

Natural Color Concept: A Systematic Approach to Visual Shade Selection

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During the past decade manufacturers of ceramic veneering materials have made efforts to improve the shade communication related to laboratory-fabricated dental restorations. Shofu has performed extensive research in this area, resulting in a constant improvement and development of new techniques and materials. For instance, studies by Shofu and Yamamoto on the structure of enamel^{1,2} led to the development of opalescent enamel porcelains, a standard that was adopted by the industry and is now offered as a “must” by all of the most important manufacturers of veneering materials for the dental laboratory.

For the past 2 years, Shofu has offered the Natural Color Concept, a comprehensive visual shade determination system that incorporates almost 10 years of research and, for the first time, fulfills all necessary parameters.

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COLOR CONCEPTS

To date, there is no systematic training on visual shade determination³⁻⁵ for dental technicians or dentists.⁶ Therefore, all attempts to improve the color communication fail at this barrier. Many concepts⁷ attempt to improve shade communication, however, and various color standards are available from market leaders such as Vita Classic, Vita 3D Master, Chromascop, and Biodent. Other manufacturers have tried to copy these color standards.

The above mentioned color standards are based solely on observations and represent a relatively small spectrum of the color variations that are present in nature. The many difficulties associated with visual shade determination of manufactured or customized shade tabs for natural teeth are further complicated by the fact that color interpretation by the human eye is influenced by a variety of factors[Au: sentence ok?]:

- Light conditions
- Gingiva shade
- Influence of the surroundings
- Type and arrangement of the shade guide
- Position of the shade tab

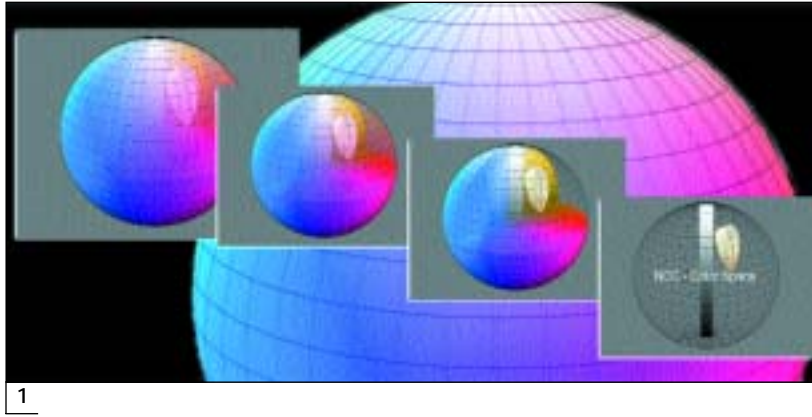


Fig 1 The color space can be easily explained by means of a simulation model. Imagine a globe: The outer shell shows the variety of colors as a rainbow. On the surface of the outer shell, the pure hue is present in its strongest chroma. Cutting this model along the north pole–south pole axis reveals the value. Another cut at the level of the equator shows the chroma, which increases toward the outer shell.

- Different color perception capacities
- Knowledge about color and its perception
- Experience in shade selection
- Acting mechanism of the eye (simultaneous contrast, contrast increase)

When determining a color, the human eye perceives a certain shade; however, under modified light conditions, the color perception and the subsequent shade selection can be completely different. This implies that when shade guides are used exclusively, the tooth shade required is always described in an insufficient manner.⁷⁻⁹

It is important to use auxiliary tools and a shade indicator that is arranged according to a logical system oriented by the natural model.^{4,5}

VISUAL SHADE SELECTION

There are many postulates on the issue of shade determination. As long ago as the 1930s, over 600 dentin and enamel shades were verified in a clinical study^{6,10} in which more than 1,000 patients were evaluated. The standard for visual shade determination was established by Sproull^{1,2} as a result of his investigations:

- Shade guides present a different stratification than do natural teeth.
- The material of which shade guides are made does not correspond to the restorative mate-

rial. This leads to metamerism when reproducing color.¹¹

- There is no logical organization of the hues of natural teeth in the current shade guides.

