Clin Oral Invest (2010) 14:587–591
DOI 10.1007/s00784-009-0331-z

ORIGINAL ARTICLE

Differences in lightness, chroma, and hue in the anterior teeth of quinquagenarians and septuagenarians

Constantin Eiffler · Engin Cevirgen · Stephan Helling · Juanita Zornek · Maria Pritsch · Alexander Jochen Hassel

Received: 28 November 2008 / Accepted: 30 July 2009 / Published online: 18 August 2009
© Springer-Verlag 2009

Abstract The purpose of this study was to evaluate, for both genders and two elderly age groups, differences in lightness, chroma, and hue of pairs of natural anterior teeth, so that more accurate information on color would be available for the production of dentures with a natural appearance. The subjects in the younger group (YG) were 54 to 56 years of age, those in the older group 73 to 75 (N= 195, 48% women). Tooth color was measured using a spectrophotometer. Mixed models were calculated for each pair of teeth, with gender as a fixed factor. Gender did not have a significant effect in either age group. In both groups, differences in chroma between upper canines and lateral incisors and in lightness and hue between upper and lower canines were observed. In the YG, additional differences were found, with the only exception of the comparison between upper central and lateral incisors. The nongender-specific color differences observed should be considered when producing denture teeth for these groups of patients, in order to come as close as possible to the natural color ideal.

Keywords Color · Lightness · Chroma · Hue · Color difference · Color measurement

C. Eiffler (✉) · E. Cevirgen · J. Zornek · A. J. Hassel
Department of Prosthodontics, University of Heidelberg,
Im Neuenheimer Feld 400,
69120 Heidelberg, Germany
e-mail: constantin.eiffler@med.uni-heidelberg.de

S. Helling
Color Science and Color Image Processing,
RWTH Aachen University,
Templergraben 55,
52056 Aachen, Germany

M. Pritsch
Department of Medical Biometrics and Informatics,
University of Heidelberg,
Im Neuenheimer Feld 305,
69120 Heidelberg, Germany

Introduction

Patients regard esthetic appearance, and especially tooth color, as primary success criteria of prosthodontic restorations. Tooth color can be determined by visual assessment with the aid of shade guides or by means of electronic tooth color measuring devices, such as colorimeters [1], spectrophotometers [2–5], or digital cameras [6].

Tooth color can be described by these instruments within the cylindrical L*C*h* color space. L* is lightness. It is defined as the perceived brightness, ranging from black to white, and quantified on a scale from 0 to 100. C* is chroma and describes the saturation of a surface color, the degree of visual difference from neutral grey. Hue (h*) forms a continuous circular scale and is indicated in angles from 0° to 360°. The cylindrical L*C*h* color space can be transformed into the L*a*b* color space, and vice versa, without any loss.

Clinicians frequently have to replace a large number of, or even all, the anterior teeth of a patient. In this challenging situation, the standard shade taking procedure is to determine one global tooth color. As a result, there are no differences in color between canines and central or lateral incisors, which means that the restoration may not match the natural ideal.

In addition to reports of differences in color between the cervical, middle, and incisal tooth regions [2, 6, 7], there are a few internationally published studies on this topic,

focusing mainly on upper anterior teeth. A colorimetric examination of 2,830 anterior teeth (patient age range, 17–70) showed, in general, maxillary teeth to be slightly more yellowish than mandibular teeth, maxillary central incisors to be lighter than mandibular central incisors, and canines to be darker than neighboring incisors [8]. The results were, however, reported without any adjustment for gender or age, which might be influencing factors because color changes with age and differs slightly between genders [8–11]. Another study investigated relations in color among maxillary incisors and canines, using digital photography (mean age, 34.4; SD, 10.5) [12]. Relations between the colors of canines and incisors, especially in the cervical region, were reported. Statistically significant color differences were found more frequently between canines and central incisors than between central and lateral incisors. Again, a wide age range was examined, and no adjustment for gender was reported.

Only little information is available specifically for elderly patients, which presents a problem, since this rapidly growing group of patients has a high need for dentures. The objective of this study was therefore to evaluate, for both genders and two elderly age groups, differences in lightness, chroma, and hue of upper anterior teeth, lower canines, and central incisors, and also the upper first premolars. The null hypothesis stated that no significant differences in lightness, chroma, and hue would exist between the anterior teeth of one individual. Consequently, it was furthermore hypothesized that gender and age would not influence color differences between the teeth of one individual.

