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DOES THE BACKGROUND AND THE ILLUMINANT INTERFERE WITH THE COLOR SELECTION OF NATURAL TEETH? AN INTEGRATIVE REVIEW OF CLINICAL STUDIES

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ABSTRACT

Background: Visual shade selection is subjective and influenced by exterior factors. Different auxiliary devices, such as specific background, illuminant and polarization filter have been developed aiding at the achievement of better esthetic results. This integrative review aimed to determine whether these devices interfere in shade match of natural teeth. **Materials and methods**: Electronic searches were performed with no language or date restrictions, based on the research question “Does the background and the illuminant interfere with the color selection of natural teeth?” In vivo studies that compared visual selection on natural teeth under different background and illuminants were included. Quality assessment and bias control were carried out according to Fowkes and Fulton guidelines and Quadas 2. Study screening, appraisal and data extraction were performed in duplicate, independent and blind fashion. Data were analyzed and presented descriptively. Protocol registration no. CRD42019124437. **Results**: Screening of studies led to 8 final studies out of 1932 references. Observers for shade match were dental students, dentists, lay people, post-graduate students, research assistants and dental professors. Two studies involved tab-to-tab shade match, while the others assessed shade in human

volunteers. No study assessed the effect of background color. Varying alternatives of light were tested, including room lights and hand-held correcting lights. The results were expressed as proportion of visual-instrumental agreement, ΔE* and weighted kappa, and were conflicting as to the effect of lighting on shade match. Risk of bias was identified mainly due to lack of blinding. **Conclusions**: Illumination influenced differently the shade matching performances. The effect of background color is still to be determined. Therefore, additional well-designed studies are required to further elucidate the role of illuminant and background color on shade matching performance. **Clinical significance:** This study may guide further required studies on dental shade matching. Moreover, it can help clinicians to improve their daily dental practice to achieve greater predictability and longevity of restorative and aesthetic dental treatments.

Keywords: Shade selection. Color selection. Background. Illuminant.

Polarization filter.

INTRODUCTION

Tooth shade selection in dentistry is a routine clinical procedure and one of the key parameters to obtain esthetically successful restorations.[1,2] Color mismatch has been shown as one of the most frequent reasons for failure of anterior restorations placed for esthetic reasons.[3] Although this may occur due to change of color of the restorative material over time as a result of degradation, it may be also caused by incorrect shade selection at the placement of the restoration. Shade may be selected either by the visual method using a shade guide or by instrumental methods with the aid of spectrophotometer, colorimeter, and intraoral digital scanner.[4–7]

Visual shade selection is the most used method, mainly due to its low cost. On the other hand, visual shade selection is quite subjective and inconsistent, mostly characterized as a ‘trial and error’ method and influenced by the clinician proficiency, visual fatigue, and the surrounding light source.[4,8] Also, it depends on the interaction of light with the complex dental surface and structures. As a result, the final decision on color selection is influenced by a multitude of factors that may or may not be related to the operator.[4–6,9–15]

Light-correcting devices are available to minimize lighting interference and to allow neutral clarity to assist the visual method of shade matching.[16–18] One example is a handheld device that contains light-emitting diodes whose light is in a color temperature of 5500K, which corrects for varying light conditions such as the time of day, season of the year, and type of light sources in the dental office. Such devices reduce reflected light to allow for a more accurate assessment of dental translucency and, therefore, provide more reliable visual shade-matching results.[19,20]

The color of the background is also controversial, and some studies have utilized a grey, pink or blue background to reduce eye fatigue.[18,20,21] Besides, there seems to exist an interaction between the illuminant and the background color that may affect visual shade selection.[18] Under these circumstances, the effectiveness of light correcting and background devices in preventing mismatch during shade selection has been deemed uncertain and such uncertainties may hinder adequate shade selection, eventually leading to early demand for replacement of the restoration. Therefore, this integrative review aimed to determine whether background and illuminant interfere with the shade selection of natural teeth.

MATERIALS AND METHODS

Research question:

This integrative review was conducted in accordance to the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA)22 and was registered in the PROSPERO database (PROSPERO registry number CRD42019124437). It was designed to answer the question that follows: Does the background and the illuminant interfere with the color selection of natural teeth?

Search strategy and eligibility criteria:

Six electronic databases were searched up to November 2022: MEDLINE via PubMed, Scopus, Lilacs/BBO via BVS, Web of Science, Cochrane Central, Google Scholar and Trip Data Base. The grey literature (OpenGrey) was also searched. The search strategy used MeSH terms and synonyms in order not to impose any restrictions and to maximize the search for articles in this research phase (Table 1).