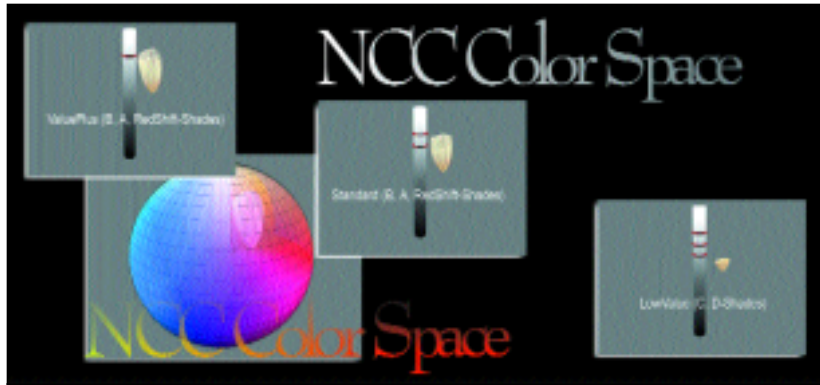
The conclusion from over 60 years' work and research has been that despite the availability of necessary knowledge, a better shade determination system has not yet been achieved. Only the increased esthetic demands in the 1980s and 1990s have stimulated new ideas.⁹

In a worldwide clinical study undertaken by Yamamoto in conjunction with Minolta and Shofu, the tooth shades of more than 3,500 patients were recorded and analyzed by means of a spectrophotometer.¹²⁻¹⁴ These color data formed the basis of the dental color space and led to the development of the Natural Color Concept (NCC) color indicator and the Vintage Halo Porcelain System.

THE DENTAL COLOR SPACE

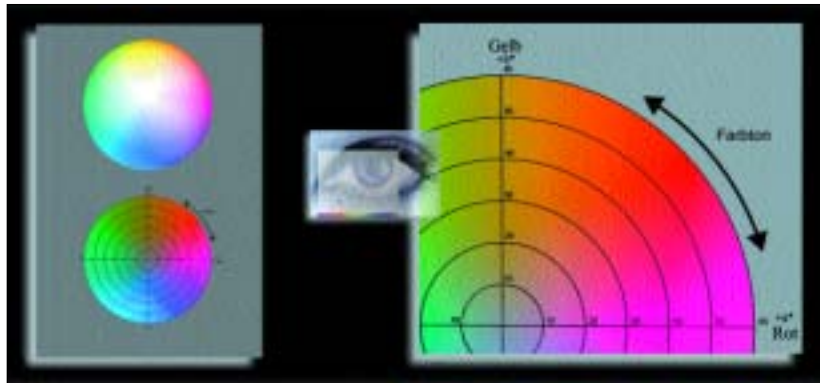
Evaluation of these color data shows that the color space of natural teeth is limited to a narrow range (Fig 1). Natural teeth can be classified in three shade groups according to their hue (Fig 2): yellowish shades, orange shades, and reddish shades. Furthermore, there are differences in the color intensity (chroma) and brightness (value)^{15,16} (Figs 3 to 5). These features can be illustrated

Fig 2 The color range of natural teeth is reminiscent of a cloud. It ranges from yellow to red, with variations in value and chroma, starting with the B shades for yellow, then the orange A shades, and the red-dish shades of the RedShift group on the right. The most intense colors are found on the perimeter of the outer shell: B root, A root, and R root. Moving toward the polar axis, the colors decrease in intensity until we reach B1, A1, and R1. Now moving upward, the brightness (value) increases—the ValuePlus shades represent these shades. Again, the most intense shades are located on the outer part (VB4, VA4, VR4), and the less intense shades are on the inside (VB1, VA1, VR1). C and D shades are not individual hues, but represent a darker orange; ie, they are A shades with reduced value, and are therefore located on the latitudes below the Standard B, A, and R shades. This color space was established by means of spectrophotometric analysis of more than 3,500 patients.



