SHADE SELECTION RATIONAL PROTOCOL SUGGEST

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Shade guides
Natural teeth
Cosmetics restorations

MOTS CLES
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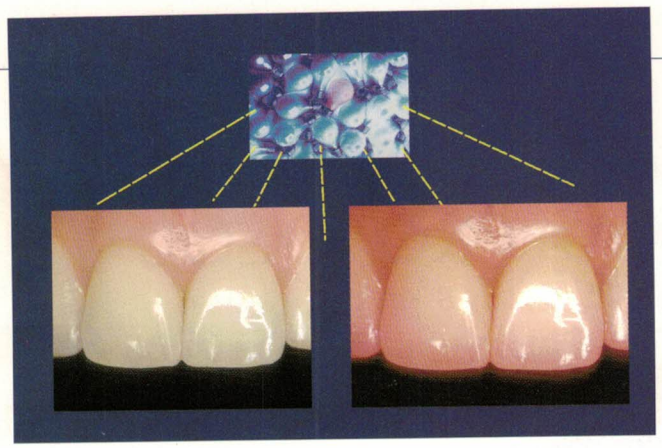
Color is a language which has always helped men communicate. Scientists define color through equations, wavelengths and particles. However, the physiological, psychological and emotional factors associated with color cannot be overlooked.

In our practice, shade matching is an everyday act be it for ceramics, composites or resin denture teeth.
This ordinary process seems simple, but is rather complex, requiring scientific knowledge, a trained eye and a precise protocol in order to obtain a satisfactory and reproducible result. This clinical article has for objective to give clinicians a practical and realistic approach to color in dentistry.
First of all, the clinician must develop his observation skills and train his eye to distinguish the different parameters of natural tooth color.

In today's Hi-Tech world we can say, without risk of being old-fashioned, that the combined use of shade guides, pictures and diagrams for a correct transfer of data from clinician to laboratory technician.



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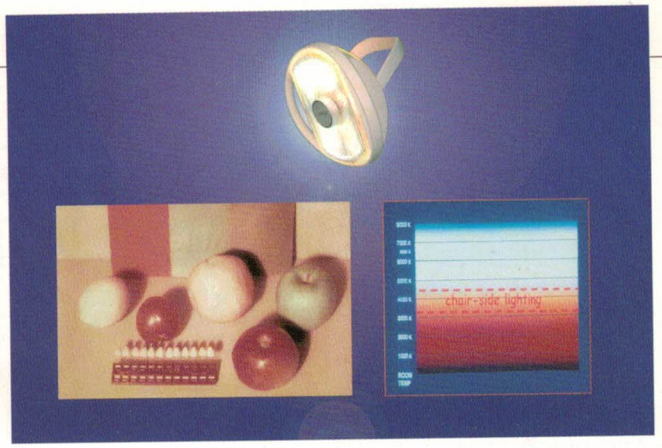

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Fig. 1 - The incident light must have all visible wavelengths. If the lighting has too many red wavelengths, then the crown will appear red.

Fig. 2 - The overhead light of the operatory is not adapted for shade selection. It is too intense (20000 lux), washing out the colors and its color temperature (4000 to 5000 K) shifts colors towards orange.

UNDERSTANDING COLOR'S BASIC PHYSICS

For scientists, light is the visible range of a field of electromagnetic rays characterized by their wavelengths. The wavelengths visible to the human eye range from 360nm to 780nm.

When a light source, with its specific spectrum of wavelengths, hits the tooth, part of it is reflected on the eye's retina.

2 fundamental rules concerning the light source from these observations:

- **the incident light should neither be too strong nor too weak.**

No light, no color. A tooth is visible only when hit by an incident light. Too much light "washes out" colors.

- **the incident light must contain all visible wavelengths in order for the tooth to reflect correctly part of the spectrum.**

Therefore, when the incident light contains too many red wavelengths then the tooth appears predominantly red (10,12,14,16) (fig. 1).

In our dental offices, the physical characteristic of the light (ceiling light, operatory overhead light) plays a predominant role in color perception:

- the overhead light is incompatible with proper shade perception. It is too intense (20000 lux) and washes out colors. Its color temperature (4000 to 5000 K) shifts colors towards orange. With this light, all teeth have a dominant yellow-orange hue, making it difficult to distinguish them. (11,12, 21) (fig. 2) ;
- the ceiling light generally has a color temperature close to 5500 K. This color temperature mimics that used by photographers. But, in order to correct this color temperature too yellow, photographers use colorimetric correctors, which we cannot use in the dental field.

In the 70's, a number of articles detailed the criteria for proper lighting underneath which to observe teeth.

