Color unit differences (ΔE) of acrylic resins related to powder-to-liquid ratio, sample thickness and trade marks

Diferenças de unidades de cor (ΔE) de resinas acrílicas em função de proporções, espessuras e marcas

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ABSTRACT

The purpose of this study was to verify color differences (ΔE) of acrylic resins using specimens with 6, 4 and 2mm of thickness. The acrylic resins tested were two medium pink - Clássico and Vipi - and three 66-shade materials - Dencor (Clássico), Vipi-cor (Vipi) and Duralay (Reliance). By means of a spectrophotometer were obtained the color parameters (L, a*, b*). ΔE values were determined according to the following conditions: 1) +10, –10 and –20 powder/liquid ratios (in wt%) compared to the normal ratio recommended by the manufacturer; 2) 4 and 2mm thicknesses compared to the 6mm control; 3) comparison between pink-colored resins and among the three 66-colored resins. Results led us to conclude that under a clinical point of view, variations on the powder/liquid ratio had little influence on color alteration when compared to the normal ratio, as the greatest value (ΔE=1.6) would not be noticeable by a large number of examiners. When compared to the 6mm control, it was demonstrated that specimens with 4mm of thickness did not show great color alteration (ΔE=1.7 maximum), whereas the 2mm specimen suffered unsatisfactory alterations, which, depending on the material and ratio, reached ΔE=8.4. Color similarity between pink-colored resins was good, but differences among 66-colored resin were unsatisfactory (up to ΔE=16.2).*

UNITERMS

Acrylic resins, Color; dental materials

INTRODUCTION

Esthetics, when considered as an imitation of nature, is an especially seek out characteristic in the current dental practice. Undoubtedly, the correct imitation of natural colors is a fundamental component to reach satisfactory aesthetic results. In many cases, color matching is dependent of capacity to evaluate, register and communication between the members of the staff involved in the work.

The color evaluation of an object can be made based on subjective or objective methods. Subjective methods are based on visual observation, whereas in objective tests color parameters (L*, a*, b*) are quantified. L* represents brightness on vertical axis from black to white. On horizontal planes, a* represents red on the positive side and green on the negative side, whereas b* represents yellow on the positive side and blue on the negative one[13,14]. Color differences (Δ*E*) between two objects are evaluated using one object as control (with its coordinate L*, a*, b*) while the other (with its coordinate L*, a*, b*) is compared to it. Both coordinates belong to the Cartesian space and the difference of color between them is determined by the coordinate differences of the respective parameters, as according to the following formulate: $\Delta E = [(\Delta L)^2 + (\Delta a)^2 + (\Delta b)^2]^{(1/2)}$ [13].

O'Brien[13] (1997) presented a correspondence between values of color difference (ΔE) and clinical perception: perfect (0); excellent (0.5 to 1); good (1 to 2); clinically acceptable (2 to 3.5); unsatisfactory ($\Delta E > 3.5$). Some individuals present sensitivity to differentiate ΔE=0.5, whereas others cannot distinguish ΔE=4, a reason for frequent disagreement among professionals. In a comparative study[4] between visual and spectrophotometer evaluations, it was verified that 50% of all examiners could not detect differences lower than ΔE=5.4.

Clark[1-3] (1931,1933) was one of the first authors to worry about color of teeth and restorative materials, and introduced a color scale several decades ago. However, it was verified that different materials present color differences, even when they have the same color according to the scale[6]. Horn et al.[8] (1998) referred in their study to the lack of reliability in color scales when they are subjectively employed.

Discrepancies among color scales[17], materials with same color shade[6,16], and the low visual sensitivity of some observers[1,4,8,] are leading researchers to employ an intraoral spectrophotometer to determine tooth and material colors with more reliability[11,12].

In acrylic resins, the staining pigment is added to the powder, a fact that may lead to the idea that different powder/liquid ratios may influence the final color. As resins are translucent, thickness may also have influence on color depending of the color of the underlying material and on the powder/liquid ratio. Hence, it is the purpose to study color differences (ΔE) among acrylic resins, as related to powder/liquid ratio, thickness and material trade mark.

Thus the null hypothesis were the following: a) different powder/liquid ratios to perform specimens present similar color parameters; b) acrylic resin specimens of different thickness present similar color parameters when evaluated over white or black background; c) acrylic resins with same color codes present similar color parameters.

