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Original Research Article

Influence of Background Color And Target Tooth Shade on Shade Matching Accuracy

Arka Plan Rengi ve Hedef Diş Renginin Renk Seçim Doğruluğu Üzerine Etkisi

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ABSTRACT

Aim: This study analyzed the effect of background color and target tooth shade on visual shade matching.

Material and Method: Twenty prosthodontists performed visual shade matching on four different backgrounds (green, gray, white, black) using the Vita Classical shade guide. Two identical shade guides were used for shade matching. One of them was blinded so that the color codes on it could not be identified. Each observer matched all 16 shade tabs using the second shade guide on four different backgrounds. The effects of background and target tooth shade factors on shade matching accuracy were analyzed with the Pearson's Chi-squared test. P<0.05 was considered statistically significant.

Results: The background significantly affected shade matching accuracy (p=0.006). The correct match percentages were 79.7%, 74.7%, 69.7%, and 68.8% on gray, black, green, and white backgrounds, respectively. More accurate matching was achieved on the gray background than the green and white backgrounds. The target tooth shade significantly affected shade matching accuracy (p<0.001). The correct matching rates by target shade tab were obtained as follows: A1 (75%), A2 (55%), A3 (63.8%), A3.5 (81.3%), A4 (81.3%), B1 (96, 3), B2 (75%), B3 (78.8%), B4 (71.3%), C1 (63.8%), C2 (70%), C3 (58.8%), C4 (86.3%), D2 (96.3%), D3 (45%), and D4 (73.8%).

Conclusion: Background color and target tooth shade significantly affected visual shade matching accuracy.

Keywords: Color perception; Dental aesthetic; Dental prosthesis; Prosthesis coloring

ÖZET

Amaç: Bu çalışma, arka plan renginin ve hedef diş renginin görsel renk seçimi üzerindeki etkisini analiz etti.

Gereç ve Yöntem: Yirmi protetik diş tedavisi uzmanı, Vita Classical renk skalasını kullanarak dört farklı arka plan (yeşil, gri, beyaz, siyah) üzerinde görsel renk seçimi gerçekleştirdi. Renk seçimi için iki özdeş renk skalası kullanıldı. Bunlardan birisi üzerindeki renk kodları belirlenemeyecek şekilde kapatıldı. Her gözlemci, ikinci renk kılavuzunu kullanarak 16 renk tonunun tamamını dört farklı arka plan üzerinde eşleştirdi. Arka plan ve hedef diş rengi faktörlerinin renk seçim doğruluğu üzerindeki etkileri Ki-kare testi ile analiz edildi. P<0.05 istatistiksel olarak anlamlı kabul edildi.

Bulgular: Arka plan, renk seçim doğruluğunu önemli ölçüde etkiledi (p=0.006). Doğru eşleşme yüzdeleri gri, siyah, yeşil ve beyaz arka planda sırasıyla %79.7, %74.7, %69.7 ve %68.8 idi. Gri arka planda, yeşil ve beyaz arka planlara göre daha doğru eşleştirme elde edildi. Hedef diş rengi renk seçim doğruluğunu önemli ölçüde etkiledi (p<0.001). Hedef renk sekmesine göre doğru eşleşme oranları şu şekilde elde edildi: A1(%75), A2(%55), A3(%63.8), A3.5(%81.3), A4(%81.3), B1(96.3), B2(%75), B3(%78.8), B4(%71.3), C1(%63.8), C2(%70), C3(%58.8), C4(%86.3), D2(%96.3), D3(%45), D4(%73.8).

Sonuç: Arka plan rengi ve hedef diş rengi görsel renk seçim doğruluğunu önemli ölçüde etkiledi.