Nevertheless, it is interesting to note that most lightings are completely inappropriate. It would be better if our lighting the follow recommendations of industrial colorimetry. In various fields, such as automobiles or textiles, the color temperature of reference is 6500 K, corresponding to daylight (10,12) (fig. 3).

Some lightings do present such color temperature characteristics, but this not sufficient. A fluorescent light of 6500 K is very poor in intense blues and deep reds, whereas the incident light should cover a full spectrum of wavelengths (fig. 4).

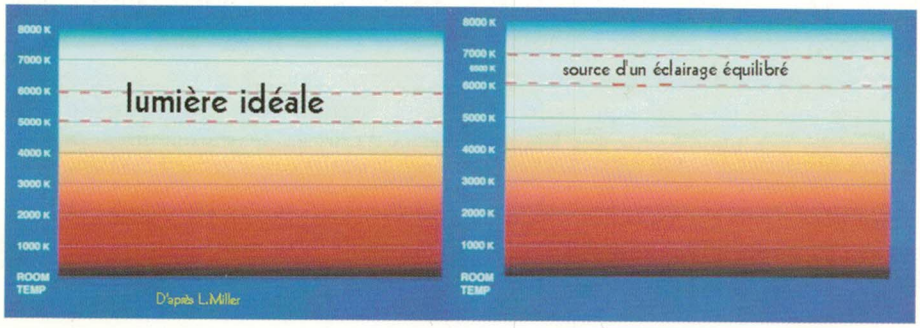

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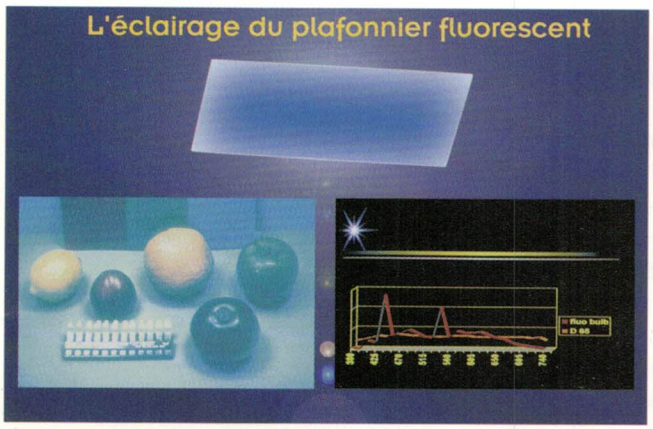
Fig. 3 - Most ceiling light give a color temperature close to 5500 K. Our lightings should take into account recommendations of the Colorimetry Industry, such as a color temperature of 6500 K corresponding to that of daylight.



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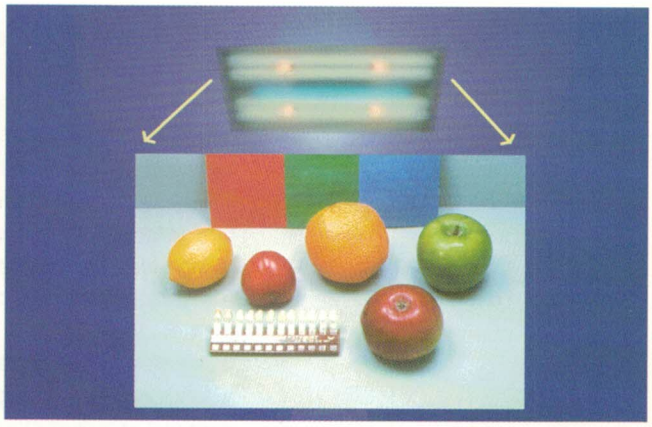

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Fig. 4 - A fluorescent light of 6500 K is poor in intense blues and deep reds, when the incident light should have a full spectrum.

Fig. 5 - Light sources must be mixed so as to obtain a balanced day light.

Fig. 6 - The environment affects color perception, for example lipsticks give a dominant red appearance to the dental tissues.

A balanced lighting with the full spectrum cannot be obtained with only one type of light such as fluorescent light. There has to be a mix of different light sources. Based on this hypothesis, the French light designer Claude Gamain suggested, from the 70's, the use of a balanced daylight (e.g. : Gamain 2965 HF). This type of lighting facilitates color differentiation. Furthermore, it does not damage the cells of the retina, which do not function when exposed to light with an intensity beyond 4000 lux and require many minutes to recover (9,14) (fig. 5).

The incident light plays such a predominant role that researchers, working on a color machine, have decided on a specific incident light, independent of the environment. Unfortunately, no shade matching device is reliable enough to surpass the perception threshold of the human eye. (3, 4, 5, 15, 22).