Materials and methods

Subjects and recruitment

The subjects were recruited from an Interdisciplinary Longitudinal Study of Adult Development (ILSE), conducted in two urban regions in Germany [13]. The sample for this analysis comprised subjects born from 1930 to 1932 (age 73 to 75 years) and from 1950 to 1952 (age 54 to 56 years) from the cities of Heidelberg and Mannheim. Although the original study, involving psychological, medical, and psychiatric examinations, was designed to be representative of the German population (not for gender), only a subsample had teeth which could be measured during dental examination. This subsample is unlikely to be representative, but it is a random population sample without any bias towards dental purposes. The ethics committee of the University of Heidelberg approved the investigation (No. 181/2005). In 195 subjects (101 in the YG and 94 in the OG), tooth color was measured (1,391 teeth); 48.2% of the subjects were female.

Inclusion criteria

Subjects with extrinsic staining (smokers, self-anamnestic assessment) or intrinsic staining (e.g., discoloration after root canal treatment and clinical assessment) were excluded. Only teeth without prosthodontic restorations, e.g., crowns or veneers, were used. Although teeth with tooth-colored fillings were included, the fillings were not allowed to overlap the probe tip of the measuring device. All maxillary anterior teeth and first bicuspids, and the mandibular canines and central incisors, were measured. Because of the inclusion criteria and the age of the subjects, the number of teeth measured in one subject varied.

Measuring device and procedure

The VITA Easyshade 1 spectrophotometer with software release 11R(b), 2° observer and light source D65 (VITA Zahnfabrik, Bad Säckingen, Germany) was used for measurement. All examiners were theoretically and practically instructed in the handling of this instrument by its development manager. Different rooms had to be used for examination, so environmental conditions were not standardized. An infection-control shield was applied over the probe tip, and the instrument was calibrated for each subject. The examiners were instructed to measure tooth color by a single measurement, placing the probe tip over the region of the tooth where the largest amount of dentin was expected to underlie the enamel (2 mm from gingival margin and incisal edge). The middle third of the facial tooth surface was considered most suitable in this respect, rather than the incisal or cervical thirds. Because of time constraints in the interdisciplinary study, the teeth could only be wiped and dried with gauze; professional or instrumental cleaning was not possible. Tooth color was recorded in the form of L*C*h* values, displayed by the Easyshade.

Statistical analysis

L*C*h* values were measured, and differences in L*, C* and h* (ΔL*, ΔC*, Δh*) were calculated for the following pairs of teeth (according to the FDI system), grouping the same pairs of the right and left sides together: color differences between 11 and 12, as well as 21 and 22, for the comparison of central and lateral incisors, between 12 and 13/22 and 23 for the comparison of lateral incisors and canines, between 13 and 14/23 and 24 for the comparison of canines and first biscuspids, between 11 and 41/21 and 31 for the comparison of upper and lower central incisors and between 13 and 43/23 and 33 for the comparison of upper and lower canines. The number of pairs could vary between analyses, because of missing teeth. To make

adjustments for the possible presence of a subject with two differences for the same location (grouping of the teeth of the left and right sides), a mixed model procedure was used. In the first step for each dependent parameter (ΔL*, ΔC*, and Δh*) a mixed model with gender as fixed effect and a random effect associated with the intercept for each subject was applied. The variance–covariance matrix of the random effects thus reduced to one variance component. Since none of the dependent variables could be shown to be influenced by gender, gender was generally dropped in the second step of the analyses and only the intercept was estimated and tested. Check of model fit was done by means of graphical exploration of the residuals. Adjustment for multiple testing (five comparisons for each of the three dependent variables, resulting in 15 testings) was done according to Bonferroni method resulting in a local significance level of $\alpha=0.05/15$ for each test ($\alpha=0.003$). All statistical analyses were done with the aid of SPSS 16.0.

Results

The results of color measurement are listed in Table 1. Gender had no significant effect on the color differences in either age group ($p>0.003$ in all cases). In the OG, ΔL*, ΔC*, and Δh* values were statistically significant for the differences between maxillary canines and lateral incisors (canines showing higher chroma), and also between upper and lower canines, with lower lightness and hues tending more towards yellow-red than yellow-green in the upper canines (Table 2). In the YG, only the comparison of upper central and lateral incisors did not reveal any significant differences in color (Table 2). The upper canines showed lower lightness, higher chroma, and hues tending more towards yellow-red than yellow-green, as compared with the lateral incisors. The canines were lighter, but more saturated, and again more yellow-red than the first bicuspids. The upper canines showed a lower lightness and were more yellow-red than the lower canines. The hue of the upper central incisors, in contrast, tended more towards yellow-green than that of the lower central incisors.