Anahtar Kelimeler: Dental estetik; Dental protez; Protez renklendirmesi; Renk algısı

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INTRODUCTION

In dentistry, it is essential to combine factors such as aesthetics, function, and longevity to achieve an acceptable restoration. One of the most important aesthetic parameters is the restoration color. The first step in obtaining restorations that look like natural teeth is shade matching. Tooth shade matching can be performed with visual methods, instrumental methods, or a combination of the two techniques.[1–3]

Visual shade matching using shade guides is the most common method of determining tooth color.[4] Visual shade matching is affected by factors such as background color,[5–8] light source,[5,9–11] shade guides,[12–14] age,[12,15] gender,[15–17] experience,[16,18,19] surface properties of the object,[20] color training,[21,22] and vision defects.[23] The background refers to the surface upon which samples are placed along with the environment extending for about 10° from the edge of the stimulus in all directions (ISO TR 28642/2011).[6]

Adjacent teeth, dental restorations, gingiva, lips, and rubber dams may become the background during shade matching. Shade determination may be negatively affected due to the color contrast between these structures and the target tooth.[24] As the color contrast between the background and the target tooth increases, the background's effect on visual perception also increases. Therefore, one should remove the makeup and the rubber dam before shade matching.[25] Dazzling clothes, glasses or items that distort visual perception should be avoided.[26] Although the effect of background on shade matching is generally considered important, few studies have identified and measured its effects.[5–8] Liberato *et al*.[8] reported less difference between visual and instrumental shade matching made with a gray background than with no background. Dudea *et al*.[6] found that white and black backgrounds had the best results, followed by gray and red backgrounds, with blue backgrounds producing the worst results. Another study reported that shade matching performed on a pink background resulted in higher accuracy than on a blue background.[5]

This study aimed to analyze the effect of background color and target tooth shade on visual shade matching. The null hypotheses of the study were that visual shade matching would not be affected by background color (1) and target tooth shade (2).

MATERIAL AND METHOD

This study was reviewed and approved by Erciyes University Clinical Research Ethics Committee (Approval number: 2023/823). Twenty prosthodontists, comprising ten women and ten men aged between 25 and 40, were included in the study. All participants signed an informed consent form. Similar to previous studies, the participants' color discrimination abilities were verified using the Ishihara Color Vision Test (Shinobu Ishihara, Tokyo, Japan) which is an acceptable test for screening color vision deficiencies.[6,27]

Visual shade matching was performed on four different backgrounds (green, gray, white and black) using two identical shade guides (Vita Classical, Vita Zahnfabrik, Bad Sackingen, Germany) consisting of 16 shade tabs (A1-D4). The colors of the shade tabs were measured using a spectrophotometer (SpectroShade Micro II, Niederhasli, Switzerland) to verify the identity of the shade guides. The original color codes on one shade guide were visible, while on the other shade guide, which served as the target tooth, they were covered and numbered from 1 to 16. Before the shade matching, the participants were reminded of the following color scheme of the VITA classic shade guide as described in the user manual: A1-A4, reddish brownish; B1-B4, reddish yellowish; C1-C4, grayish shades; D2-D4, reddish gray. For shade matching, a shade tab with the color code covered was removed from the shade guide, which served as the target tooth, and placed against the background. Observers were asked to determine the shade of the target tab using the shade guide with the original codes visible on it (Figure 1A-D). This procedure was applied for all shade tabs on the target guide in a random order.

In this study, 25x25 cm color fabrics were used as backgrounds. Each observer made a total of 64 shade matches by determining the shades of 16 shade tabs in the target shade guide against 4 different backgrounds. Thus, 1280 shade matches were performed by 20 participants. Shade matching was performed between 10:00 and 14:00 under natural light. To prevent errors due to eye fatigue, a waiting time of 30 seconds was applied after each shade matching and 20 minutes before moving to the next background. In addition, the background sequence was rotated for each observer to avoid

fatigue or habituation bias. For example, one observer performed shade matching on green, gray, white and black backgrounds, while the next observer performed shade matching on black, green, gray and white backgrounds, respectively. This cycle continued for each participant.

Data were analyzed in SPSS 22.0 (IBM Corp. Armonk, NY, USA). For each of the 16 VITA Classical shade tabs, the percentage of correct matches was calculated. The effects of background and target tooth shade factors on shade matching accuracy were analyzed with Pearson's Chi-squared test. $P<0.05$ was considered statistically significant.