Table 1. Search strategy

Database	Search strategy
Pubmed	((((((Color selection[Title/Abstract]) OR Teeth shade matching[Title/Abstract]) OR Color matching[Title/Abstract]) OR Shade[Title/Abstract]))) AND ((((((((((((Spectrophotometry[MeSH Terms]) OR Spectrophotomet*[Title/Abstract]) OR Light polarization[Title/Abstract]) OR Polarization[Title/Abstract]) OR Polarization filter[Title/Abstract]) OR Illuminat*[Title/Abstract]) OR Illuminant[Title/Abstract]) OR Light source*[Title/Abstract]) OR Background colo*[Title/Abstract]) OR Surrounding area[Title/Abstract]) OR Visual methods[Title/Abstract]) OR Instrumental methods[Title/Abstract]))) AND (((((Tooth[MeSH Terms]) OR Tooth[Title/Abstract]) OR Teeth[Title/Abstract]) OR Natural teeth[Title/Abstract]) OR Dental[Title/Abstract])
Scopus	(TITLE-ABS-KEY ("Color selection" OR "Shade matching" OR "Color matching" OR shade)) AND (TITLE-ABS-KEY (spectrophotomet* OR "Light Polarization" OR polarization OR "Polarization filter")) AND (TITLE-ABS-KEY (tooth OR teeth OR "Natural teeth" OR dental))
Web of Science	TÓPICO:(Color selection OR Shade matching OR Color matching OR Shade) AND TÓPICO: (Spectrophotomet* OR Light polarization OR Polarization OR Polarization filter OR Illuminant* OR Light source* OR Background colour OR Background color OR Surrounding area OR Visual methods OR Instrumental methods) AND TÓPICO:(Tooth OR Teeth OR Natural teeth OR Dental)
Cochrane Central	ID Search Hits #1 (“Color selection”)10 #2 (“shade matching”) 35

#3	(“Color matching”)	87
#4	“shade”	799
#5	#1 OR #2 OR #3 OR #4	880
#6	MeSH descriptor: [Spectrophotometry] explode all trees	647
#7	“spectrophotometer”	762
#8	#6 OR #7	1324
#9	(“Light polarization”)	1
#10	“polarization”	616
#11	(“Polarization filter”)	0
#12	illumina*	2675
#13	(Light source*)	27479
#14	(Background colo*)	24831
#15	(“Surrounding area”)	141
#16	(“Visual methods”)	28
#17	(“Instrumental methods”)	31
#18	#8 OR #9 OR #10 OR #11 OR #12 #13 OR #14 OR #15 OR #16 OR #17	27559
#19	MeSH descriptor: [Tooth] explode all trees	4354
#20	“tooth”	28816
#21	#19 OR #20	29363
#22	“teeth”	28816
#23	(“Natural teeth”)	597
#24	“dental”	43371
#25	#21 OR #22 OR #23 OR #24	54153
#26	#5 AND #18 AND #25	212
Lilacs - BBO	("Color selection" OR “seleção de cor” OR "Shade matching" OR “correspondência de cor” OR "Color matching" OR “shade” OR “sombras”) AND (mh:“spectrophotomet*” OR "Light polarization" OR polarization OR "Polarization filter") AND (“tooth” OR “dente” OR teeth OR “dentes” OR "Natural teeth" OR “dentes naturais” OR “dental”) AND (collection:("06-national/BR" OR "05-specialized") OR db:("LILACS" OR "MEDLINE"))	

OpenGrey Trip Database Google Scholar	(“Color selection” OR “Teeth shade matching” OR “Color matching” OR Shade OR Spectrophotometry OR Spectrophotometer) AND (“Light polarization” OR “Polarization filter” OR Illumination OR Illuminant OR Light source* OR “Background colour” OR “Background color” OR “Surrounding area”) AND (Teeth OR Tooth OR “Natural teeth” OR Dental)

An expert librarian guided and adapted the search strategy for each database. No language or date restrictions were applied. A manual search was also performed in the references of the included articles. Articles available in more than one database were considered only once.

Randomized controlled trials (RCTs) and non-randomized studies of interventions (NRSIs) were eligible for inclusion, based on the PICO criteria that follows: P – dentists of both genders with no visual problems on color detection to perform shade selection; I – presence of illuminant and/or background during shade selection; C – shade selection involving instrumental method (spectrophotometer, colorimeter, etc) and O – proportion of correct shade selection. Literature review studies, in vitro or ex vivo studies and opinion articles were excluded, as well as studies in which the examiners did not undergo a visual color test, and studies involving volunteers in orthodontics treatment or non-natural teeth.