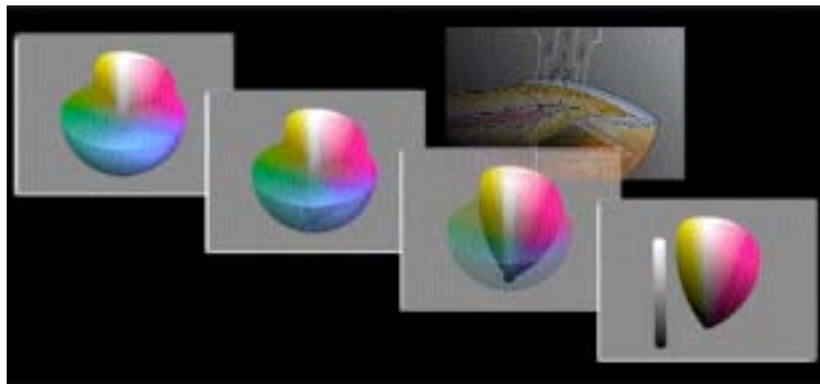
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Fig 3 The chroma decreases from the outer shell toward the center of the globe. The left side of the graphic shows a view of the “north pole”/white of the globe. A cut made at the equator (see amplification on the right side) shows the change in color.



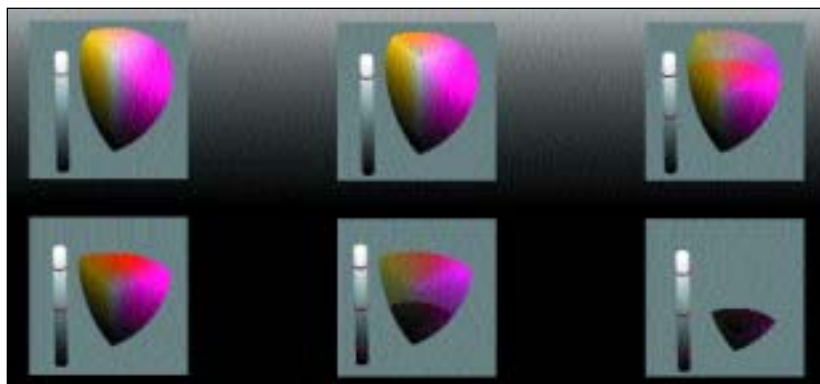
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Fig 4 If the “color globe model” (L*a*b color space) is cut along the north pole–south pole axis, modification of the value is observed.



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Fig 5 Moving along the value axis toward the “south pole”/black, the influence of the two dimensions, value and chroma, can be seen. Value decreases toward the lower part, chroma decreases toward the axis.



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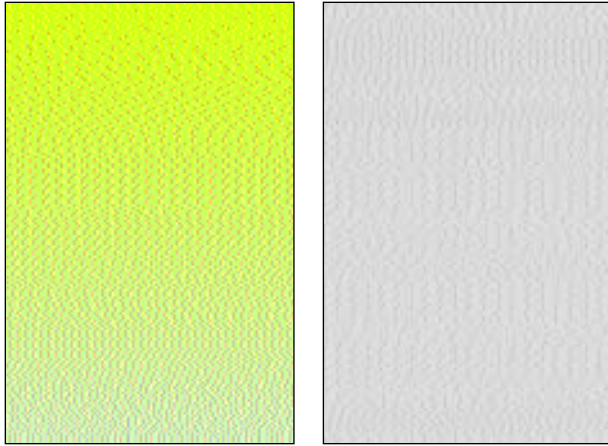


Fig 6 The modification of the color intensity (chroma) does not necessarily lead to a decrease of the value, as shown by the transformation of this graphic into the gray mode.

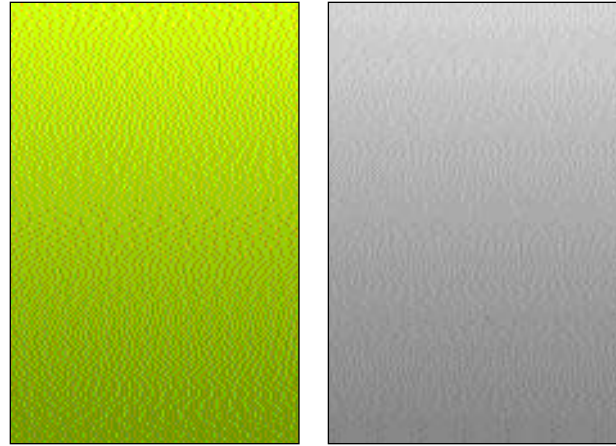


Fig 7 The modification of the color brightness (value) while maintaining the same chroma, however, leads to an increase or decrease of the gray value.

using the color yellow as an example: there are stronger and weaker (chroma) as well as lighter and darker yellow shades (value) (Figs 6 and 7).