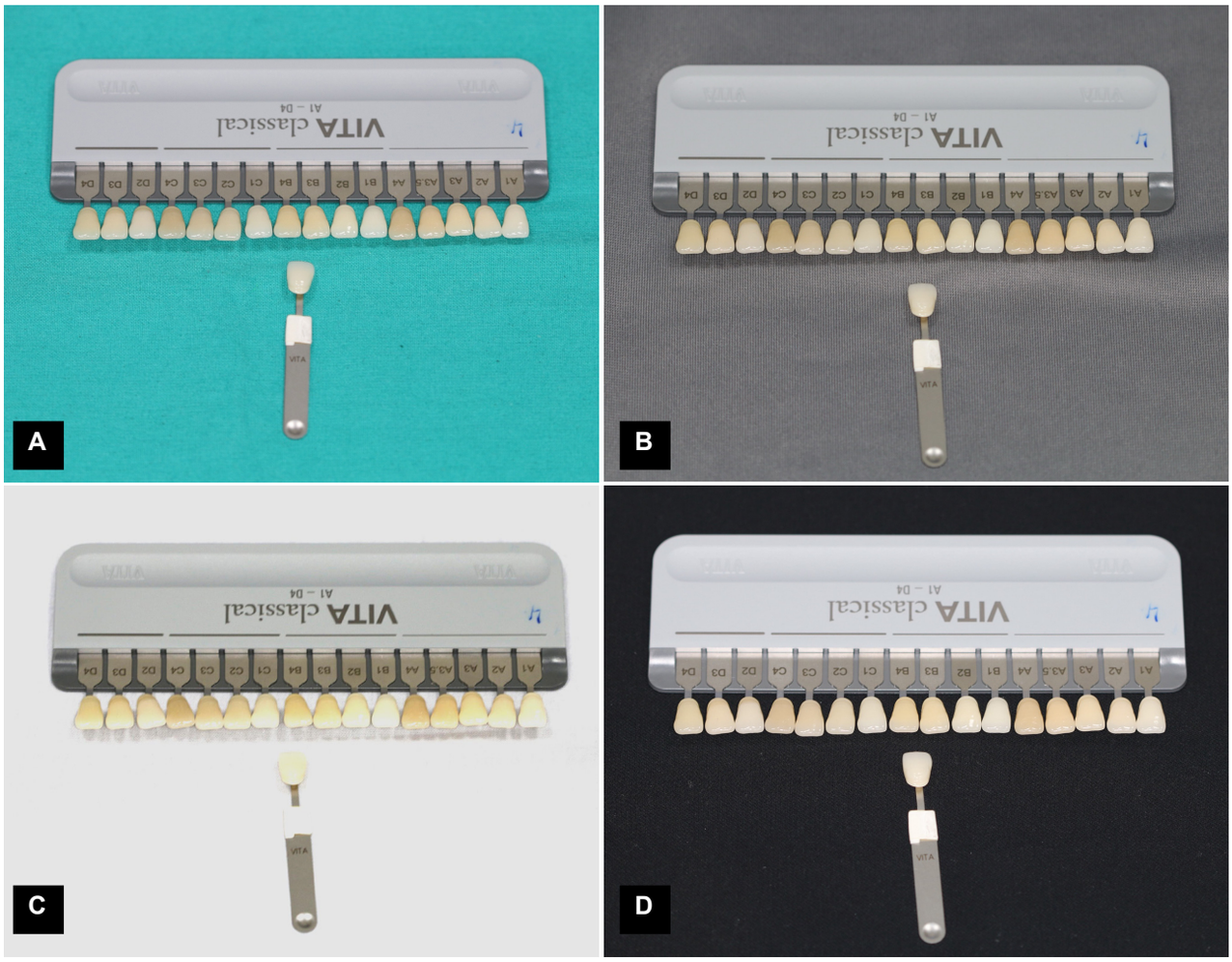

Figure 1.
A. Shade matching on a green background
B. Shade matching on a gray background
C. Shade matching on a white background
D. Shade matching on a black background