Study screening:

Study databanks from each database were uploaded to Endnote®, and the duplicates were automatically removed and double checked by the reviewers.

Two reviewers searched for eligible studies independently based on titles and abstracts of the studies identified in the electronic databases. Full-text copies were retrieved from studies that met the inclusion criteria, or for which there were insufficient data in the title and abstract to make a clear decision. These copies were assessed independently. Any disagreements on the eligibility of included

studies, at any point in the screening process were resolved through consensus, or through discussion with a third reviewer.

Data extraction:

Details of the study (author(s), year of publication, country and study design), details of participants (number of participant's evaluators and evaluated, and source of sample), study methods, and results were extracted and tabulated by two reviewers. If some information was not clear in the study text, the study author was emailed to clarify.

Outcome measures:

The determination of efficacy of both the illuminant and the background for shade selection could be expressed as percent of correct shade selection or inter-rater agreement coefficient established by the comparison groups.

Assessment of risk of bias of the included studies:

The study methodological quality and risk of bias were assessed based on instrument developed by Fowkes and Fulton 23. This quality assessment can be applied to observational studies and to controlled trials. It includes questions about study design, study samples, control groups, the quality of measurements and outcomes, completeness, and distorting influences. For each included study, the analyzed criteria assigned were major problems (red), minor problems (orange), or no problems (green), in terms of their expected effect on the results. If the question was not applicable, 'NA' was written and colored grey.

Also, considering the diagnostic nature of the interventions studied, the assessment of risk of bias and quality of the studies was complemented using Quadas 224. Quadas 2 has four key domains, namely patient selection, index test, reference standard and flow and timing, for which a classification of high, unclear or low risk of bias may be attributed. For the 'patient selection' domain, the following signaling question was used: 'Was a consecutive or random sample of patients enrolled?'. Also, studies that assessed shade match only with shade guides (no patient) were downgraded based on this domain. For the 'index test'

domain, the signaling question ‘Were the index test results interpreted without knowledge of the results of the reference standard?’ was adopted. For the ‘reference standard’ domain, the two signaling questions that follow were considered: ‘Is the reference standard likely to correctly classify the target condition?’ and ‘Were the reference standard results interpreted without knowledge of the results from the index test?’. Finally, for the ‘flow and timing’ domain, the signaling question adopted was ‘Was there an appropriate interval between the index test and the reference standard?’.

Once a detailed appraisal of the methods and results was conducted, the methodological quality and risk of bias of the individual studies was summarized. The assessments were performed by two reviewers, independently, and were also checked by other reviewers.