It is important to note that the structure of a tooth renders the spectro-photometric devices' interpretation hazardous. The tooth structure is in fact multi-layered (enamel, dentine, pulp, cement) and convex altering light reflection. Part of the light is absorbed, part of it is reflected, explaining why a spectro-photometer is absolutely reliable to read a car or textile's color but not to interpret measurements made on a tooth.

The human eye still remains, the most reliable mean for shade matching and and the duty of perfecting this tool is the responsibility of the clinician. Each person must increase the knowledge of its own perception: colorimetric functions, physiologic capacity and work limits.

KNOWING THE HUMAN EYE : A RELIABLE AND SENSITIVE ORGAN

The human eye is capable of distinguishing 2 very similar colors. In scientific vocabulary, we speak of E, with the difference between 2 colors being E = 3. In the retina, there are 2 cell types, the rods and the cones.

The cones are responsible for discerning color groups such as red, green or blue. There are only a few of them. They require an intense incident light with a balanced spectrum.

The rods are responsible for discerning the value, key factor in color. Value is the quantity of light reflected by an object. It varies from the very dark to the very luminous, or from darkness to brightness.

There are more rods than cones, around 100 millions. This explains the importance of value in color determination. The rods tire quickly, in a few seconds, and cannot withstand too intense a light (9, 13,14, 16).

The clinical consequences of these physical characteristics of the retina are of the utmost importance.

We must first determine the value of a color under weak light (22)

Clinically, how can we dim the incident light ? No lighting system solves this problem. A ceiling light is either on or off. The only way is to simply upright the patient's chair, so as to increase the distance between the patient and the light source, which is now positioned behind the patient. This is an application of a physics law stating that light intensity is divided by the square of the distance between object and source (light intensity received by the tooth = incident ceiling light/distance ceiling-tooth) (21) (fig. 12, 13).

This weak lighting renders the rods' work easier and has the advantage of avoiding metamerism errors (metamerism is a physical phenomenon by which 2 objects identical under a first lighting appear different under another lighting). For example, a crown undistinguishable under Gamain's

lighting can be totally unaesthetic under a darker or just different lighting. By varying the intensity of light and the distance between the head of the patient and the ceiling light, we modify not only the incident light but also the predominance of certain rays. If the tooth and the prosthesis seem alike under such different conditions, then we will have avoided, in part or completely, the effects of metamerism.

Other factors influence vision. They have been described in depth in the literature (8, 9,10, 11, 14, 16, 18) and we can mention a few:

- the color of the surrounding walls: a neutral color such as beige or light grey is suggested,
- the iatrogenic colors of lipsticks or scarfs (fig. 6),
- the state of the neighboring teeth, parodontium which always has to be observe in wet conditions.

Thus, the human eye is sufficiently sensitive to perceive the nuances of colors, yet the clinician must know the specific parameters of tooth color in order to best use his visual sense.

KNOWING THE CHARACTERISTICS OF NATURAL TOOTH COLOR

The color of a tooth is traditionally defined according to the following parameters (1,17) :

- hue, chroma, value
- translucency
- opalescence
- fluorescence
- surface texture
- brilliance.

Here are some definitions.

- **Hue or shade family** varies from purple (380nm) to dark red (760nm). It is the base of the color or the term given to color: orange, red, brown, blue, green (shade).
- **Chroma or chromatic intensity** corresponds to the quantity or pureness of a tone of color. It enables to define the quality of a color, strong or weak. (saturation)
- **Value** : is the degree of brightness or darkness of a color. It is also the quantity of color reflected by a tooth. We can appreciate it on a black and white picture. Not to be confused value with the quantity of gray.
- **Translucency** : a material is said to be translucent when part of the light can go through it. Therefore part of the light is absorbed, part is diffused and part is transmitted.

The structure of natural teeth affects color by the architecture of its stratification or layering, by its composition and the quality of the enamel. The root is covered by cementum which gives it an opaque aspect. Dentine is more opaque than enamel (dentine translucency = 40 %). Enamel translucency is at 70 %. At the incisal edge, the enamel is thick and gives this area a translucent aspect. In the cervical area, there is only a thin layer of enamel, the tooth's aspect comes therefore from the underlying dentine (20). Clinical applications : we choose the enamel shade in the incisal zone and the dentine shade at the

Fig. 7 - In the shade form, E. Hegenbarth has classified teeth in groups according to their translucency. He has added sub-classes in order to give more precision to the selection.

