. 10 represents a white or high value with the mid-tones being grey.

the colours has a different wavelength, each is bent by a different amount. Rainbows are formed when water droplets in the sky act as natural prisms. As sunlight passes through the droplets, each of the different rays is bent by a different amount, creating the rainbow. The rainbow colours form one 'octave' of light and are known as the 'true hues.' Red has the longest wavelength, is visible and has the slowest frequency of vibration. Violet has the shortest wavelength and the quickest vibration.

Beyond the visible spectrum

At either end of the visible spectrum are many wavelengths we cannot see. Ultraviolet light is just beyond violet, and farther beyond this are electromagnetic rays with increasing frequencies as the wavelengths get progressively shorter; these include X-rays and gamma rays. At the opposite end, infrared light is located just beyond red light. Beyond this are electromagnetic rays with increasing wavelengths and decreasing frequencies. These include radio waves. Human colour recognition depends upon light, objects that reflect light, and the viewer's eyes and brain. The colour of a self-luminous object is called self-luminous colour and can be natural or artificial. The colour of an illuminated object is called object colour and can arise from reflected or scattered light. The energy carried by waves (which are approximately 400-700nm) stimulate the receptors in the human retina, producing colour stimuli. This gives rise to the three primary colours:

- 400-500nm – blue
- 500-600nm – green
- 600-700nm – red

All colours encountered in nature can be reproduced by combining light of these three wavelengths in varying intensities:

- 100% = white light
- 0% = black
- 50% = grey

The colour wheel and complementary colours

If we arrange all these colours around a circle we have a colour wheel. Looking at the colour wheel we can see that certain colours fall opposite to each other. Each colour has a complementary or opposite hue, so that on the colour wheel we have three complementary pairs. Just as positive and negative magnets attract each other, complementary colours also attract. Figure 3 graphically shows the relationship between the three primary colours of red, green and blue and the three primary lights, cyan, magenta and yellow.

The Munsell Colour System

This system defines three attributes of colour: H (hue), C (chroma), and V (value). Colour matching in dentistry is based on this system. Munsell established numerical scales with visually uniform steps for each of these attributes.

Hue

Hue is that attribute of a colour by which we distinguish e.g. red from green, blue from yellow, etc

Munsell termed red, yellow, green, blue, and purple principal hues and placed them at equal intervals around a circle. He inserted five intermediate hues:

- Yellow-red

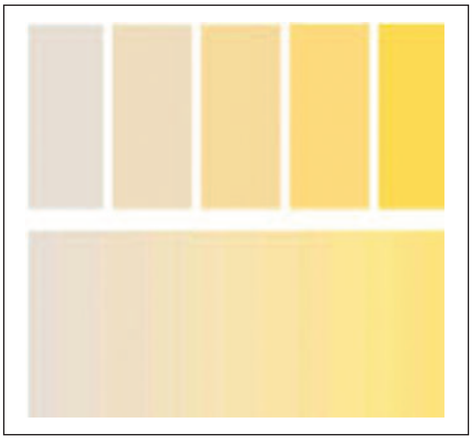


Figure 5: Chromatic scale, extending from weakly saturated on the left to densely saturated chroma on the right.

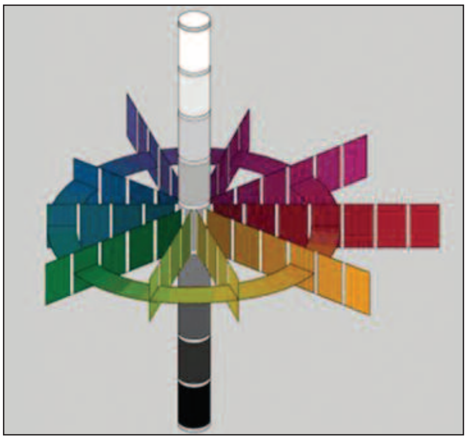


Figure 6: Munsell Colour Space.Vertical axis represents value extending from black on the bottom to white on top, with grey in the middle. The colour wheel arranged around the axis represents the hues and chroma increases outwards and perpendicular to the vertical axis.Thus hue, chroma and value can be observed at various combinations.

- Green-yellow
- Blue-green
- Purple-blue
- Red-purple

Thus making ten hues in all.