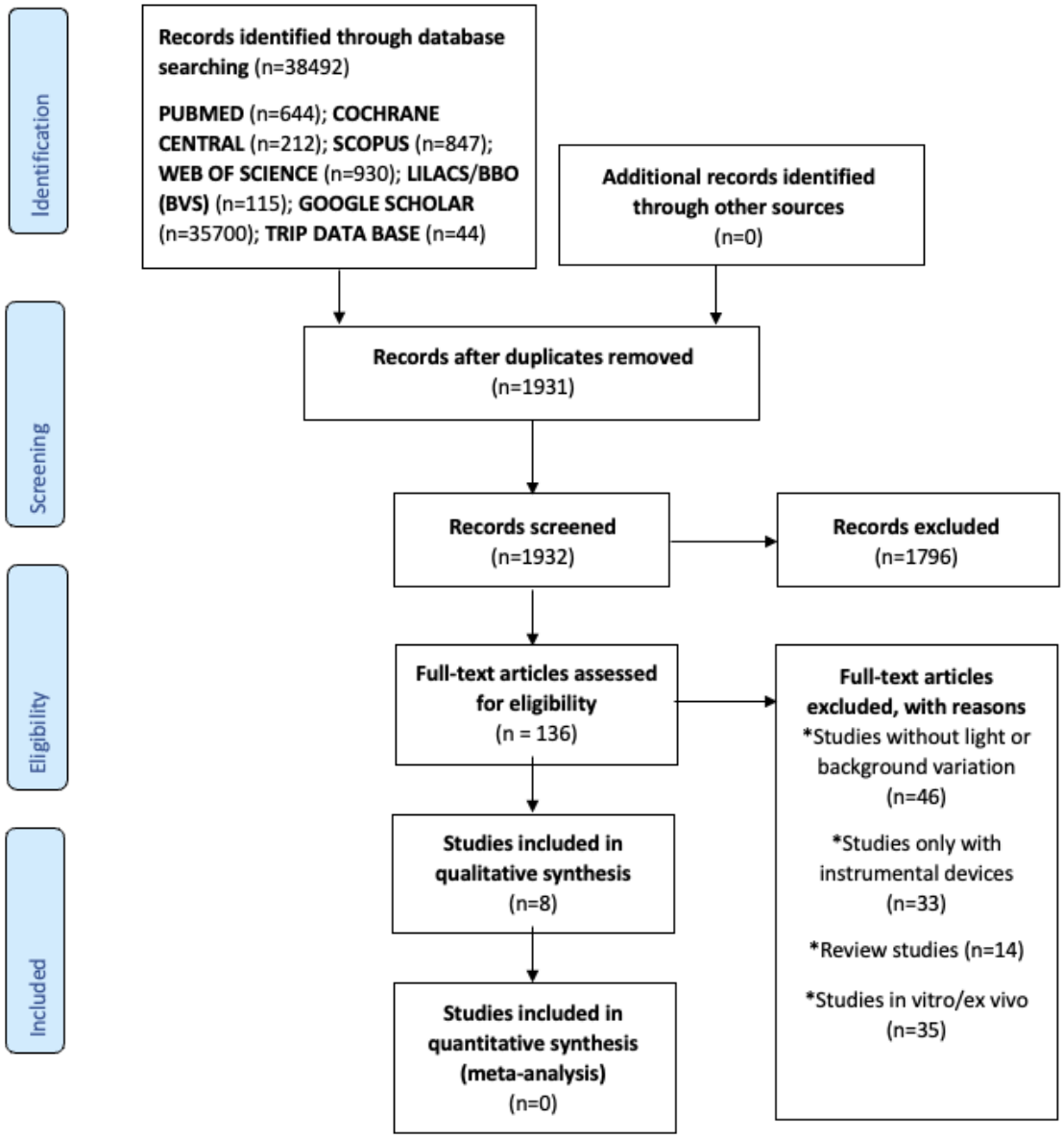
Synthesis of results:

Considering the variability of experimental settings, lightning characteristics and interventional approaches, this study analyzed and presented data descriptively only, not performing meta-analysis. Data of results and of quality assessment and risk of bias were presented in descriptive tables.

RESULTS

Initially, 38,492 articles were retrieved from the databases. Following duplicate removal, 1,932 were screened by reading of titles and abstracts. After that, 136 articles were read full-text and, in the end, 8 articles were included in the qualitative synthesis (Figure 1).

Figure 1: Flow Diagram (PRISMA 2009)



All studies were of prospective observational design. Two studies were from Brazil, and the others were from Malaysia, Romania, India, Turkey, Dominican Republic and Poland. The studies were published from 2009 to 2020 (Table 2).

Table 2. Characteristics of the study and study participants

First author (year)	Country	Journal	Evaluator group (n)	Female (n/%)	Vision test	Mean age ± SD (range)	Evaluated group
Della Bona (2009)	Brazil	Dent Mater	600 observers: General population (n=200); first-year dental students (n=200); dentists (n=200)	General population: 105/52.5; First-year dental students: 103/51.5; dentists: 91;45.5	Ishihara color vision test	(19-50)	Four tab-to-tab shade matches by each general population observer; pair observation of the right upper central incisor by dental students and dentists (2400 matches total)
Baharin (2013)	Malaysia	Sains Malaysiana	100 4th and 5th year dental students	-	Non-specified color test	-	2 individuals (a Chinese and an Indian male student) – maxillary right central incisor
Gasparik (2015)	Romania	J Esthet Restor Dent	21 observers (undergraduate and postgraduate students)	16/76.2	24-plate Ishihara color blindness test	-	One patient (maxillary right central and lateral incisors and maxillary canine)
Chitrarsu (2017)	India	J Prosthodont	One male observer with 10 years of experience in visual shade selection	-	Ishihara color blindness test	30 years	300 participants above the age of 18 with, at least, one permanent maxillary central incisor