MATERIALS AND METHODS

The materials tested in this study were: two medium pink thermally activated acrylic resins, Clássico (Artigos Odontológicos Clássico, Campo Limpo Paulista, SP, Brazil) and Vipi (Dental Vipi, Pirassununga, SP, Brazil) and three 66 color chemically activated acrylic resins, Dencor (Artigos Odontológicos Clássico, Campo Limpo Paulista, SP, Brazil), Vipi-cor (Dental Vipi, Pirassununga, SP, Brazil) and Duralay (Dental MFG Co, Worth, Ill, USA).

Specimens were composed of a single piece, prepared in a proprietary flask (Figures 1 and 2), as three concentrically superposed discs with 2mm thickness each one, which had the following diameters (in mm): 10, 30 and 50, associated to the thickness of 6, 4 and 2mm respectively (the flask is used by Artigos Odontológicos Clássico, Campo Limpo Paulista, SP, Brazil for quality control process, and is obtained by machining of brass).

The specimens (n=3) were obtained as follows: **1)** powder/liquid ratio: all specimens were obtained with a constant amount of liquid (3±0.05ml). The powder was weighted (accuracy 0.01g) to the following amounts: 6.60g for the normal ratio (provided by the manufactures – 3:1 by volume); 7.26g for +10% ratio; 5.94g for -10%; 5.28 for -20% ratio. **2)** Mixing powder and liquid in a plastic jar provided with cover. **3)** After reaching dough-forming stage the mixture was placed in the flask (Figure 1 and 2) and submitted to a load of 500kgf in a special press with electrical resistances to maintain temperature at 100^{o}C. Flask was kept under load for 10 minutes. This technique was used for both kinds of resins, thermically and chemically activated, in order to get a quick total polymerization (quality control process, Artigos Odontológicos Clássico, Campo Limpo Paulista, SP, Brazil). **4)**The flask containing the specimen was then removed and cooled by immersion in water at room temperature. Specimens were removed, air-dried and stored dry for seven days in closed recipient protected from light, until spectrophotometer readings were performed.

The spectrophotometer (968, X-Rite, Grandville, MI, USA) provided color (L*, a* and b*) and opacity parameters. With the color parameter differences between two readings from different situations, it was possible to calculate color differences (ΔE). According to the spectrophotometer technique, readings were performed placing the specimens on black and white surfaces (following manufacturer's instructions of the spectrophotometer).

Three different types of comparisons were performed: a) considering as control the mean values of color parameters obtained with normal ratio, for each thickness and material. With theese normal ratio parameters were compared those of ratios +10%, -10% and -20%; b) considering as control the 6mm thickness were compared the thicknesses of 4 and 2mm, in each ratio and material; c) comparing the two pink resins (leading to one comparison) and the three 66 color resins (leading to three comparisons). In each comparison the control was the mean of parameters (L*,a*, b*) of one material (x) to which was compared the other material (y), getting n=3 values. Afterwards were used as control the mean values of the other material (y) to which were compared the values of material x (n=3). This procedure lead to n=6 repetitions.

The values of color differences (Δ*E*) for each of that three type of comparisons were submitted to a separated analyses of variance (ANOVA – three-way): a) effect powder/liquid ratio (three main factors): ratio (3 levels: +10%, -10% and -20%); thickness (3 levels: 2, 4 and 6mm); materials (5 levels). b) effect of thickness (3 main factors): thickness (2 levels: comparing 2mm to 6mm and 4mm to 6mm); ratio (4 levels: normal, +10%, -10% and -20%); material (5 levels); c) effect comparison of material (3 main factors): resin comparison (4 levels: *Pink Classico x Pink Vipi*; *66 Dencor x 66 Vipi*; *66 Dencor x 66 Duralay*; *66 Vipi x 66 Duralay*); ratio (4 levels: +10%, normal, -10% and -20%); thickness (3 levels: 2, 4 and 6mm).

RESULTS AND DISCUSSION

As the comparisons of color differences (Δ*E*) were performed by three different ways, it was our choice to join results and discussion as a single item, and thus not mix up the various approaches.

Effect ratio

The analysis of variance of color differences (Δ*E*) when comparing ratio effect showed statistically significant differences on main factors (ratio, thickness and resin) and all interactions of two factors. The means of Δ*E* corresponding to the interaction *resin x ratio x thickness* can be found in Table 1, which also shows the critical value Δ*E* = 1.00 for contrasts obtained by Tukey's test (if differences between any 2 means are higher than this critical value is characterized statistical difference).