Value

Value indicates the lightness of a colour. The scale of value ranges from 0 for pure black to 10 for pure white. Black, white and the greys between them are called neutral colours. They have no hue. Colours that have a hue are called chromatic colours (Figure 4).

Chroma

Chroma is the degree of departure of a colour from the neutral colour of the same value. Colours of low chroma are sometimes called weak, while those of high chroma are said to be highly saturated, strong or vivid (Figure 5).

Munsell colour space

Hue, value and chroma can be varied independently and the colours can be arranged in a three-dimensional space. The neutral colours are arranged in the vertical line called the neutral axis. Black is at the bottom, white at the top and all greys are in between. Hues are displayed at various angles around the neutral axis and chroma arranged perpendicular to the axis, increasing outward (Figure 6).

Chromatic and achromatic colours

Achromatic colours are white, black, and the grey in between. They lack the attributes of hue and saturation. Chromatic colours are everything that we perceive as having 'colour'; everything other than white, black, or grey.

Colour of the natural tooth

In describing the colour of a natural tooth we find there are two additional attributes. In addition to hue, chroma and value, there are the attributes of opalescence and fluorescence. The definitions of the first three attributes are identical to those defined by Munsell, but each can be qualified further:

- Hue: the primary source of colour is dentine and the hue of a vital, healthy tooth is in the yellow to yellow-red range
- Chroma: in natural teeth the chroma is dictated primarily by dentine but is influenced by the translucency and thickness of enamel. The thinner the enamel, the less the effect on the chroma. Thus in the cervical area, with its thin enamel, the chroma appears densely saturated. The thicker the enamel, the more the chroma is masked giving rise to a diffuse chromatic appearance.
- Value: in natural teeth this is primarily influenced by the quality and thickness of enamel. The thicker the enamel, the greater the optical effects resulting in a higher value. Thick, dense opaque dentine has the effect of lowering the enamel value (Figures 7, 8 & 9).
- Opalescence: in a natural tooth, this is an effect produced in enamel and is due to different refractory indices of the various organic and inorganic components of enamel as well as the ability of hydroxyapatite crystal to scatter incident light. The result is that the long wavelengths are transmitted through the tooth whilst the short wavelengths are reflected, producing a bluish gleam. The effects vary from blue to grey to white gleaming areas (Figure 10)

Figures 7, 8 & 9: Variations in value in natural teeth. Low value giving a grey appearance, mid-value giving a cream appearance and high value giving a white appearance.

• Fluorescence: this effect occurs when a body absorbs luminous energy and then diffuses it back to the visible spectrum. In nature this is caused by ultraviolet light striking pigments in the dentine/enamel interface resulting in light emission ranging from intense white to light blue.

Translucency and opacity

These are difficult parameters to explain and even more difficult to quantify:

• Opacity: most of the light rays are reflected or absorbed due to the presence of dense particulate matter within the object

• Transparency: most of the light rays are transmitted due to the object being mainly devoid of particulate matter

• Translucency: light rays are both transmitted and reflected due to the presence of discrete minute particles in the object.

A translucent material, by definition, must have particulate matter embedded which when struck by light reflects and scatters the rays. In natural teeth, these particles (owing to their minute irregular size and shape) primarily reflect the shorter wavelengths (i.e. blue wavelength). When struck by light, these particles have the property of imparting a 'glow' or 'vitality' to the tooth, i.e. opalescence. Translucency is currently one of the 'buzzwords' in aesthetic restorative dentistry and clinicians, in their search for the invisible restoration, demand more and more translucency from their ceramists. However, the desire is not for more semi-transparency but rather for more glow and vitality effects i.e. opalescence.

The observed colour of a tooth results from the combined effects of the interaction of light with dentine and enamel.

Dentine effects

The macro- and micro-anatomical structure of the dentine produces areas of high and low saturation of opaque colour resulting in dentine being primarily responsible for the hue and chroma of the tooth. The scientific literature describes the predominant hue as being in the yellow-red range, but varies in quantification of this as being between 76% and 86%, with the remaining percentage leaning towards the yellow range. The Vitapan standard would describe the hue of teeth as being predominantly in the A range with a small percentage of B shades.