NATURAL COLOR CONCEPT

This logical arrangement was put into practice by Shofu through the Natural Color Concept System.¹⁷ The human eye can distinguish about 300 shades, of which almost 100 are irrelevant from a statistical point of view. In the Natural Color Concept System, 208 color blends, based on 38 basic shades, are possible.

The color blends are organized by their position in the L^*a^*b color space in a simple and clearly arranged manner according to hue, chroma, and value.¹⁸ As a result, there are yellowish shades (group B), orange shades (group A), and reddish shades (RedShift). The chroma of the hues increases from left to right and is identified by the increase of the numbers (B1, B2, B3, etc). As Yamamoto's study¹⁷ shows, the shades in the Vita Classic color system that belong to the C and D ranges are not shade groups as such, but should be included in the dark orange shades.

The third dimension of color—the value—is subdivided into three levels in the NCC System:

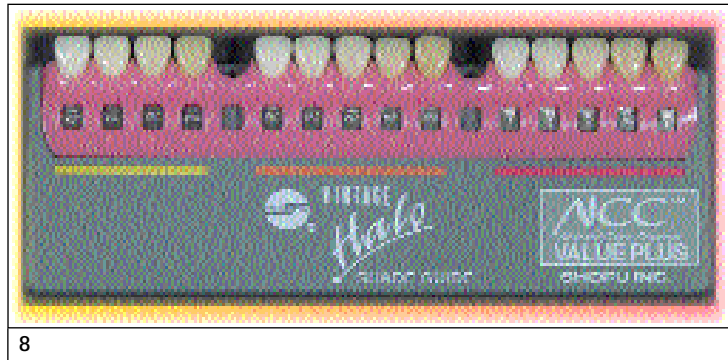
1. Brighter yellowish, orange, and reddish shades—the so-called ValuePlus shades, ie, shades with an increased value (Fig 8).
2. Yellowish, orange, and reddish shades with a medium value—standard shades. Around 55% to 60% of all shades in nature belong to this range (Fig 9).
3. Darker orange shades—LowValue shades, ie, shades with decreased values (Fig 10).

CONTRAST EFFECT

When a dental restoration is being fabricated, the surroundings of the teeth, especially the shade of the gingival tissues, are decisive for the color integration of the restoration. With the conventional visual shade determination, so-called simultaneous contrast effects and contrast increases^{12,17,18} occur.

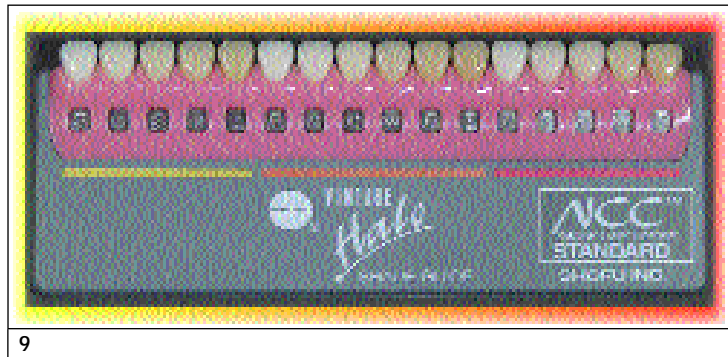
To explain briefly: Shade selection is performed in a reddish environment—skin, lips, and gingival tissues. This environment, and especially

Fig 8 The ValuePlus shade guide comprises 14 shade tabs.



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Fig 9 The Standard shade guide comprises 16 shade tabs.



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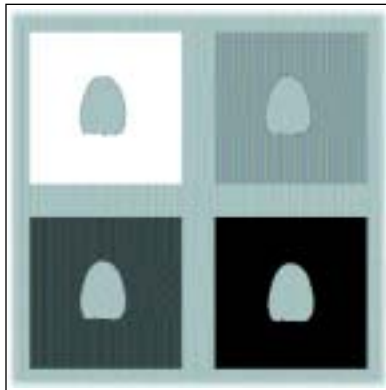
Fig 10 The LowValue shade guide comprises 8 shade tabs.