Liberato (2018)	Brazil	J Prosthet Dent	3 observers (experienced clinicians)	1/33	Ishihara color blindness test	-	28 participants aged between 20-40 years
Yilmaz (2019)	Turkey	J Esthet Restor Dent	25 observers divided into five groups according to professional experience; S1 – first-year students (n=5), S5 – fifth-year students (n=5), RA1 – research assistants <2 years (n=5), RA2 – research assistants ≥2 years (n=5); PR – professors (n=5)	15/60 S1=3/60; S2=3/60; RA1=3/60; RA2=4/80; PR=2/40	Ishihara color blindness test	(19-47) S1 (19-21); S2 (22-25); RA1 (24-28); RA2 (26-30); PR (37-47)	Five volunteers (three females and two males) with ages ranging from 21 to 40 and healthy maxilary right central incisor
Reyes (2019)	Dominican Republic	Helyion	30 observers divided into three groups according to professional experience; 4th year students (n=10), 5th year students (n=10), prosthodontists (n=10)	15/50	Ishihara color blindness test	-	10 volunteers with healthy maxillary right central incisor
Smieleck a (2020)	Poland	Dent Med Probl	1 observer	-	-	-	100 participants (22 males and 78 females, with age ranging from 22-40 years – mean age: 25.1 ± 3.2 years) – maxillary right central incisor and maxillary right canine

Seven out of the eight studies described the observers. Dental students were observers in five studies and dentists in four studies. Other studies had the involvement of lay people, post-graduate students, research assistants and dental professors. Seven studies declared having performed color-blindness test. Two studies involved shade guide tab-to-tab assessments. The others had the shade of teeth of human volunteers determined, mostly assessing the maxillary right central incisor and the maxillary right canine. The number of volunteers varied from 1 to 300, while the number of observers varied from 1 to 600 (Table 2).

Table 3 presents the testing conditions and the assessment methods used in the included studies. All eight studies assessed the effect of lighting, while none assessed the effect of the background. All studies had the visual shade selection method compared with, at least, one instrumental method. For the visual method, five different shade guides were used in total. A spectrophotometer was used as the instrumental method in seven studies, while an intraoral scanner was used in three. Six studies addressed the natural daylight as a lighting condition for shade selection. The other artificial lightings studied are presented in Table 3.

Table 3. Testing conditions and assessment method for the shade selection

First author (year)	Light source	Background	Groupings	Assessment method
Della Bona (2009)	✓	×	Light sources: - 'Out-of-doors' natural sunlight; - 'In-doors' cool white fluorescent light	Two shade guides: - Vita Classical - Vita 3D Master Spectrophotometer Easyshade
Baharin (2013)	✓	×	Light sources: - operating light on; - operating light off; * Patient position in chair: upright position and supine position	- Vita Classical - Spectrophotometer Easyshade
Gasparik (2015)	✓	×	Light sources: - dental office light (500-600 lux): mixes daylight and light from fluorescent light tubes; - light-correcting device (1,000 lux at a distance of	Two shade guides: - Vita Classical - Vita 3D Master Spectrophotometer Easyshade

			20cm) (Smile Lite Model no. 6,500, Smile Line, Switzerland); - light-correcting device (1,000 lux at a distance of 10cm) with live polarization filter (Style LENSE polarizing filter Model no. 6,510, Smile Line, Switzerland)	
Chitrarsu (2017)	✓	×	Light sources: - Daylight; - Incandescent light; - LED light; - Filtered LED light	- Vita 3D Master - Spectrophotometer Easyshade Advance 4.0
Liberato (2018)	✓	×	Light sources: - Natural light; - light-correcting device Smile Lite, Smile Line	Two shade guides: - Vita Classical - Vita 3D Master Instrumental: - Intraoral scanner TRIOS; 3Shape A/S - Spectrophotometer Easyshade Advance 4.0
Yilmaz (2019)	✓	×	Light sources: - Light source with 4000 k; - Light source with 6500 k Both had 40 W of power, 3200 lm of luminous flux and color rendering index of 85	- Vita 3D Master - Spectrophotometer Easyshade Compact - Intraoral scanner TRIOS; 3Shape A/S
Reyes (2019)	✓	×	Light sources: -fluorescent celing light -natural sunlight	- Vita 3D Master - Intraoral scanner TRIOS; 3Shape A/S
Smielecka (2020)	✓	×	Light sources: - Natural daylight; - Operating light KAVOLUX® 1410C (Kaltenbach & Voigt GmbH & Co., Germany); - Handheld light designed for color matching (Demetron Shade Light®, Kerr Corporation, USA)	Two shade guides: - Vita Classical - Vita 3D Master Spectrophotometer Easyshade