Dentinal tubular architecture, exhibiting varying diameter, frequency and an S-shaped distribution produces areas of dense and sparse mineralization. The various micro-anatomical structures, tubular architecture, combined with the overall gross anatomy of dentine result in areas of differing refractive indices resulting in a non-homogenous reflection and scattering of light rays. This results in areas of dense opacity and saturation of colour giving dentine a polychromatic effect. Vanini (1996) studied this effect and defined and applied the term 'chromatic banding' to the polychromatic effects (Figure 11). Traditionally, chromatic banding has been described at the gross level as consisting of three broad areas:

• The cervical third

• Middle third

Figure 10: Typical opalescent effects showing a blue comb-like halo in the incisal region and solid white opalescence in the middle third. Note the band of solid colour at the outer edge of the 'halo'.

Figure 11: Longitudinal section of a central incisor. The relationship of the varying thicknesses of enamel and dentine is illustrated. The polychromatic effects, caused by areas of dense chroma are clearly evident as are the opalescent areas of dense particulate matter in the enamel. With thanks to Micerium and Lorenzo Vanini for permission to use the slide.

• Incisal third.

The chroma is most saturated in the cervical area, gradually decreasing through the middle third into the incisal third which exhibits the lowest chroma. Vanini demonstrated that even within the three broad bands there are areas of dense opacity and saturated chroma mixed with areas of less saturation, giving rise to a true polychromatic appearance. These areas can be organised in a definite pattern resembling bands of differing chroma or there might be a randomised scattering of differing chromas. Organic pigments present within the microstructure of dentine are responsible for fluorescent effects giving iridescent areas of white or blue.

Enamel effects

The inorganic organised arrangement of the enamel prisms, the varying thickness of enamel over the dentine contours and the presence of organic protein pigments allows light to be reflected, refracted and transmitted. The translucent and opalescent characteristics of enamel impart value as well as areas of intense colour and/or opalescent effects to the underlying dentine giving the sparkle and vitality to the tooth. The thicker the enamel, the more light is refracted and reflected, thus increasing the luminosity and hence the value, giving a whiter appearance.

Combined effects of enamel and dentine

The observed colour of a tooth is achieved through the combined optical effects of enamel and dentine. The opaque dentine, exhibiting the attributes of hue and chroma, has the tendency to decrease the value of enamel, thus moving the overall colour towards the grey. If the enamel is very thin and the dentine very saturated (such as the cervical area) then the hue of the dentine dominates the overall perception. As the enamel thickens and the dentine decreases in density (middle third) so does the value of the enamel increase, leading to a whiter effect. Careful observation of the tooth will show that the polychromatic nature of dentine will exert similar effects on the value, giving rise to a pattern of variance of value of enamel that matches the polychromatic pattern of dentine (Figure 12).

Opalescent, translucent and intensive effects

Opalescence in a tooth is caused by minute particles in the translucent enamel reflecting and refracting light. This particulate matter is so minute that only the short wavelengths are reflected, thus creating a blue gleam. In the natural tooth this occurs usually at the edges of the incisal third where the tooth is devoid of dentine, causing the familiar blue halo. As the dentine thickness increases so more wavelengths are reflected leading from grey to white opalescent effects (Figure 13).

He further suggests that there is a definitive pattern to the translucent effects of enamel. This pattern can be classified into categories and further divided into effect elements. Vanini postulates that the sum total of all

Figure 12: Typical opalescent effects of enamel. Notice the blue incisal halo surrounded by a band of opalescent enamel. An area of intense stain is present in the incisal third and the whole surface is covered with flaky white opalescence. Notice as well the obvious polychromatic influence of dentine, arranged in this instance, in definite bands of differing chroma.

Figure 13: Another example of the combined polychromatic effects of dentine and the opalescent effects of enamel.

opalescent, translucent or enamel effects fall into one of three categories:

- Intensive effects
- Opalescent effects
- And/or characterisation.