By analyzing the mean values demonstrated in Table 1, it is verified that resin dilutions (-10% and -20% of powder) led to the highest color differences Δ*E* (only numerically in general) just for 66-shade resins, a result that is in accordance with Costa[5] (1970). Even so, the influence of resin dilution was generally higher for the largest thickness, probably due to a smaller influence of the background. That suggests that in specimens with small thickness the dilution of the pigments is not so severely affected. Because specimens with small thickness are more translucent than thicker ones, final color parameters will be more dependent on the background, different than with the thicker specimens, when color parameters are more dependent of pigments concentration.

A general appreciation of the mean values in Table 1 shows that the Δ*E* values are low, considering the visual perception, as many of them were lower than one color unit Δ*E* (a value up to 1 is clinically excellent and up to 2 is good)[13]. Therefore the powder/liquid ratio had very little influence on the alteration of color in acrylic resins, considering human eyes color sensibility.

Effect of specimen thickness

The analysis of variance demonstrated statistically significant differences for all main factors (resin, ratio and thickness) and corresponding interactions. Table 2 presents the mean values corresponding to the *resin x ratio x thickness* interaction and critical value for contrast obtained using Tukey's test.

Table 2 shows that for all comparisons between thicknesses of 4 and 6mm (odd lines), color differences were relatively small. All mean values are below Δ*E* = 2, which is not even noticeable for most observers[13]. On the other hand, comparisons between thicknesses of 2mm and 6mm reached very high differences (up to Δ*E* = 8.4, line 6 from Table 2). Δ*E* values of 66 Vipi and 66 Duralay resins were not very high at 2mm thickness, especially for the latter, for which no value exceeded Δ*E* = 3.5, which would be the acceptable limit from a clinical point of view[13]. This is probably due to the great opacity and little variation on the color parameters with relation to the thicknesses of Duralay resin (Table 4). The great influence of small thickness is in accordance with other authors[5,7,9] and it is probably due to its higher translucency, being enhanced the influence of underground.

Differences between materials with the same color code

The analysis of variance for this comparison also showed statistically significant differences for main factors (resin, ratio and thickness) and corresponding interactions. The mean values related to the *resin x ratio x thickness* interaction are presented in Table 3, as well as Tukey's critical value for contrast.

The comparison between pink resins showed great similarity (Table 3, lines 1 to 3). No statistically significant difference was detected among the mean values and the highest deviation (ΔE = 1.4) does not characterize visual discrepancy[13]. On the other hand, comparisons among 66 *Dencor x 66 Duralay* and *66 Vipi x 66 Duralay*, for which values from ΔE = 11.4 to 16.2 (Table 3) were obtained, characterize different colors, as stated by Ichiwata et al.[9] (1984). The *66 Dencor x 66 Vipi* comparison presented smaller differences (ΔE = 4.7 to 8.9), but even so, it was beyond clinical acceptability[13]. Using Tukey's test for comparisons among mean values may be usefull to know what ratio and thickness influence to ΔE be significantly higher or when color discrepancies are more pronounced. It was verified that with normal ratio and 6mm thickness, the difference between resins 66 Dencor and 66 Vipi (Table 3, line 4, ΔE = 8.1) was significantly smaller than the difference between resin 66 Dencor and 66 Duralay (line 7, ΔE = 14.5) or between 66 Vipi and 66 Duralay (line 10, ΔE = 11.9). This means that colors 66 Dencor and 66 Vipi are more alike than the others resins.

Color differences among materials with same color code were found by several authors[5-7,10,16,17], a fact that led some researchers[10,15] to suggest the elaboration of universal color codes, which should be followed by manufacturers when developing their products.

The color differences (ΔE) observed among materials can be explained by the parameters presented in Table 4. Although they are very similar for pink resins, differences between parameters for 66-colored resins are remarkable, and because of that ΔE differences became very high. It is also interesting to note that the color parameter L* of resin 66 Duralay presents higher values (more brightness), while in resin 66 Vipi predominate the values of parameter a* (more influence of pink shade) and in resin 66 Duralay values of parameter b* are small (less influence of yellow shade).

The present study was limited to only two color codes (medium pink and 66) and three commercial brands. Differences found suggest to enlarge the research including new brands and color codes. On the other hand, the results showed the lack of uniformity of pigments and brightness between brands with same color code. To get better clinical results it would be convenient if the manufacturers would follow more rigorous specifications, so that a given color code would describe the same color, regardless of the resin brand.