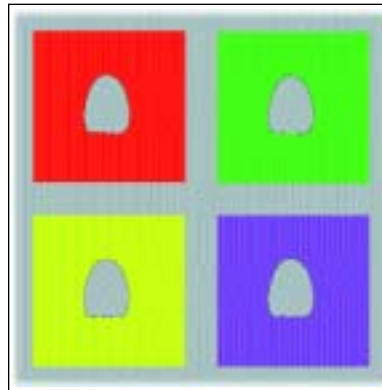
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the reddish-violet color of the gingival tissues, leads to a marked decrease in the receptiveness of this area to the color spectrum (Figs 11 to 13). The brain replaces the apparent excess of red with the complementary shades green to yellow.

This leads to a subjectively modified color perception, which expresses itself in a tendency toward seemingly objective yellowish shades. This contrasting effect can be neutralized by the use of a gingival mask.



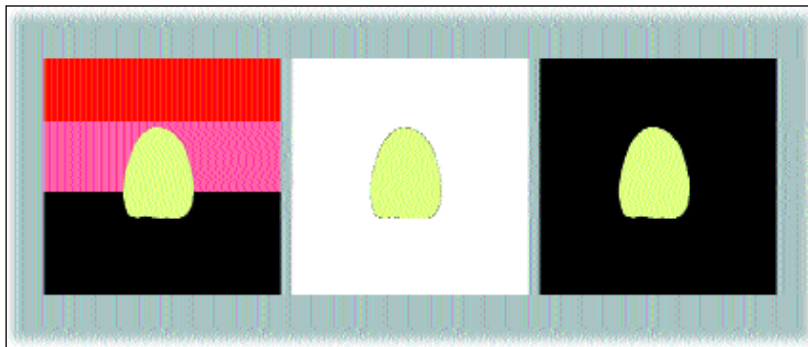
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Fig 11 Contrast increase: the brightness of the gray tooth is perceived differently depending on the background.

Fig 12 Shade contrast: the color impression of the same gray tooth appears different depending on the surrounding color.



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Fig 13 The color environment influences our color perception of the gray tooth significantly (from Yamamoto).

THE CLINICAL PROCEDURE

The first step consists of selecting a Gummy gingival mask, which is available in three different values. In this way, it is possible to selectively imitate the pigmentation of the mucosa and closely approximate the color of the environment during shade selection (Figs 14 to 16). The subsequent visual shade selection is achieved through several steps, starting with determining the chroma. The procedure can be explained by means of simple questions.

Evaluation of Chroma: Is the shade weak or strong?

Determination of the chroma is performed using the A hue group. Of course, the chroma can also be established with either of the other two hue groups, yellow or red, but the tooth shades of more than half of the population fall into the or-

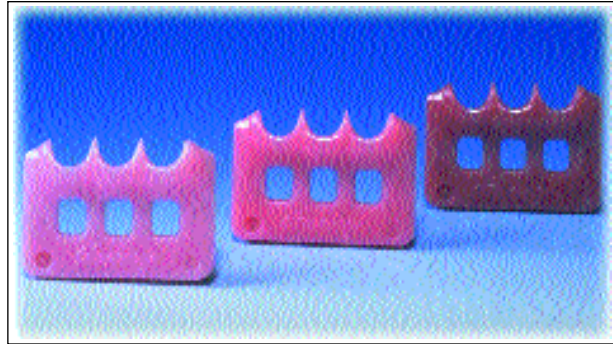
ange spectrum. By determining the chroma with the A group of medium value (Standard), the eye is less offended by possible shade differences (Figs 17 to 19).

Evaluation of Hue: Is it a yellow, orange, or red shade?

The hue is now analyzed with the shade tabs of the B/A and R groups (yellowish, orange, reddish) of the previously selected chroma, eg, B2, A2, R2, of the Standard shade guide. Once the hue is established, the chroma is checked again (Figs 20 to 25). For example, if the selected hue is A and the previously established chroma was 2, then the shade tabs placed in the Gummy for second evaluation are A1, A2, and A3. It is important that the chroma selected in the first step be placed in the middle of the Gummy during the second evaluation.

Fig 14 The Gummy gingival mask was developed to neutralize the influence of the color environment on our color perception during visual shade selection.