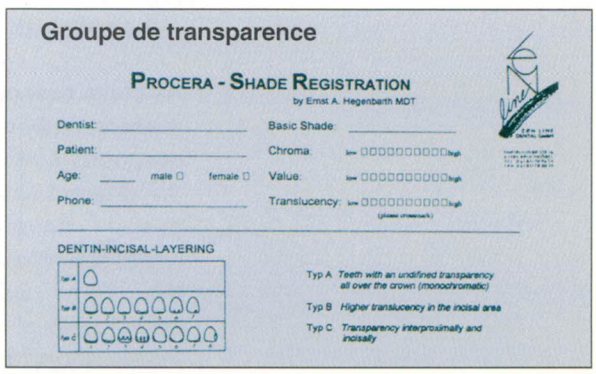

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Fig. 8 - Type A teeth: the translucency is spread over the entire tooth
Fig. 9 - Type B teeth: the translucency is mostly in the incisal area.

junction of the middle 1/3 and cervical 1/3.

During life time there are modifications in the tooth structure due to wear leading to color variations. Young teeth have a lot of enamel with optical effects due to the apatite crystals. With time the enamel layer becomes thinner and there is loss of translucency and opalescence (see further). The saturation increases as the enamel diminishes. Sometimes the enamel has areas of increased opacity (Retzius Striae). These correspond to hypercalcified enamel areas occurring during enamel formation. Dentine influences the tooth color. Reactive dentine is brown or transparent grey, giving an aged tooth a darker appearance. After abrasion, areas of opaque dentine become visible at the incisal edges (20).

All these nuances in structure are not mathematically quantifiable. Only clinical observations allow the dentist to identify the different types of dental structures present. Nevertheless, a number of classification have been put forth. As of the 70's, Sekine suggested a classification of teeth in relation to their translucency (18).
He described 3 groups :

- Group A : translucency spread over the entire surface
- Group B : translucency confined to the incisal area
- Group C : translucency present in the incisal and proximal areas

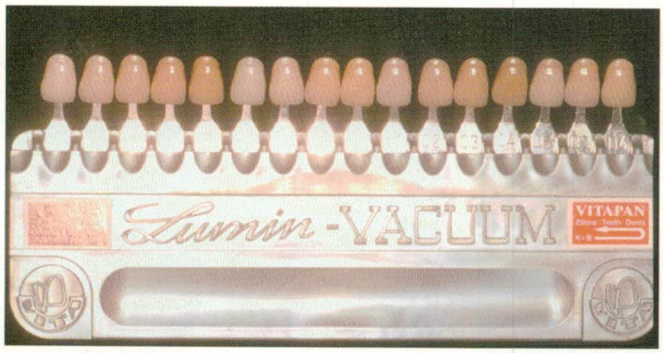
More recently, Ernst Hegenbarth, the well known German ceramist, has added sub-classes to the existing Sekine classification (19) (fig. 7, 8 and 9).

Intra-oral mirrors can be used to play with the incident light and to observe more the tooth's stratifications easily. Of course quantitative measurements of the pourcentage of enamel translucency would be welcomed but is yet to be clinically possible.
Other factors are complementary :

- **fluorescence**: when an incident UV ray between 330nm and 340nm hits an object, this object appears to be emitting visible blue rays. We say that the object is fluorescent.

All of today's ceramics have this fluorescent property and we therefore avoid the black crown in night clubs.

- **Opalescence**: is the enamel's capacity to distinguish wavelengths. The short wavelengths are reflected (they appear blue). The long wavelengths pass through enamel and appear orange when exiting on the other side of the



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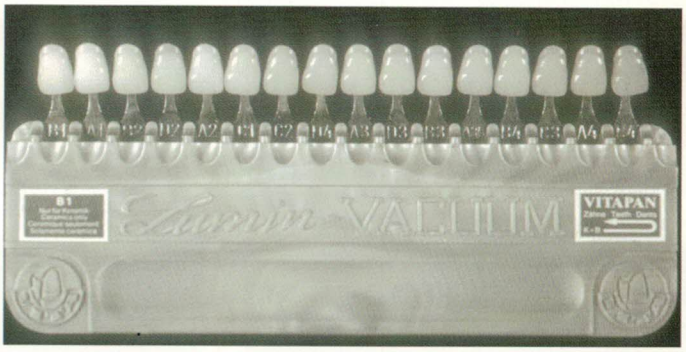

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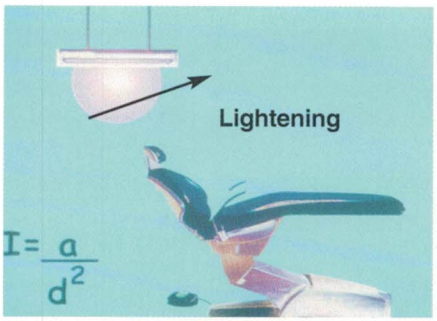
tooth. Most of today's ceramics have this opalescent property generally found in the yellow tooth.