RESULTS

Table 1 shows the correct matching rates and the comparison of shade matching accuracy across backgrounds. When the target tooth shades were analyzed separately, the results of the Chi-square test showed that the correct match rate of Tab B1 was statistically lower on white backgrounds than on other backgrounds (χ^2=9.35, p=0.025). No significant differences were observed between the backgrounds in the correct matching rates of the other shade tabs. Considering the correct matching rates of all shade tabs, the effect of background on shade matching accuracy was found to be statistically significant (χ^2=12.47, df = 3 (4x2 table), p=0.006). Percentages of correct shade matching were 79.7%, 74.7%, 69.7% and 68.8% for gray, black, green and white backgrounds, respectively. Pairwise comparison results showed significantly more accurate matches on gray backgrounds than on green or white backgrounds (Table 1).

Rates for correct matching by target shade tab were as follows: A1 (75%), A2 (55%), A3 (63.8%), A3.5 (81.3%), A4 (81.3%), B1 (96.3%), B2 (75%), B3 (78.8%), B4 (71.3%), C1 (63.8%), C2 (70%), C3 (58.8%), C4 (86.3%), D2 (96.3%), D3 (45%), D4 (73.8%). Target tooth shade affected shade matching accuracy (χ^2=119.41, df = 57 (20x4 table), p<0.001). Table 2 shows the rates of shades matched by participants to each target tab. Tab A1 was matched as C1 in 17.5% of cases. Tab A2 was matched as A3 in 31.3% of cases and Tab A3 was matched as A2 in 16.3% of cases. Tab A3.5 and A4 were matched as each other in 11.3% of cases. Tab B2 was matched as A1 in 12.5% of cases. Tab B3 was matched as A3 in 10% of cases. Tab B4 was matched as B3 in 23.8% of cases. Tab C1 was matched as A1 in 27.5% of cases. Tab C2 was matched as C3 in 13.8% of cases. Tab C3 was matched as C4 in 13.8% of cases. Tab D3 was matched as A3 in 28.8% of cases. Tab D4 was matched as B3 in 15% of cases.

Table 1. Comparison of shade matching accuracy across backgrounds. N(%); shows the frequency and percentage of correct shade matching

	Background color					
	Black	**White**	**Gray**	**Green**	**Total (n=1280)**	**P***
Target tab (n=20)						
A1	15 (75)	15 (75)	16 (80)	14 (70)	60 (75)	0.912
A2	9 (45)	8 (40)	13 (65)	14 (70)	44 (55)	0.154
A3	14 (70)	12 (60)	14 (70)	11 (55)	51 (63.8)	0.691
A3.5	16 (80)	17 (85)	17 (85)	15 (75)	65 (81.3)	0.825
A4	15 (75)	16 (80)	17 (85)	17 (85)	65 (81.3)	0.825
B1	20 (100)[a]	17 (85)[b]	20 (100)[a]	20 (100)[a]	77 (96.3)	0.025
B2	16 (80)	15 (75)	17 (85)	12 (60)	60 (75)	0.292
B3	15 (75)	15 (75)	17 (85)	16 (80)	63 (78.8)	0.844
B4	15 (75)	12 (60)	17 (85)	13 (65)	57 (71.3)	0.308
C1	10 (50)	13 (65)	16 (80)	12 (60)	51 (63.8)	0.255
C2	18 (90)	12 (60)	15 (75)	11 (55)	56 (70)	0.067
C3	11 (55)	10 (50)	13 (65)	13 (65)	47 (58.8)	0.707
C4	17 (85)	18 (90)	17 (85)	17 (85)	69 (86.3)	0.957
D2	19 (95)	19 (95)	20 (100)	19 (95)	77 (96.3)	0.792
D3	12 (60)	7 (35)	11 (55)	6 (30)	36 (45)	0.154
D4	17 (85)	14 (70)	15 (75)	13 (65)	59 (73.8)	0.520
Total (n=320)	239 (74.7)[a, b, c]	220 (68.8)[c]	255 (79.7)[b]	223 (69.7)[a,c]	937 (73.2)	0.006

*Pearson Chi-square; a-cDifferent superscript lowercase letters in the same row indicate significant differences among backgrounds (p<0.05).

