ORIGINAL ARTICLE

Influence of background on natural tooth colour coordinates: an in vivo evaluation

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Abstract The aim of this study was to evaluate the influence of different backgrounds on spectrophotometric colour values of natural teeth. Twenty volunteers (10 males and 10 females) with a mean age of 25 years and 9 months ($\pm$3 years and 2 months) were each subjected to 4 spectrophotometric measurements of their upper right central incisor. Each sample was measured with alternatively black, 50 % grey, white or no background (positive control). ΔE medians ranged from 0.9 to 5.9. All artificial backgrounds presented significant differences ($p < 0.05$) when compared to values obtained without any background. No significant differences were observed between black and 50 % grey background ($p > 0.05$). If an artificial background needs to be used, as for example when performing in vitro studies, preference should be given to a black background as it approaches best the clinical situation (i.e. no background). Even if no statistically significant differences were found when compared with the grey background, the black background should be preferred due to its lower ΔE medians, standard deviation as well as lower minimum and maximum values.

Keywords $L*a*b*$ · Spectrophotometer · Colour evaluation

Introduction

Resin composite materials are widely used due to their good mechanical and aesthetic properties and relatively low cost price. Their clinical success is related to their ability to mimic tooth appearance in terms of gloss [1], microtexture [2, 3] and colour [4]. Various elements such as illuminant source [5], surface roughness [6], sample thickness [7] and background colour [8] influence colour perception.

The influence of background is quite a controversial topic; in fact, it has been claimed to have no influence [9], little influence [10] or, as considered by the majority of authors, great influence [11–13] on colour perception. Within this last group, no consensus is found on which is the ideal background for in vitro evaluations and alternatively grey [14, 15], white [16, 17] or black [8, 11] backgrounds have been proposed and used in resin composite laboratory tests.

Since the majority of chromatic tests on dental materials are performed in the laboratory, it is of paramount importance to determine the background that corresponds best to the intra-oral situation, to mimic best the oral environment in the laboratory. Thus, the aim of this in vivo study was to determine the influence of the background on spectrophotometric colour measurements and to determine which background colour simulates best the intra-oral situation.

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The first null hypothesis was that background colour influences spectrophotometric colour measurements; the second null hypothesis was that all the investigated backgrounds equally simulate the intra-oral situation.

Materials and methods

Twenty students of Geneva Dental University (Geneva, Switzerland) participated in this clinical study. The group of volunteers consisted of 10 males and 10 females with a mean age of 25 years and 9 months, SD ± 3 years and 2 months. A calibrated reflectance spectrophotometer (SpectroShade, Handy Dental Type 713000, Serial No. HDL0090, MHT, Arbizzano di Negar, Verona, Italy) was used in this study, according to the method and rationale published in previous studies [18, 19]. With this device CIE $L*a*b*$ measurements of the total surface of each upper central incisor were performed (Fig. 1) over a white ($L* = 92.6$, $a* = -1.2$, $b* = 2.9$) as well as a black ($L* = 1.6$, $a* = 1.2$, $b* = -1.0$) and grey ($L* = 50.6$, $a* = -0.2$, $b* = -0.13$) background made of plastic paper or no background (positive control).

Colour differences were then calculated as differences in $L*$, $a*$ and $b*$ values obtained with different artificial backgrounds and the positive control (no background) according to the following formula:

$$\Delta E = \sqrt{(L_1 - L_2)^2 + (a_1 - a_2)^2 + (b_1 - b_2)^2}.$$

In order to check the possible statistical evidence of colour differences between the different backgrounds values, a Friedman ANOVA by ranks (a non-parametric repeated measures ANOVA) was performed, pointing out that the background colour significantly ($p < 0.001$) influenced the values of ΔE. Afterwards, a Newman–Keuls post hoc test was carried out to investigate eventual statistical differences between the different backgrounds investigated (white, grey, black and no background).

The clinical significance of colour differences was also analysed, following the methodology used in a previous study [11] with respect to human eye perception threshold, according to the confirmed range of colour change perceptibility or imperceptibility [20–23].

Results

Significant differences were detected between spectrophotometric values obtained with and without background, irrespective of the colour of the background used.

ΔE medians varied from 0.9 (range 0.2–3.4) (ΔE black–no background) to 5.9 (range 1.4–8.8) (ΔE white–no background). ΔE median for the comparison between grey and no background was 1.2 (range 0.4–4.4), showing no significant differences when compared with ΔE black − no background.