The surface texture and brilliance also affect the shade since they modify the reflection of light. The geography of a crown (convexities, depressions...) is visible on the master model, if the impression of the collateral teeth is accurate (14).



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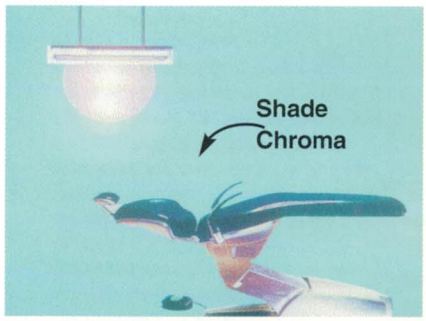

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KNOWING SHADE GUIDES AND HOW TO BETTER USE THEM

Each shade guide is based upon a similar technique to that of a copy-paste on a computer. You have to choose the sample closest to the tooth to reproduce.

The most popular shade guide is that of Vita Lumin Vacuum (Vita). It has 16 different shade samples ranked by shade group A/B/C/D (fig.10).

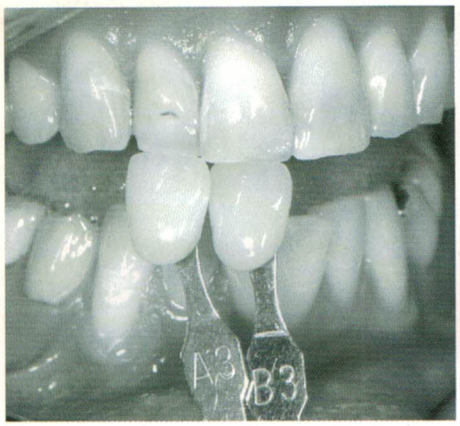
In each group, the shades are ranked according to increasing saturation. This order is logical, but does not take into account the eye's physiology (Cf human eye) (1, 8, 10, 13,14,16).

The value must be chosen first, and it can be done with the Lumin Vaccum shade guide. This shade guide respects an order which goes from the lightest shade B1 to the darkest C4. But this is usually unknown to most clinicians. There are therefore 16 levels of value and this shade guide remains until today the most precise for distinguishing different levels of value (10, 13, 22) (fig. 11).

On a more practical level, to decrease the intensity of the incident light and not burn the rods, the patient's chair can be up-righted and the value quickly chosen within a few seconds. The clinician must not face the patient but always be slightly to the side, so as to work the rods located on the periphery of the retina. (21) (fig. 12).

Once the value is chosen (for example A2), the 2 other factors of color must be determined : hue and chroma.

Fig. 10 - The Vita Lumin Vacuum shade guide: classification according to shade groups: A, B, C, D.
Fig. 11 - The Vita Lumin Vacuum shade guide: classification according to different levels of value, from the lightest shade B1 to the darkest C4.
Fig. 12 - When choosing the value, the patient's chair should be up-righted so as to place the patient furthest from the ceiling light. Saturation of the rods is avoided in this way.
Fig. 13 - When choosing hue and chroma, the chair should be in a horizontal position so as to place the patient straight under the ceiling light.



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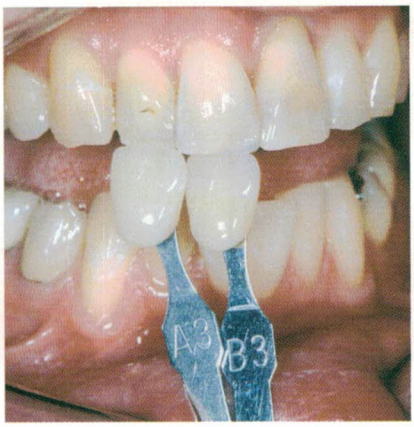

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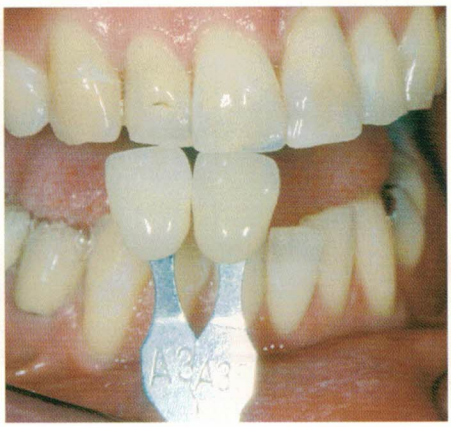