Conclusions

Based on the results obtained in this study, it can be concluded that:

a) from a clinical point of view, the powder/liquid ratio had little influence, when considering the human visual sensitivity;
b) the 2mm thickness led to great color differences when compared to the 6mm control, whereas the 4mm thickness resulted in almost unnoticeable differences from a clinical point of view;
c) comparison between pink-colored resins demonstrated little differences from a clinical point of view, whereas among 66-colored resins the discrepancies were unsatisfactory.

Table 1 – Mean values (n = 3) of color differences (ΔE) for the specimens made of different studied ratios when compared to the "normal" ratio, considering each resin and thickness (critical Tukey's value for any two mean comparisons ΔE = 1.00 – p<0.05)

Thickness (mm)	Ratio	Line	Resin				
			Pink Clássico	Pink Vipi	66 Dencor	66 Vipi	66 Duralay
6	+ 10	1	1.2	1.4	0.6	0.8	0.5
	- 10	2	0.7	1.2	1.2	0.7	0.7
	- 20	3	1.2	1.1	1.6	1.6	1.3
4	+ 10	4	1.1	0.8	0.3	0.6	0.4
	- 10	5	0.6	1.1	1.2	0.7	0.6
	- 20	6	0.7	1.1	1.4	0.8	0.9
2	+ 10	7	0.6	0.7	0.6	0.4	0.6
	- 10	8	0.8	1.3	0.7	0.6	0.9
	- 20	9	1.0	0.7	0.7	0.8	0.7

Table 2 – Mean values (n = 3) of color differences (ΔE) for 4 and 2mm thickness as related to the 6mm control, considering each resin and ratio (critical Tukey's value for any two mean comparisons ΔE = 1.17 – p<0.05)

Resin	Thickness (mm)	Line	Powder ratio (%)			
			+ 10	Normal	- 10	- 20
Pink Clássico	6/4	1	1.2	1.3	1.3	1.5
	6/2	2	6.2	7.4	7.6	7.2
Pink Vipi	6/4	3	1.2	1.6	1.7	1.7
	6/2	4	6.9	8.1	7.3	8.2
66 Dencor	6/4	5	1.0	1.6	1.5	1.7
	6/2	6	6.6	7.2	8.2	8.4
66 Vipi	6/4	7	0.7	0.7	0.6	1.4
	6/2	8	3.2	3.4	3.6	4.1
66 Duralay	6/4	9	0.7	0.7	0.5	0.6
	6/2	10	2.9	2.5	2.0	2.7

Table 3 – Mean values (n = 6) of color differences (ΔE) among pink-colored and 66-colored resins (critical Tukey's value for any two mean comparisons ΔE = 0.83 – p<0.05)

Resin comparisons	Thickness (mm)	Line	Powder ratios (%)			
			+ 10	Normal	- 10	- 20
Pink Clássico x Pink Vipi	6	1	0.9	0.7	1.2	1.0
	4	2	0.9	1.3	0.8	1.4
	2	3	1.2	1.3	0.6	1.2
66 Dencor x 66 Vipi	6	4	7.6	8.1	8.9	8.4
	4	5	6.8	6.8	8.0	7.8
	2	6	4.7	5.1	5.2	5.0
66 Dencor x 66 Duralay	6	7	13.9	14.5	16.2	16.0
	4	8	14.0	13.6	15.2	14.6
	2	9	12.4	11.9	12.5	11.9
66 Vipi x 66 Duralay	6	10	11.4	11.9	12.0	12.3
	4	11	11.6	11.6	11.8	11.7
	2	12	11.9	11.6	12.0	11.9

Table 4 – Mean values for color (L*, a*, b*) and opacity (%) parameters. (n = 12 - all four ratios were included)

Resin	Thickness (mm)	Line	Color parameters			
			L*	a*	b*	Opacity (%)
Pink Clássico	6	1	47.5	15.3	7.0	100.0
	4	2	48.2	16.1	7.6	98.8
	2	3	53.0	17.6	10.9	81.8
Pink Vipi	6	4	48.0	15.2	6.8	100.0
	4	5	49.1	15.6	7.5	98.1
	2	6	53.5	17.1	11.5	82.9
66 Clássico	6	7	57.3	2.1	13.0	100.0
	4	8	58.4	2.3	13.9	97.8
	2	9	63.1	2.3	17.9	80.8
66 Vipi	6	10	63.4	4.8	17.8	100.0
	4	11	63.9	4.9	18.1	100.0
	2	12	66.0	5.8	19.9	95.1
66 Duralay	6	13	72.2	0.7	11.0	100.0
	4	14	72.4	0.9	11.1	100.0
	2	15	74.0	1.3	12.5	95.2