Table 2. Frequencies and percentages of shades matched to target tabs

	Matched shade n(%)														
	A1	A2	A3	A3.5	A4	B1	B2	B3	B4	C1	C2	C3	C4	D2	D3	D4
Target tab																
A1	60 (75)	0 (0)	0 (0)	0 (0)	0 (0)	6 (7.5)	0 (0)	0 (0)	0 (0)	14 (17.5)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
A2	1 (1.3)	44 (55)	25 (31.3)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	1 (1.3)	0 (0)	2 (2.5)	7 (8.8)	0 (0)
A3	0 (0)	13 (16.3)	51 (63.8)	0 (0)	0 (0)	0 (0)	0 (0)	7 (8.8)	1 (1.3)	0 (0)	1 (1.3)	1 (1.3)	0 (0)	0 (0)	6 (7.5)	0 (0)
A3,5	0 (0)	0 (0)	0 (0)	65 (81.3)	9 (11.3)	0 (0)	0 (0)	0 (0)	5 (6.3)	0 (0)	0 (0)	0 (0)	1 (1.3)	0 (0)	0 (0)	0 (0)
A4	0 (0)	0 (0)	0 (0)	9 (11.3)	65 (81.3)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	6 (7.5)	0 (0)	0 (0)	0 (0)
B1	1 (1.3)	0 (0)	0 (0)	0 (0)	0 (0)	77 (96.3)	0 (0)	0 (0)	0 (0)	2 (2.5)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
B2	10 (12.5)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	60 (75)	0 (0)	0 (0)	6 (7.5)	3 (3.8)	0 (0)	0 (0)	1 (1.3)	0 (0)	0 (0)
B3	0 (0)	0 (0)	8 (10)	0 (0)	0 (0)	0 (0)	0 (0)	63 (78.8)	6 (7.5)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	2 (2.5)	1 (1.3)
B4	0 (0)	0 (0)	1 (1.3)	2 (2.5)	1 (1.3)	0 (0)	0 (0)	19 (23.8)	57 (71.3)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
C1	22 (27.5)	0 (0)	0 (0)	0 (0)	0 (0)	2 (2.5)	4 (5)	0 (0)	0 (0)	51 (63.8)	1 (1.3)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
C2	1 (1.3)	3 (3.8)	1 (1.3)	0 (0)	0 (0)	0 (0)	2 (2.5)	1 (1.3)	0 (0)	0 (0)	56 (70)	11 (13.8)	0 (0)	2 (2.5)	2 (2.5)	1 (1.3)
C3	0 (0)	1 (1.3)	6 (7.5)	6 (7.5)	0 (0)	0 (0)	0 (0)	3 (3.8)	1 (1.3)	0 (0)	2 (2.5)	47 (58.8)	11 (13.8)	0 (0)	2 (2.5)	1 (1.3)
C4	0 (0)	0 (0)	1 (1.3)	4 (5)	3 (3.8)	0 (0)	0 (0)	0 (0)	2 (2.5)	0 (0)	0 (0)	1 (1.3)	69 (86.3)	0 (0)	0 (0)	0 (0)
D2	1 (1.3)	1 (1.3)	0 (0)	0 (0)	0 (0)	0 (0)	1 (1.3)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	77 (96.3)	0 (0)	0 (0)
D3	0 (0)	4 (5)	23 (28.8)	1 (1.3)	0 (0)	0 (0)	0 (0)	7 (8.8)	1 (1.3)	0 (0)	1 (1.3)	6 (7.5)	0 (0)	0 (0)	36 (45)	1 (1.3)
D4	0 (0)	0 (0)	1 (1.3)	0 (0)	0 (0)	0 (0)	0 (0)	12 (15)	2 (2.5)	0 (0)	4 (5)	1 (1.3)	0 (0)	0 (0)	1 (1.3)	59 (73.8)

DISCUSSION

This study analyzed the effect of background color and target tooth shade on visual shade matching. The first and second null hypotheses were rejected because the results of the study showed that shade matching accuracy was affected by the background color and target tooth shade.