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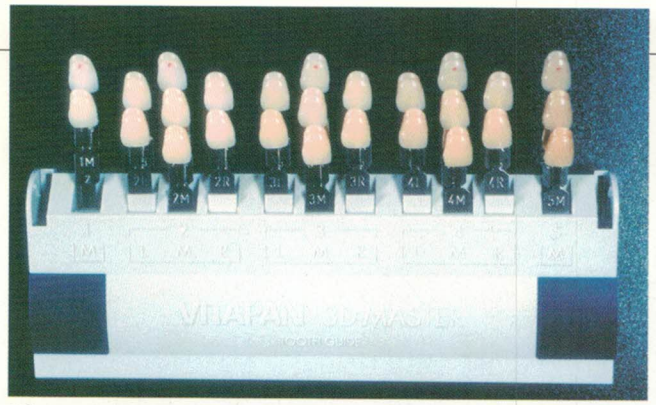
Fig. 14
a) An example of value determined positioned as always slightly to the side of the patient. A3 seems to be the closest match. But there can be a confusion with other parameters of shade matching.
b) Shade A is more appropriate than B.
c) Choice of chroma.
d) The ceramic facet on 11 is integrated in its environment (M. Magne Laboratory).

d

A tooth with A2 value may be part of the C group with a chroma of 2, but this may create confusion. The shade guide Lumin Vacuum does in fact create confusion between value, chroma and hue (fig. 14a, b and c).

To solve this problem and find a clearer classification function of value, the Vita Company commercialized in 1999 the 3D Master shade guide. This shade guide has known a limited success because of the popularity of the classical shade guide to which clinicians have grown accustomed to. The 3D Master presents 5 groups of teeth, each having a different lightening. In each group, each sample has the same value (2, 6, 7). After choosing the value, you have to



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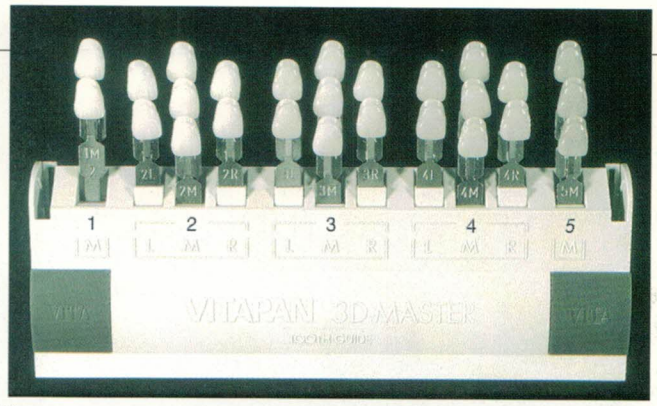

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determine the chroma (3 levels) and last the hue. L = gray, M = medium, R = pink.

Every sample of the 3D Master are within the limits of natural teeth shades. With the existing Lumin Vacuum, the shades were outside these limits, such as the group B (10) (fig. 15, 16, 17). With the 3D Master, we are even tempted to say that more than 5 groups of value would have been even better.

The Shofu Company commercialized just recently the "Natural Color Concept" shade guide, with the hopes of providing an even more precise choice in value. This system has 3 specific shades. Value plus for teeth with high value, Standard, Low value for teeth with low value (fig. 19) Unfortunately, in this system value is last chosen when the rods are quite saturated.

Although all shade guides give basic information on color (value, hue, chroma), very few allow for the analysis of the color in the cervical, the incisal edge or reactive dentine areas. The most interesting shade guide to give such information is that of Creative Color from Degussa. It gives an array of color choices from purple, orange to dark brown (8) (fig. 18).

In certain clinical situations, ceramic samples of dentine and enamel may help clinicians in their search, but this technique is mostly used by laboratory technicians.

Clinicians sometimes can add photopolymerizable colorants to personalize ceramic shade guides.

When all of the information is collected, it has to be communicated to the laboratory technician. Diagrams combined with the shade description are as important as pictures. With numeric or digital pictures, communication is facilitated via E-mail or with the use of magnetic support. Pictures are taken with the shade samples in the mouth,

Fig. 15 - The 3D Master shade guide has 5 groups of value. In each group, all the samples have the same value. After choosing the value, chroma (3 levels) and finally hue must be determined.

Fig. 16 - The 3D Master: black and white view: 5 groups of value can be observed

THE STEPS IN SHADE MATCHING

1) Shade matching is done in a clean dental environment, before preparing the teeth and on hydrated teeth.

2) Lighting: turn off the overhead operatory light and other sources of parasite light. Use a full spectrum ceiling light (Gamain), otherwise take a shade in daylight, facing the window under a not too bright sky.

3) Eliminate any iatrogenic color sources such as lipsticks, scarfs ...

4) Take off magnifications for color matching purposes. Use loops to evaluate dental surface texture. Do not use tinted or shaded prescription glasses.