The descriptive statistics for ΔEs between different backgrounds is illustrated in Table 1.

Statistical analysis

The dataset was made of four repeated colour measurements per tooth taken on twenty subjects using three different backgrounds (W, white; G, grey; and B, black) and without any background (N). For any of these twenty subjects, the three ΔE distances between the measurements with background against the natural one (ΔE_{WN}, ΔE_{GN}, ΔE_{BN}) were measured and are summarised in Table 1. In order to determine whether the background influenced the $L*a*b*$ values of teeth measured by means of a spectrophotometer, a Friedman ANOVA by ranks (a non-parametric repeated measures ANOVA) was performed, pointing out that the background colour significantly ($p < 0.001$) influenced the values of ΔE. In Fig. 2, the conditional distributions of the ΔEs are given in a box-plot

Fig. 1 Clinical use of spectrophotometer employed in this study

Table 1 Descriptive statistics for the ΔEs

ΔE	Minimum	Median	Maximum	Range
ΔE_{BN}	0.2	0.9	3.4	3.2
ΔE_{GN}	0.4	1.2	4.4	4.0
ΔE_{WN}	1.4	5.9	8.8	7.5

ΔE_{BN} mean differences between values obtained over a black background and no background

ΔE_{GN} mean differences between values obtained over a grey background and no background

ΔE_{WN} mean differences between values obtained over a white background and no background

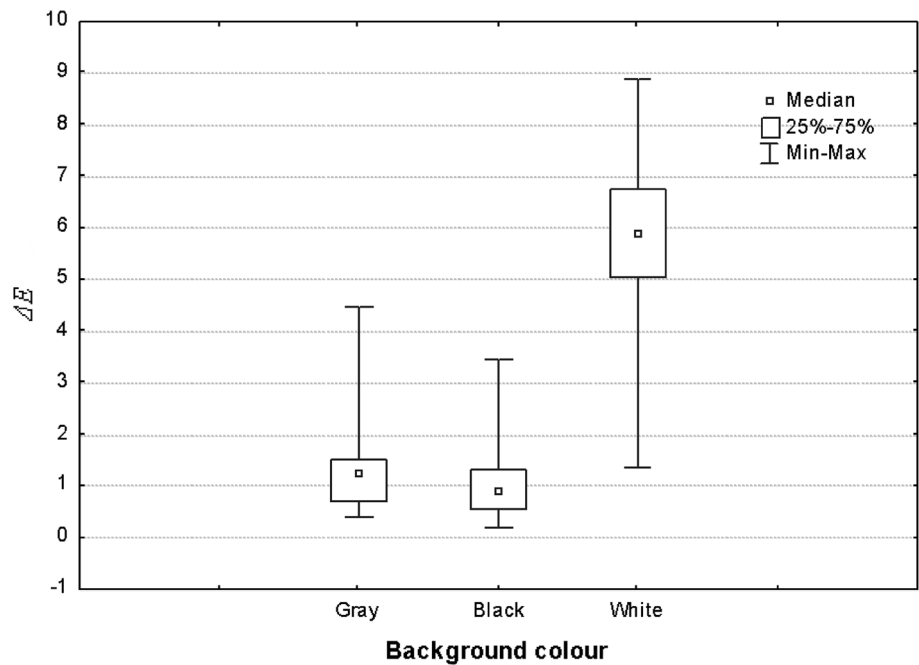**Fig. 2** Box plot of ΔE distributions by background colour

	No	White	Grey	Black
Average ΔE	0.0000	5.7812	1.3902	0.9439
No		0.0001	0.0003	0.0052
White	0.0001		0.0001	0.0001
Grey	0.0003	0.0001		0.1768
Black	0.0052	0.0001	0.1768	

representation. The main difference was perceived when the background was white (average $\Delta E_{WN} = 5.78$), whereas the black and grey backgrounds gave similar results (averages $\Delta E_{BN} = 0.94$ and $\Delta E_{GN} = 1.39$). The Newman–Keuls post hoc test (Table 2) indicates that there was always a statistically significant difference when the measurement was made over a background ($p < 0.01$), but black and grey backgrounds were not significantly different ($p = 0.1768$).