Figs 15 and 16 The dark pigmentation was selected as the proper gingival mask.



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Fig 17 Determination of the chroma. The procedure is carried out with the orange shade references of the A group.

Figs 18 and 19 While establishing the chroma, the shade tabs should not be taken out of their housings, in order to avoid any contrast increases.



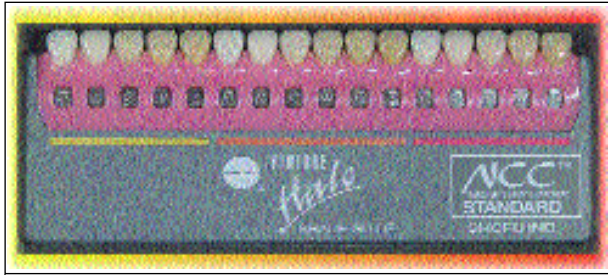
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Fig 20 Determination of hue. The shade tabs cover the range of possible hues: yellowish (here, B2), orange (here, A2), and reddish (here, R2).

Fig 21 to 23 The proper shade is very easy to select through direct comparison.



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Fig 24 The evaluation results in a reddish shade, in this case R2.

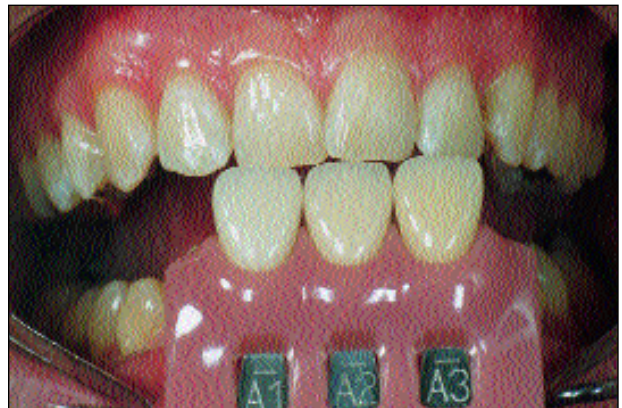


Fig 25 The second evaluation of the chroma helps to recognize a possible difference in the value. Because chroma and value are very difficult to differentiate with pale shades (as in teeth), this measure helps to increase the sensitivity.

Evaluation of Value: Is it a light or dark color?

Once the proper hue and chroma are selected, fine tuning is achieved by determining the proper value (Fig 26). If the tooth to be checked looks lighter than the shade tabs placed in the Gumy, the value is higher than that of the Standard

shade guide (Figs 27 and 28). If so, the shade reference (the shade tab placed in the middle) is compared to shade tabs of the ValuePlus shade guide. If the tooth to be compared to looks darker than the shade tabs placed in the Gumy, then the tooth has a lower value, and the Low-Value shade guide should be used (Figs 29 to 31).

Fig 26 Determination of value. The value selection is carried out by means of a shade tab of the same chroma and a shade tab of a higher chroma (here, VR2 and VR3).

Figs 27 and 28 To do this, shade tabs of a higher value are placed next to the previously properly selected shade (here, R2) in the Gummy.



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Figs 29 and 30 If the new evaluation of the chroma shows a reduced value, the corresponding LowValue shade tabs of the same chroma level are placed into the Gummy.

Fig 31 The shade selection leads to a pale, reddish shade on a Standard value level. The chroma is located between 1 and 2. To reproduce the base color, R1 and R2 have to be mixed in a 50:50 proportion.



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CONCLUSION

After more than 2 years of personal clinical experience and numerous training courses regarding this color system, it can be concluded that the Natural Color Concept is an easily understood visual shade determination system that fulfills the requirements^{1–6,9,12,18,19} for precise color reproduction:

- A color space according to the natural model.
- The arrangement of the shade tabs corresponds to the logical organization of the dental color space and is clearly arranged by means of a classification in the areas yellow, orange, and red.
- Color analysis is accomplished by asking simple questions and leads to a precise result.
- The effect of metamerism¹¹ between shade tabs and veneering material is avoided, because the shade tabs are made of the same ceramic as the veneering ceramic.
- The contrast increase effect is eliminated by the use of the Gumy gingival mask.

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