Table 4 presents the outcome measures and the main results. The proportion of visual/instrumental agreement was assessed in five studies, while ΔE* was assessed in two, and weighted kappa was assessed in one study. Two studies revealed improvement in shade selection by using correcting light devices.16,25 One study observed an association between sex and the type of light,17 while one did not.26 Another study found influence of the lighting on shade matching by lay people and dental students, but not by dentists.27 One study found better shade matching results using natural light,28 while other observed a better performance under incandescent light.29 Finally, for one study, lighting did not

play a role in the visual shade matching ability as compared to the instrumental methods.30

Table 4. Outcome measure and main results

First author (year)	Outcome measure	Main results
Della Bona (2009)	Proportion of visual-instrumental agreement	The proportion of visual-instrumental agreement (PVIA) for the general population was higher under fluorescent light (31%) than natural light (26.2%) ($p<0.05$); For dental students, PVIA also was higher under fluorescent light (29%) than under natural light (20.7%) ($p<0.007$); The PVIA of dentists was not affected by the source of light ($p>0.05$); In general, combining the 2400 color matchings, the PVIA was not significantly affected by the light source ($p=0.23$)
Baharin (2013)	Proportion of visual-instrumental agreement	The highest proportion of visual-instrumental agreement (accuracy) was observed with the patient in the upright position and the operating light off (56%), followed by the patient in supine position with the operating light on (47%), by the patient in the upright position and the light on (44%) and by the patient in supine position and the light off (35.5%)
Gasparik (2015)	ΔE_{ab}* between the reference shade and the selected shade	The lightning conditions significantly affected the shade matching scores ($p<0.001$). Also, the interaction between gender and lightning conditions significantly affected the shade matching scores, with women performing significantly better than men only under office lightning. The Vita Classical shade guide led to the best matching scores compared with the Vita 3D Master ($p<0.001$)
Chitrarsu (2017)	ΔE_{ab}* between the reference shade and the selected shade	ΔE_{ab}* values between shade detection using spectrophotometer and Vita 3D Master shade guide significantly differed for all groups (A1, A2 and A3) under the different lightning conditions ($p<0.001$). The incandescent light produced better shade matches compared to daylight, LED light and filtered LED light
Liberato (2018)	Fleiss´ and weighted kappa coefficients	The instrumental methods were more reliable than the visual methods. Visual shade matching without a light-correcting device was the least reliable method (Vita Classical: 0.177; Vita 3D Master: 0.206). The light-correcting device increased the reliability of the visual shade matching (Vita Classical: 0.322; Vita 3D Master: 0.306). The correcting device increased the agreement between the visual matching method using the Vita Classical shade guide and the intraoral scanner and the spectrophotometer.
Yilmaz (2019)	Proportion of visual-instrumental agreement	Visual shade selection performed by all observer groups under both color temperatures did not significantly differ from the shade measured with the spectrophotometer under either color temperatures ($p>0.05$). Also, shade measured by T-3S under both color temperatures did not significantly differ from the shade measured with the spectrophotometer under both color temperatures ($p>0.05$). The lightning conditions did not significantly affect shade measurement either with the spectrophotometer or the intraoral scanner ($p>0.05$).
Reyes (2019)	Proportion of visual-instrumental agreement	Ambient lighting had a direct effect on the repeatability of the shade selection for the visual method ($P=0.002$), whereas the observer's sex and clinical experience did not ($P=0.199$).
Smielecka (2020)	Proportion of visual-instrumental agreement	The light sources significantly affected the results of shade selection ($p<0.05$). The highest agreement with the spectrophotometer was obtained under the Demetron Shade Light, followed by the natural light. The operating light produced the lowest agreement. Amongst the shade guides, Vitapan Classical produced higher agreement with the spectrophotometer than the 3D Master ($p<0.05$).

Table 5 presents the assessment of the study quality and risk of bias by Fowkes and Fulton 23 and Table 6 presents the assessment of risk of bias based on Quadas 2.24

Table 5. Quality assessment and risk of bias based on Fowkes and Fulton (1991)