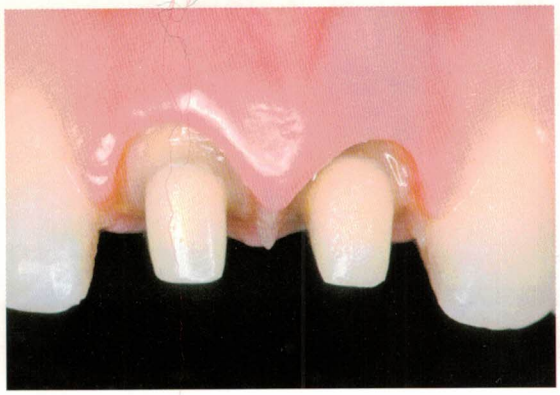
5) Value selection should be done with the chair in an upright position so as to decrease the incident light intensity. Do not face the patient, be slightly to the side so as to work the rods quickly (10 seconds maximum) and not saturate them. Then place the sample in the mouth and take a black and white picture.

6) Hue and chroma of dentine are evaluated at the cervical and middle third junction. Then place the sample in the mouth and take a color picture.

7) Eventually, use a complementary shade guide for the cervical area.

8) The enamel characteristics are evaluated in the incisal thirds (opalescence, translucency, halo).

9) At bisque try in, refine the value choice with a black and white picture with the crown in place (fig. 20 and 21).



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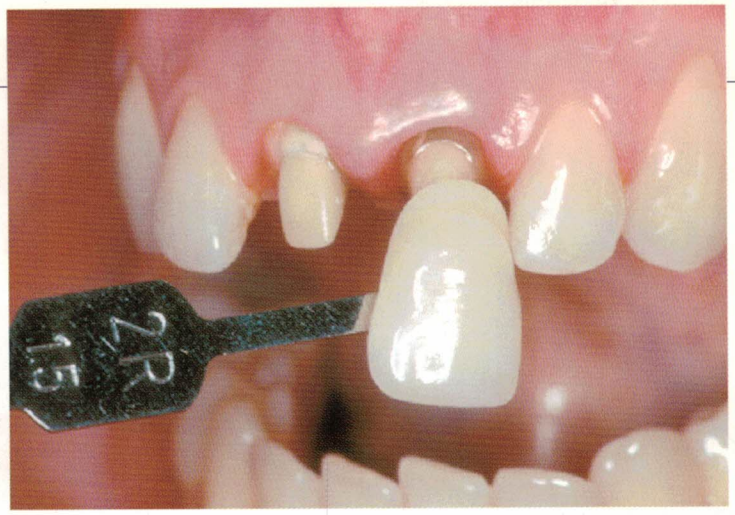

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Fig. 17
a) A young patient has 2 central incisors needing restorations. 2 ceramic inlay-cores (Alumine) are cemented and 2 In-Ceram crowns are cemented as final restorations. This combination allows optimum light transmission through the crowns in an environment with light teeth and thin gingival contour.
b) Using the 3D Master shade guide, the closest match to the observed tooth is a 2R 1.5.
c, d) Final result after cementation of In-Ceram crowns (M. Leriche Laboratory) from up close and from a far.

c

d

allowing the laboratory technician to evaluate and compare the colors (23).

CONCLUSION

Patients often judge the quality of our restorations based on their appearance and color match. In order to satisfy them, the dentist must understand the scientific and physics basis of color. Only then can a dynamic and precise system, using a trained eye, be determined for shade selection and this until one day a "magical machine" can shade match for the clinician.

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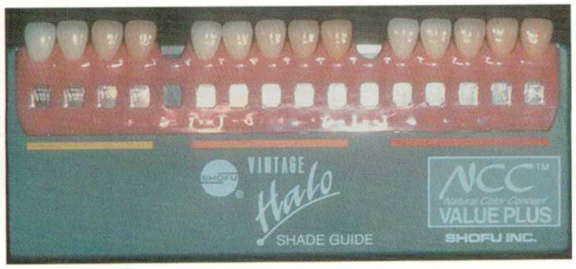

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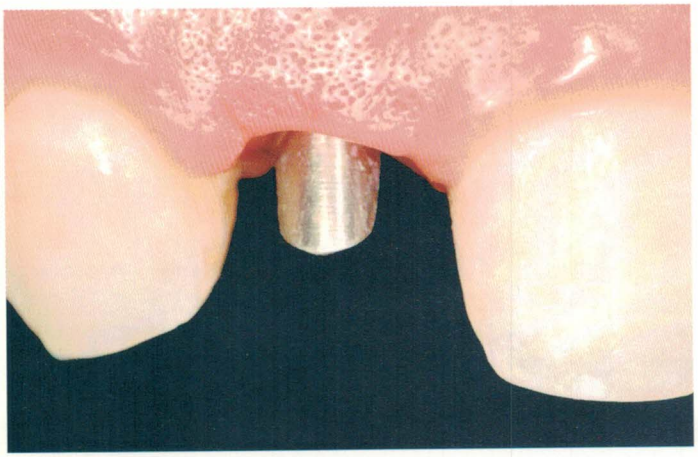
Fig. 18 - The Creative Color (Degussa) complementary shade guide allows a color analysis of the cervical, incisal and reactive dentine areas.
Fig. 19 - The new NCC (Shofu) shade guide gives details on the level of value. High value teeth can be distinguished from low value teeth.