Moreover, ΔE distribution was modelled using appropriate statistical distributions [$\Delta E_{BN} \sim$ lognormal (-0.16, 0.69); $\Delta E_{GN} \sim$ lognormal (0.13, 0.61); $\Delta E_{WN} \sim$ logistic (5.78, 0.91)] and the expected percentages of measurements below the 1.1 ΔE were computed. This resulted in the fact that differences between spectrophotometric values over a black background and no background (ΔE_{BN}) were lower than 1.1 in 64.4 % of the cases. On the other hand, ΔE values lower than 1.1 were achieved only in 47.8 % of the cases when a grey background was used and only in 0.5 % of the cases when a white background was employed.

Discussion

The influence of background on colour is a quite controversial topic due to the fact that there is no consensus in literature. Several authors, in fact, claimed that background cannot influence [9], may slightly influence [10] or can heavily influence [11–13] colour perception. Even within this last group of authors, no consensus was found on which is the ideal background that should be used for in vitro evaluations. Alternatively, grey [14, 15], white [16, 17] and black [8, 11] backgrounds have been proposed and used in their laboratory tests with the intention to simulate the natural intra-oral situation. Therefore, this "in vivo" study was performed to determine whether the type of background has an influence on colour perception.

In this research paper, the influence of the background on natural tooth colour coordinates was evaluated by means of a spectrophotometer. This device allows a quantitative evaluation approach and analyses with high precision even small variations in colour. Thus, a spectrophotometric device was preferred to an analysis through a common colorimeter. This latter, in fact, has a less precise examination approach due to the fact that its analysis relies on the colours of the three human eye receptors, being red, green and blue, while a spectrophotometer analyses every 1–10 nm of the visible spectrum. The result of the spectrophotometric analysis is a transmittance curve of the visible spectrum and, obviously, the obtained data are more accurate [19].

Specifically, the MHT spectrophotometer analyses the sample every 8 nm and incorporates a "tool mode" which

allows a standardised angle of measurement that enables a reproducible position perpendicular to the facial tooth surface to ensure equal measurement conditions for all teeth evaluated.

Based on the data obtained in this "in vivo" study, it can be claimed that the type of background influences natural tooth colour coordinates. $L*a*b*$ values on all three backgrounds were statistically different from measurements done without any background. Neither a black, nor grey or white background could successfully mimic what was considered as the positive control (no background). However, data obtained with a white background were statistically different from the ones obtained with black or grey plastic papers, showing a much higher ΔE. These results show that white background should not be used as ideal background in "in vitro" studies to simulate the intra-oral environment. Black and grey backgrounds, on the other hand, even if statistically different from the "ideal substrate", showed data rather close to the ones obtained without any background. However, even if from a statistical point of view differences exist, small differences in colour variations can remain imperceptible within certain limits to the human eye and, consequently, still be clinically acceptable [11].

Therefore, an aesthetic quantitative approach, based on human eye perception and its generally accepted key values proposed in the literature, should be considered in addition to the purely mathematical statistical approach. According to various studies [20–23], in fact, differences in ΔE lower than 1.1 cannot be detected by the human eye, a ΔE between 1.1 and 3.3 can be detected but is still considered clinically acceptable, while a ΔE higher than 3.3 can be detected and is by an aesthetic point of view considered as clinically not acceptable. Therefore, even if black and grey backgrounds can be statistically considered as similar alternatives, preference should be given to the black background rather than the grey one as ΔE_{BN} (black and no background) presented a lower mean, standard deviation, minimum and maximum values than ΔE_{GN} (grey and no background).

Furthermore, higher percentages of ΔE values below 1.1 (thus not detectable by the human eye) were achieved when a black background was used (64.4 %) than when a grey background was used (47.8 %).

The first null hypothesis was, therefore, accepted, while the second null hypothesis was rejected.

However, caution has to be paid when interpreting data obtained in this "in vivo" study. Further investigations with more samples, different operators and ideal black, grey and white background (where black $L* = 0$, $a* = 0$, $b* = 0$; white $L* = 100$, $a* = 0$, $b* = 0$; and grey $L* = 50$, $a* = 0$, $b* = 0$) should be performed to confirm results obtained in this study.

Conclusion

This in vivo study demonstrated that background has an influence on colour measurements and that black and grey backgrounds better simulate intra-oral environment than white background.

Black background can be preferred for "in vitro" studies because of its capacity and tendency to better mimic the "in vivo" situation. In fact, even if no statistical differences could be found with the grey background, the black background could be chosen as "more ideal" due to its ΔE (black–no background) lower median and minimum and maximum values.

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