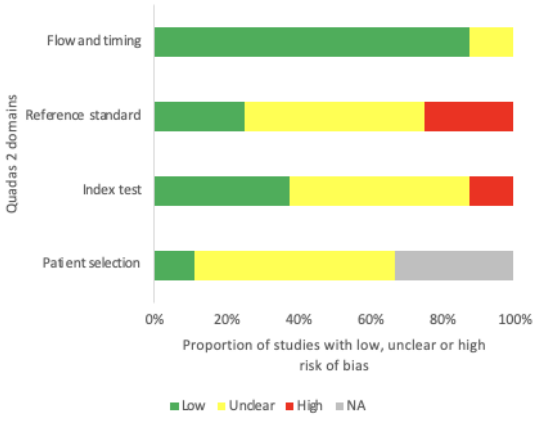
Study	Risk of bias						
	Study design appropriate to objetive	Study sample representative	Control group acceptable	Quality of measurements and outcomes	Completeness	Distorting influences	Summary questions*
Della Bona (2008)	☺	☹[a,b]	☺	☹[g,h]	NA	☺	☺
Baharin (2013)	☺	☹[a,b,c]	☺	☹[e,h]	NA	☺	☺
Gasparik (2015)	☺	☹[a,b,c]	☺	☹[e,h]	NA	☺	☺
Chitrarsu (2017)	☺	☹[a]	☺	☹[g]	NA	☺	☺
Liberato (2018)	☺	☹[a,b,c]	☺	☹[e,f]	NA	☺	☹
Yilmaz (2019)	☺	☹[a,b]	☺	☹[e]	NA	☺	☺
Reyes (2019)	☺	☹[a,b]	☺	☹[e,h]	NA	☺	☺
Smielecka (2020)	☺	☹[a,b]	☺	☹[f,g]	NA	☺	☹

Reasons for downgrading each methodological issue: a – No sample size rationale or calculation; b – sampling process is not described; c – participants were not representative of the general population; d – no instrumental control group; e – reproducibility based only on different observers, not considering different timing; f – observer of the instrumental shade matching not blind to the visual matching results; g – no reproducibility; h – blinding between visual and instrumental matches uncertain; i – no blinding between shade guides at visual matching; * - summary questions answered as “NO” for existence of identifiable bias, distorting influences of confounding factors or that the results occurred by chance.

Table 6. Risk of bias assessment of the included studies based on Quadas 2 and proportion of studies with low, unclear or high risk of bias

Study	Risk of bias			
	Patient selection	Index test	Reference standard	Flow and timing
Della Bona (2008)	NA	☺	?	☺
Baharin (2013)	?	?	?	?
Gasparik (2015)	NA	☺	☺	☺
Chitrarsu (2017)	☺	☹	☹	☺
Liberato (2018)	?	☺	☹	☺
Yilmaz (2019)	?	?	☺	☺
Reyes (2019)	?	?	?	☺
Smielecka (2020)	?	?	?	☺

☺ = low risk; ? = unclear risk; ☹ = high risk; NA = not applied



DISCUSSION

The influence of the illuminant and the background color on visual tooth shade selection was assessed in this review. Noteworthy, none of the included studies assessed the effect of the background color, which remains a doubt as to its effect on visual shade match. The type of illuminant was found to produce varying shade matching performances across the evaluated studies. Also, some studies assessed possible influencing factors, such as gender17,26 and level of student or professional experience.17,26–28,30 Conflicting results were found as to the effect of these factors on shade matching performance.

The dental shade matching is a particularly challenging procedure due to interference of environmental conditions such as lightning and background color. Light corrections have been proposed to minimize this interference, with light-correcting devices that produce neutral clarity and a color temperature of 5500K being available to dental practitioners to assist the visual, subjective shade match method.16,17,31 In addition, natural teeth do not exhibit color homogeneity.32,33

Consequently, when light reaches the tooth surface, phenomena such as light transmission, reflection, dispersion, and absorption may be observed.34

Chitrarsu et al. (2017)29 found that the yellow light produced by incandescent light produced higher shade matches compared to filtered LED light, LED light, and daylight. Also, the color-corrected LED light produced higher shade matches compared to LED light and daylight. This last finding agrees with other primary studies of the review,16,17,25 which found that light-correcting devices improve interrater agreement at shade match. For Gasparik et al. (2015),17 though, the polarization filter did not improve the shade matching results. Conversely, Yilmaz et al. (2019),30 having tested different color temperatures (4000K and 6500K), found no influence of the light sources on the shade match results. Noteworthy, the authors did not use handheld correcting lamps, while the formers did. Possibly, an intentionally directed light at a shorter distance could play an important role in providing a more accurate assessment of dental translucency and, consequently, more reliable visual shade matching results.31

The importance of tooth translucency becomes evident when color is assessed against varying background contrasts.35–38 Regardless of the existence of studies addressing this issue in controlled settings, the lack of clinical studies on this matter limits the evidence on the role of the background color in shade match procedures.21,39