The color systems of most restorative materials are based on the Vita Classical shade guide, a comprehensive guide used in dental practices and laboratories.[28,29] It was used in this study because it is one of the most frequently used shade guides in visual shade matching and is generally accepted as the gold standard.[30] The oral cavity, contraster, or rubber dam becomes the background during shade matching in dental practice. The gray background used in this study represents the neutral area, the white background represents the teeth, the black background represents the contraster, and the green background represents the rubber dam. Equal numbers of male and female observers were included in this study. However, the effect of gender on shade matching accuracy was not analyzed as it would not have any clinical significance.

The results of this study are consistent with previous studies in showing that background color affects visual shade matching accuracy.[5–8] Sasaki *et al*.[7] reported that the incisal areas of teeth are particularly affected by the background and recommended that dentists and dental technicians use the same background color to obtain correctly colored restorations.In this study, shade matching accuracy was ranked against gray, black, green and white backgrounds. Statistically more accurate shade matching was achieved on gray backgrounds than on green or white backgrounds, while no significant difference was found in other pairwise comparisons. The gray background is considered neutral and has a relaxing effect on the eye.[1] Liberato *et al*.[8] showed that a gray background under natural light improves visual shade matching accuracy.The results of this study agree with that result that the shade matching accuracy is higher for a gray background than for other colors. Dudea *et al*.[6] found that neutral gray, white, black and red backgrounds had statistically similar shade matching accuracy, with the blue background having a worse result than the other

backgrounds. As a result, they suggested that shade matching against blue rubber dams should be avoided.[6] The results of the present study are similar to the findings of Dudea *et al*., in that there is no statistically significant difference between gray and black backgrounds, and that the rubber dam color, green, gives worse results than these two colors. However, the white background in this study has the lowest shade matching accuracy, which differs from the results of Dudea *et al*.[6] Differences in the shade matching accuracy of the backgrounds between the studies may be due to variations in the light source and other operator-dependent differences. In this study, shade matching was performed under natural light, whereas Dudea *et al*. used D65 and D50 light sources. The use of artificial light sources has been reported to improve visual shade matching accuracy.[5,8] Although the fact that no light source was used in the present study is a limitation, shade matching was carried out at the same time each day to minimize differences in ambient light.

Limited information is available on the effect of target tooth shade on visual shade matching. Dudea *et al*.[6] reported that darker and more chromatic tabs in the VITA Classical shade guide (A3.5, B3, B4 and D4) were more frequently mismatched but the shades chosen by participants in the mismatched cases were not reported. However, incorrectly matched shades can be clinically informative. The correct matching rate for the A2, C3, and D3 target tabs notably low across all backgrounds, including the gray background, which demonstrated the highest overall accuracy. It was observed that adjacent tabs were incorrectly matched with one another. For example, in this study, Tab A2 was matched as A3 in 31.3% of cases (Table 2). This finding may stem from the limitations of human visual perception. The most important color parameter affecting visual shade matching is the value. Similar value levels of adjacent tabs may lead to incorrect matching. A clinician determining the shade of a target tooth may need to reconsider the possibility that the correct shade matches and adjacent tab.

The strength of this study is that its results are based on a total of 1280 shade matches performed by 20 prosthodontists. On the other hand, the limitations of this study are that shade matching was performed under natural light, and the clinical experience of the participants was not evaluated. Further clinical studies including different shade guides, different background colors, and controlled light sources are needed.

CONCLUSION

Within the limitations of this study, the following conclusions were reached:

1-Visual shade matching accuracy was affected by background color. Correct shade matching percentages were 79.7%, 74.7%, 69.7%, and 68.8% for gray, black, green, and white backgrounds respectively,
2-Target tooth shade affected shade matching accuracy. The correct matching rates by target shade tab were obtained as follows: A1 (75%), A2 (55%), A3 (63.8%), A3.5 (81.3%), A4 (81.3%), B1 (96.3%), B2 (75%), B3 (78.8%), B4 (71.3%), C1 (63.8%), C2 (70%), C3 (58.8%), C4 (86.3%), D2 (96.3%), D3 (45%), D4 (73.8%).

CONFLICT OF INTEREST STATEMENT

We have no conflict of interest.

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