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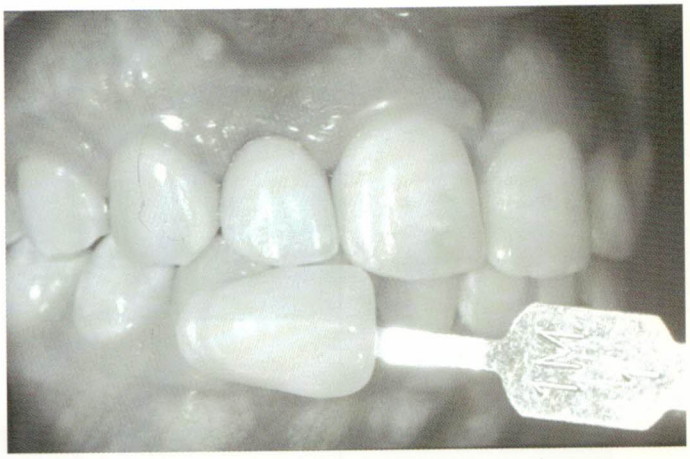

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Fig. 20
a) Congenitally missing lateral incisors. After osteo-integration of the implant, a ceramic base inlay-core is screwed on the implant in order to allow light transmission in the cervical area.
b) At bisque try in, it is important to adjust the value by taking a black and white picture to compare the bisque with the closest shade match to the tooth.
c) Final result after cementation of a Procera crown (J.M. Etienne Laboratory).

ABSTRACT

SHADE SELECTION : TOWARDS A RATIONAL PROTOCOL

Shade selection is an everyday act in our practices whether it is for ceramics, composites or resin denture teeth. It seems simple enough, but it actually is a rather complex process. It requires scientific knowledge, trained eyes and a precise protocol in order to obtain a satisfactory result. This clinical article aims to provide the clinician with a practical and realistic approach to color in dentistry. First and foremost, the clinician must develop his sense of observation and train his eye to distinguish between the different parameters of natural tooth color. The judicious use of shade guides in association with pictures and diagrams, helps the correct transfer of data from chair side to the laboratory technician.

RÉSUMÉ

LE CHOIX DE LA TEINTE ... VERS UN PROTOCOLE RATIONNEL

Choisir une couleur est un acte quotidien dans notre exercice qu'il s'agisse d'un composite, d'une céramique ou d'une dent artificielle pour prothèse amovible. Cet acte banal, simple en apparence, est en réalité complexe. Il exige des connaissances scientifiques, un œil averti et un protocole précis pour obtenir un résultat satisfaisant.
Dans cet article une approche pratique et réaliste de la couleur en dentisterie est illustrée étape par étape. Le protocole rationnel proposé permet de diminuer la part de subjectivité et d'augmenter la part d'objectivité du processus décisionnel et se faisant de prévenir les illusions et les erreurs. Avant tout, le praticien doit apprendre à développer son sens de l'observation et entraîner son œil pour différencier les paramètres de la couleur d'une dent naturelle. Il est démontré que l'utilisation judicieuse de teintiers, associés à des photographies et à des schémas, permet un transfert correct des données au prothésiste dentaire.

RESUMEN

LA ELECCIÓN DEL COLOR : PARA UN PROTOCOLO RACIONAL

Elegir un color es un acto cotidiano en nuestra práctica, ya se trate de un compuesto, de una cerámica o de un diente artificial para prótesis amovible. Este acto corriente, simple en apariencia, es en realidad complejo y exige conocimientos científicos, un ojo de experto y un protocolo preciso para obtener un resultado satisfactorio.
En este artículo se ilustra, etapa por etapa, un enfoque práctico y realista del color en odontología. El protocolo racional propuesto permite disminuir el aspecto subjetivo y aumentar la objetividad del proceso de decisión, a la vez que se evitan las ilusiones y los errores. Ante todo, el dentista debe aprender a desarrollar su sentido de la observación y a entrenar su vista para diferenciar los parámetros del color de un diente natural. Se ha demostrado que el uso racional de los muestrarios de colores, asociados a fotografías y a esquemas, permite transferir correctamente los datos al protesista dental.