When shade guides were used, conflicting results could be observed. Gasparik et al. (2015)17 and Smielecka et al. (2020)25 observed higher compatibility in shade match using the VITA Classical system when compared to the VITA 3D Master system. On the other hand, for Liberato et al. (2019)16, VITA 3D Master shade guide produced better interrater agreement than VITA Classical. Contrary to the Vita Classical, the Vita 3D Master shade guide is proposed to distinguish among each of the color dimensions (hue, chroma and value) what improved dental shade matching. Furthermore, level of experience was not found to be influential factor in shade matching when 3D-Master shade guide was used.40,41

The level of experience with shade matching was also addressed by some studies.26,27,30 One study found out that dentists did not suffer interference of lighting on the proportion of visual-instrumental agreement, while lay people and dental students did.27 The other two studies found no interference of shade matching experience on agreement,26,30 and confirm previous reports.26,41–43 The cumulative effect of experience with shade matching has been shown to produce more consistent shade matching results (Gómez et al., 2020). Still, experimental variation between studies generates settings and results that are hardly comparable, hindering solid conclusions about the issue. Then, these results lead to the conclusion that the previous education and the training in color education is more important than the light condition itself.

Risk of bias was assessed using the instrument of Fowkes and Fulton23 and was complemented with Quadas 2 due to the diagnostic nature of the intervention being studied.24 Studies addressing the influence of the illuminant on the visual shade selection had varying designs and dealt with important methodological issues differently.

Two major items led to questioning of the studies methodological quality based on the Fowkes and Fulton´s instrument: representativeness of the study sample and the quality of outcome measures (Table 5). The first relates to the possibility of establishing inferences to the population that would require shade matching procedures as part of the dental treatment and was mainly affected by the lack of a sample size calculation or power display (all studies) and of adequate description of sampling process.16,17,25–28,30 Also, some studies did not make clear whether the sample was representative of those who would be involved in shade matching procedures as a dental demand.16,17,28

Another methodological issue was related to the reproducibility of the shade matches. Reproducibility refers to the ability to obtain the same results with measurements being made by different observers or at different time intervals.23 Most studies addressed this issue by having different observers matching tooth shade.16,17,26,28,30 No study addressed reproducibility taking a time interval

for consistency of the measurements. Blindness was assessed as the lack of awareness of the results of the other group during shade matching. It generated risk of bias in two studies.16,25 For the other studies, it was unclear whether the observers were blinded to the results of the other group, as well as the risk of generating bias.

Not all signalling questions of Quadas 2 were applicable to shade match studies. When it comes to the patient selection domain, most studies did not report having applied a random or sequential patient enrolment (Table 6). Two studies addressed color match in a single patient or in pairs,17,27 while one study reported having enrolled 100 participants randomly from 300 patients.29 It remains unclear whether this domain would bias the shade match results. Random or sequential enrolment of participants plays a role in situations involving the diagnosis of a present/absent disease and should be ensured to prevent that patients with or without disease are not involved in the study on purpose, therefore inducing bias.24 Also, the study participants are likely to have represented the population of patients who require, as part of dental treatment, dental shade selection.

Most studies did not report whether the index test was interpreted without knowledge of the results of reference standard (Table 6). One study had the same outcome assessor assessing the results of the index test and the instrumental reference standard.29 Other three studies reported that the visual shade selection was performed blind to the reference standard results, which is desirable considering prevention of bias. As to the reference standard, all studies used some instrumental method. Instrumental methods, especially spectrophotometers, have been shown as the most accurate methods for shade match.8 Also, two other studies had the reference standard method used by the same outcome assessor that visually assessed tooth shade, characterizing lack of blinding for the index test.16,29

Most studies were unlikely to have timing influencing the results, since shade match visually and instrumentally were performed in a short time span. Still, for

one study,28 it was unclear whether the different day time may have influence shade matching.

Limitations of this review involved the addition of a risk of bias tool24 post protocol publication. Still, this integrative review depicted the need for well-designed studies to further collaborate to evidence generation towards the influence of illumination and background color on shade matching. These studies should consider methodological issues of diagnostic studies to avoid bias,24 mainly directed to sampling, reproducibility along time and blinding of intervention groups.

CONCLUSION

The effect of the illuminant in shade selection varies across studies, impairing the election of the most suitable. Besides, the effect of background color is not determined yet, due to the absence of clinical studies addressing the issue. Additional well-designed studies are required to further elucidate the role of illuminant and background color on shade matching performance.

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