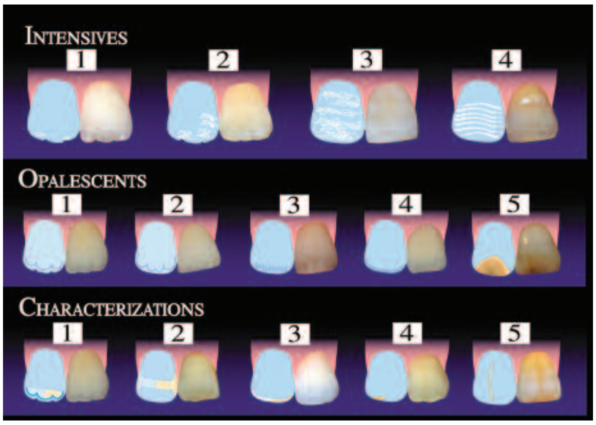
Intensive effects present discrete but intensive areas in the enamel surface, usually of a milky/white nature. A typical example of an intensive effect is the stain associated with hyper-mineralization (fluorosis) of the enamel structure. The opalescent category attempts to classify the distribution and appearance of typical enamel opalescence. The presence of the blue halo in many teeth, both anterior and posterior is typical of opalescent effects. This halo can actually be classified by describing its physical appearance, such as mammelon, split mammelon, window or comb. A fifth division will occur in the elderly patient where loss of the incisal edge has occurred, enamel has thinned and extrinsic stain mixes with the opalescent area producing an opalescent stain usually of a white/amber colour. The final category, characterisation, describes the two most common examples of character effects, the stain and crack, as well as the areas of definitive effects that can surround the areas of opalescent or intensive effects. As an example, immediately below and above the opalescent halo there is usually an area of solid enamel effect accentuating the halo and thus would be defined in the characterisation category as a mammelon or marginal effect. Therefore, by subdividing the opalescent/translucent or enamel effects into three broad categories, and further dividing each category into four or five elements, a predictable, repeatable and easily describable road-map for colour matching can be recorded and charted (Figure 14 and Table 1).

Aging effects in the natural tooth

Young teeth are generally characterised by white, bright opalescence whereas aged teeth are usually dark, opaque and worn. Young teeth have a thick, dense vascular and opaque dentine surrounded by thick enamel. The thick intact enamel masks and reduces the opaque effects of the dentine. The young enamel shows marked opalescent effects and in the incisal area the halo effects are obvious. With aged teeth, the dentine blood supply diminishes and the tubules become sclerotic. Although sclerotic dentine is slightly more translucent, the overall chroma increases and the dentine becomes darker. The enamel wears and thins with resulting reduced value as well as allowing more of the opaque dentine to show through. The thinning enamel shows reduced opalescent effects particularly at the incisal edge that shows loss of enamel due to functional wear. Accumulated stains also darken the tooth.

Colour of composite resin material

The challenge facing clinicians, researchers and manufacturers is colour matching a synthetic restorative material to a natural living tooth. A natural tooth possesses an intrinsic vitality, and its colour is a result of the anatomical and biomechanical properties of the tooth. A blending of all the components of a natural tooth give rise to an intrinsic tooth colour, and only



Opalescent Effects	Intensive Effects	Characterisation
Mammelon	Stain	Mammelon
Split mammelon	Small clouds	Band
Widow	Snowflakes	Margin
Comb	Horizontal bands	Stain
Stain		Crack

Figure 14 (left) and Table 1: Vanini's classification of enamel opalescent effects in graphic and textual form.Vanini divided the effects into three broad categories: intensive effects, opalescent effects and characterisation. Each group was further divided into more distinctive groups as outlined in Table 1. Careful consideration of this classification will surely convince the reader that the vast majority of dentine and enamel effects fall within this grouping. Understanding and application of this categorisation will present the clinician with a very simple roadmap to colour matching. Vanini has further simplified the procedure by studying the distribution of the actual colour involvement of the various effects. Thus by memorising three categories with a total of fourteen subdivisions, the clinician has a definitive route to chart the colour matching process without the need for a shade guide and, more importantly, without the need to possess exceptional artistic ability. The procedure is simplified even further by the availability of a purchasable 'chromatic chart' and the whole process of colour matching can be recorded.