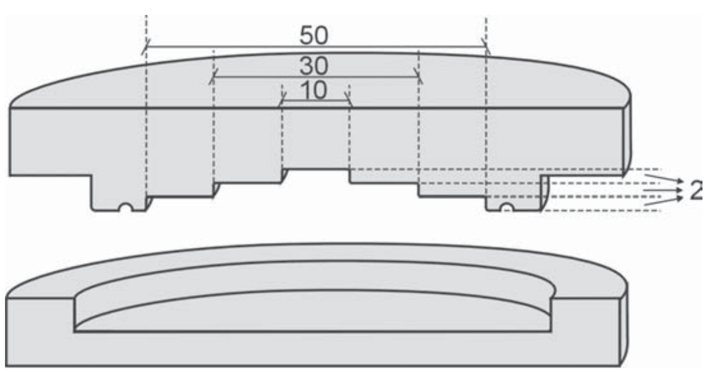

FIGURE 1 – Scheme of the flask; distances in millimeters.

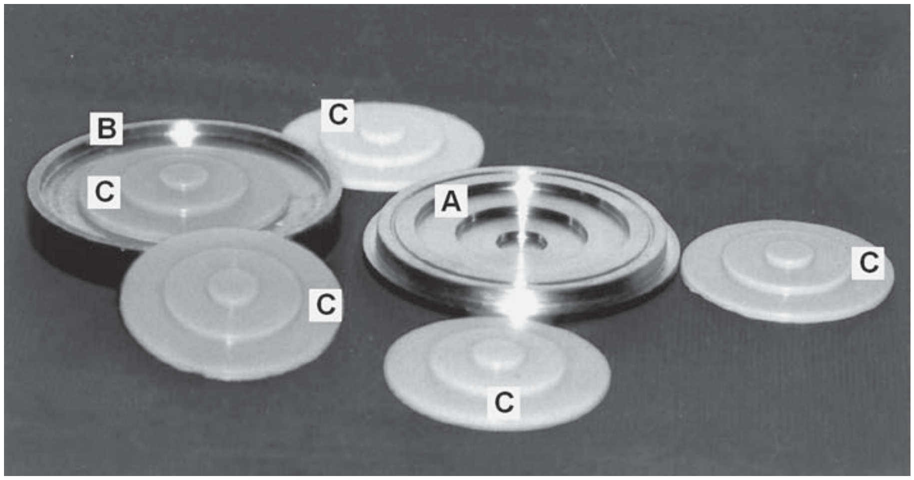

FIGURE 2 - Flask (A and B) and samples of acrylic resin(C).

Resumo

O objetivo da pesquisa foi determinar as diferenças de cor (Δ*E*) de resinas acrílicas, empregando corpos-de-prova em peça única, com as espessuras de 6, 4 e 2mm. As resinas ensaiadas foram: duas de cor rosa médio (Clássico e Vipi) e três de cor 66, Dencor (Clássico), Vipi-cor (Vipi) e Duralay (Reliance). Com um espectrofotômetro foram determinados os parâmetros de cor (L*, a*, b*) e calculados os Δ*E* entre condições diferentes. As diferenças de cor (Δ*E*) foram determinadas pelo emprego dos seguintes padrões: 1) proporção pó/líquido normal (do fabricante), à qual foram comparadas aquelas de (em %): +10, -10 e –20; 2) espessuras de 4 e 2mm, em relação ao padrão de 6mm; 3) comparação entre as duas resinas cor de rosa e entre as três de cor 66. Os resultados permitiram concluir que: a variação na proporção pó/líquido em relação à normal influenciou pouco na alteração de cor, do ponto de vista clínico, com o maior valor (Δ*E* = 1.6) não perceptível por um grande número de observadores; a comparação, em relação ao padrão de 6mm de espessura, mostrou que a de 4mm não foi grande (Δ*E* = 1.7 no máximo), entretanto, a de 2mm de espessura em relação ao mesmo padrão, apresentou alterações insatisfatórias, que, dependendo da resina e proporções, chegou a Δ*E* = 8.4 entre as resinas cor de rosa, a semelhança de cor foi boa, contudo entre as resinas de cor 66, as diferenças foram insatisfatórias.

Unitermos

Resinas acrílicas, cor; materiais dentários

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