alteration of these basic structures or the application of stain will cause a colour change, e.g. aging or pathological destruction. A synthetic material, on the other hand, requires a predetermined colour to be built in as an intrinsic part of the material. Thus, in order to accurately colour match a wide variety of different hues, chromas and values of the same material need to be manufactured. Another problem is that colour change due to aging effects is totally different in natural as opposed to synthetic materials. The manufacturers tried to solve this with the early composite materials by relying heavily on the 'chameleon effect' - the large, loosely packed filler materials allowed sufficient light to pass through the material so as to obtain colour from the surrounding tooth substance. This resulted in a near invisible restoration that was totally devoid of vitality due to low opalescent, fluorescent and value effects. In the search for better quality resins the physical and chemical properties were altered and the composite resins became denser with smaller particles, more opaque and less aesthetic, even though their restorative properties improved. This coincided with the greater public demand for aesthetic restorations. In order to combat the poor aesthetics, composite resins, like other tooth coloured restoratives, developed two-tiered systems with separate resins for dentine and enamel. The dentine provided the strength needed with larger particles and the enamels provided the aesthetics with sub-micron particles that were capable of maintaining a high polish with low wear properties. As composite filler particles grew smaller and more densely packed, so the two-tier system become more essential. Pigments were added to produce opalescence and fluorescence effects and the enamels were graded according to value with definite high, mid and low value components. Opalescent effects were produced by providing a large variety of intensive colour components. Manufacturers vied with each other to produce composite systems that offered larger varieties of component colours. Indeed, one award-gaining quality composite system actually offers 62 different shades of dentine and enamel components in their total range.

Problems in colour matching

The tendency to produce more and more so-called 'natural shades' of restorative material, whether ceramic, composite or acrylic, has led to a plethora of shade choices that has only served to confuse clinicians in their quest to achieve accurate colour matching. Multiple-choices of dentine shades and chromas, non-standardised enamel shades, intensive colours, pigments, stains and even new bleached shades defy simplicity in colour matching. The situation is aggravated even further by the fact that manufacturers, particularly of the quality materials, all provide specific protocols unique to their particular system to achieve the ideal aesthetic restoration. This author, on various lecture tours over the past decade, has found that the most common complaint regarding composite restorations is the complexity and

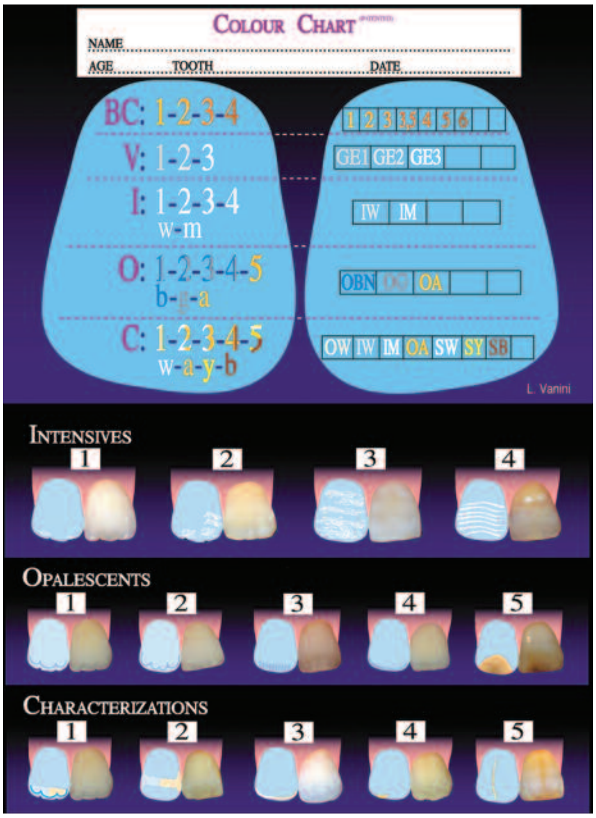


Figure 15: The Chromatic Chart. Diagnostic map for colour matching (Micerium, Genoa, Italy; Optident, Ilkley, Yorkshire).

confusion concerning colour matching, due primarily to the wide variety of shades and systems available.

A predictable roadmap to tooth colour matching

The basic requirement in producing a standardised roadmap would be to ignore the influence of the objective and subjective elements and to concentrate on the influence of the bio-physiological structures of a tooth and its interaction with light. Vanini worked on this interaction and in two keynote papers in 1996 described the interaction of light with the dental hard tissues compared to the interaction with composite restorative materials. The interaction of light and tooth has been discussed in the previous paragraphs and can broadly be described as the polychromatic effects of dentine and the translucent opalescent effects of enamel. In order to reproduce these effects in synthetic composite material the following criteria would need to be fulfilled:

• A two-tiered composite system consisting of dentine and enamel composites

• High opacity/ low translucency dentines in the yellow-red range having a range of chroma varying from 1 to 6. The ideal system would present an integrated graduated chromatic system. This is not possible with any of the Vita or Ivoclar shade guides owing to the chromatic spectral arrangement of these guides. The author is aware of only one composite system that offers this spectral arrangement of the dentine resins. The New Generation Enamel Plus HFO System (Micerium, Genoa, Italy), with its unique universal single hue dentine composites, offers a true graduated chromatic system:

• The dentine resins should have fluorescent pigments intrinsically added

• The glass 'connect' layer consisting of filled resin material

• High translucent enamels, graduated into three levels of value (i.e. high, mid and low values)

• Aesthetic modifiers containing high opalescent effects and intensive colours

• A pre-printed form on which data can be recorded

• Chromatic Map (Micerium, Genoa, Italy).

The Stratified Layering Technique

The colour matching procedure should be recorded by using a chromatic map (Figure 15). The first step is to establish the hue and chroma distribution. This step is performed prior to any restorative procedure and the colour is established with both wet and dry techniques. Surrounding, ambient conditions should match the ideal for shade taking as outlined in the scientific literature. In establishing the basic hue, the author submits that in composite resin restorations a simplistic approach should be perfected by primarily considering A shades with the very occasional B shade. The C and D shades should be eliminated as these are grey versions of A and B and can be reproduced by using low value enamels. The overriding chroma is established, recorded as well as two higher chromas of the same hue. For example, if A2 is the overriding chroma then A4 and A3 are added to the recorded map data. The value of the surface enamel is then recorded and the suitable surface enamel composite chosen. Most quality composite manufacturers offer a choice of three surface enamels being graded according to value i.e. low (grey), medium (cream) and high (white). The terminology differs with the various available composites but the principle is common to all and the clinician just needs to establish which surface enamel is low, medium or high value. The predominant opalescent pattern is then chosen and recorded, as well as the overriding colour effect of the particular pattern. Vanini has demonstrated that the predominant opalescent colours are blue, white and amber and high quality, aesthetic restorations can be predictably achieved by

Figure 16: First incremental layer of high chroma inserted in a wavy, undulating fashion, thickest in the cervical area and extending into the middle third of the tooth.

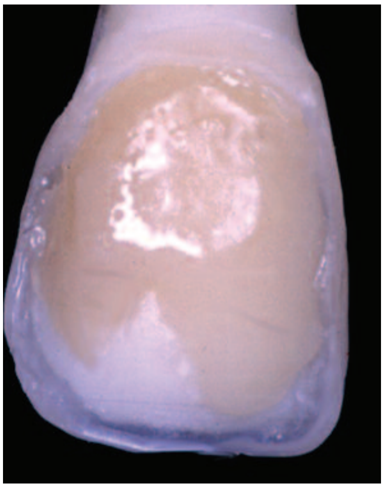


Figure 17: The second incremental layer of middle chroma, once again inserted in an undulating pattern and extending into the lower third of the tooth.

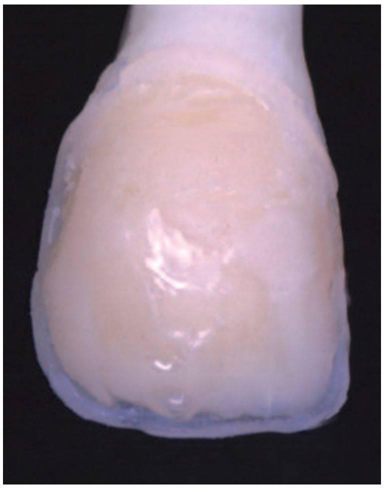


Figure 18: The final dentine layer of lowest chroma. This covers the whole tooth surface and is placed in a smooth fashion. Groves and spaces are created (prior to polymerisation) as per the patterns established with the Chromatic Chart.

limiting the opalescent effects to these three colours. If grey predominates then this can be achieved by mimicking the pattern with thicker areas of low value surface enamel. The intensive pattern is then chosen and recorded - once again Vanini has shown that the predominant colour to be an intense white and most systems offer a highly saturated white shade that can be used to reproduce the intensive patterns. Finally the characterisation patterns are established and recorded. Again, the majority of characterisation effects can be achieved from the three opalescent colours, however in the case of stains and cracks the author uses either brown or ochre ceramic stain pigments. Most quality composites have a stain kit that would suitably reproduce characterisation effects of a tooth. The completed Chromatic Map is then handed to the dental surgery assistant, who then divides the required colours into small wedge-shaped increments and lays these in a composite light well with a filtered cover to prevent premature polymerisation. 86% of quality aesthetic composite restorations can be achieved with a choice of three out of a possible five increasing chromas of A; the choice of one of three surface enamels graduated according to value and finally the choice of three opalescent colours and perhaps one intensive colour plus a stain kit. Thus, by utilising a choice of 12 colour elements of a composite system colour matching can be achieved on a daily predictable basis. The remaining 14% of tooth colours can be achieved by B shades with chroma increasing from 1-5. This offers a far simpler choice than the 62 colours offered by an award winning quality system.

Only the basic principles and broad objectives are described in this article. The broad objective is to create a dentine layer exhibiting a polychromatic optical effect or chromatic banding. For ease of description, an anterior veneer will be illustrated but the technique applies to all classes of restoration suitable for a composite resin. The first increments inserted will be the highest chroma of the chosen stage. This layer extends from the cervical area into the middle third area. The layer is thickest in the top cervical area gradually thinning into the middle third area. The layer is inserted neither uniformly nor smoothly but in an undulating fashion varying in thickness both mesio-distally and cervico-incisally (Figure 16). The next layer involves the middle chroma chosen and extends from about halfway through the cervical third into the middle of the incisal third, covering the underlying layer already placed (Figure 17). This layer is also placed in an undulating fashion creating thick and thin areas of undulating chroma. Finally, the last and lowest chroma (which corresponds to the chosen hue and chroma) is placed smoothly over the previous layers. Groves and spaces are created, prior to polymerisation, as per the patterns established with the Chromatic Chart (Figure 18). The halo is created by forming a thin groove immediately above the incisal dentine edge. A thin layer of filled resin is applied over the whole dentinal surface to act as a light diffusion layer and polymerised. This layer is critical to avoid the effects of opaque dentine lowering the value of the enamel layer. The enamel effects as recorded on the Chromatic Chart are then inserted. Blue opalescent enamel composite is placed in the groove created for the

Figure 19: Opalescent and intensive colours added to fill previously contoured grooves and ridges. In this instance opalescent blue is placed in the halo area, and opalescent white in the intensive areas.

Figure 20: Completed veneer showing polychromatic dentine and opalescent enamel effects.

halo, using a minimal quantity of the intense opalescent colour. This layer of blue enamel is then accentuated by adding a margin of dentine along the lower border of the halo shape. The mammelon areas are filled with opalescent enamels either white, amber or blue or combinations of all three. The intensive patterns are filled with intensive colours according to the desired result as obtained from the Chromatic Chart. As an example, horizontal bands are created by inserting very thin rows of intensive white enamel (Figure 19). Once the patterns of the chromatic charts have been obtained the added enamels are polymerised. Great care should be exercised with regard to the quantities of special effect enamels used. Most of the quality composite systems available offer these special effect enamels and they are always resins of intense colour. Over-exuberant use of these intense enamels can create disharmonious effects and ruin the restoration. Small, wisps of intense colour are all that is required and these are carefully and sparingly placed in the spaces created in the superficial dentine. An alternative and simpler technique would be to fill the carved areas and groves with surface enamel. By filling the shaped patterns thicker areas of enamel would be created and these would produce a subtle reproduction of the Chromatic Chart pattern even though the colour variation was not present. The restoration is then covered with surface enamel of the desired value, polymerised, polished and finished (Figure 20). This procedure, known as stratified layering, blends harmoniously and invisibly with the incremental layering technique.

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