Discussion

The null hypothesis stating that no significant differences in lightness, chroma, and hue would exist between the anterior teeth of one individual had to be rejected, as well as the hypothesis that age would not influence color differences between the teeth of one individual, because significant color differences were described in both OG and YG, more frequently in the YG. With regard to gender, however, the null hypothesis had to be accepted. Not one significant effect of gender could be found in any color difference assessment. Therefore, gender need not be taken into consideration in the industrial manufacture of sets of artificial anterior teeth or the production of extended fixed anterior prostheses in dental laboratories. In the OG of this

Table 1 Means and standard deviations (SD) of measured L*, C*, and h* values for YG (N=101) and OG (N=94)

Tooth number	Value	Younger group				Older group			
		n (t)	*n* (p)	Mean	SD	*n* (t)	*n* (p)	Mean	SD
11/21	L*			77.1	5.9			67.1	5.7
	C*	122	65	23.3	4.4	75	47	23.9	6.1
	h* (°)			91.8	3.3			88.4	4.4
12/22	L*			76.7	5.7			65.8	5.3
	C*	126	69	23.3	4.3	69	46	22.2	5.4
	h* (°)			91.1	3.3			87.8	3.9
13/23	L*			74.9	5.8			65.1	4.5
	C*	147	80	30.0	4.0	69	50	25.9	5.1
	h* (°)			88.4	2.3			87.0	4.3
14/24	L*			74.0	5.3			63.4	5.0
	C*	97	58	25.8	4.6	49	37	22.9	6.9
	h* (°)			89.8	2.5			87.5	5.8
31/41	L*			75.6	5.4			67.5	5.4
	C*	174	93	22.1	4.6	137	82	24.6	5.7
	h* (°)			90.3	3.1			88.1	3.7
33/43	L*			78.4	5.2			69.5	6.1
	C*	184	97	29.9	5.2	142	89	26.0	5.7
	h* (°)			89.5	2.4			89.4	3.8

The same teeth of the left and the right sides were grouped together, for example right (11) and left (21) central incisors. Because of missing teeth or teeth which did not meet the inclusion criteria, the numbers of measured teeth and numbers of patients differed between the various teeth and from total N

n (t) number of teeth, *n (p)* number of patients

Table 2 ΔL*, ΔC*, and Δh* in YG (N=101) and OG (N=94)

Difference	Younger Group				Older Group			
		Estimate	99.67% CI	*p*.value		Estimate	99.67% CI	*p*.value
Central and lateral incisors	ΔL*	0.43	−1.19/2.05	0.417	ΔL*	1.61	−0.67/3.89	0.033
	ΔC*	0.36	−1.17/1.90	0.469	ΔC*	1.50	−0.34/3.34	0.014
	Δh*	0.53°	−0.53°/1.58°	0.131	Δh*	0.55°	−0.81°/1.91°	0.219
	n (t)=107; *n* (p)=60				*n* (t)=65; *n* (p)=44			
Lateral incisors and canines	ΔL*	1.85	0.20/3.49	0.001*	ΔL*	0.16	−2.24/2.57	0.834
	ΔC*	−7.17	−8.53/−5.81	<0.001*	ΔC*	−3.55	−5.82/−1.28	<0.001*
	Δh*	2.88°	1.94°/3.83°	<0.001	Δh*	0.96°	−1.06°/2.99°	0.145
	n (t)=120; *n* (p)=68				*n* (t)=56; *n* (p)=42			
Canines and first bicuspids	ΔL*	1.67	0.15/3.19	0.001*	ΔL*	2.12	−0.65/4.88	0.020
	ΔC*	4.45	3.01/5.89	<0.001*	ΔC*	2.18	−1.12/5.47	0.043
	Δh*	−1.36°	−2.08°/−0.64°	<0.001*	Δh*	0.44°	−2.59°/3.46°	0.654
	n (t)=90; *n* (p)=54				*n* (t)=39; *n* (p)=32			
Upper and lower central incisors	ΔL*	1.01	−1.30/3.32	0.187	ΔL*	−1.52	−4.27/1.22	0.087
	ΔC*	1.20	−0.90/3.29	0.085	ΔC*	−0.92	−4.49/2.65	0.416
	Δh*	1.57°	−0.01°/3.15°	0.003*	Δh*	−0.11°	−2.02°/1.80°	0.856
	n (t)=106; *n* (p)=61				*n* (t)=54; *n* (p)=30			
Upper and lower canines	ΔL*	−3.75	−5.11/−2.39	<0.001*	ΔL*	−4.28	−6.80/−1.75	<0.001*
	ΔC*	0.20	−1.18/1.58	0.654	ΔC*	0.14	−2.58/2.87	0.868
	Δh*	−1.12°	−1.78°/−0.46°	<0.001*	Δh*	−2.80°	−5.11°/−0.49°	0.001*
	n (t)=139; *n* (p)=76				*n* (t)=52; *n* (p)=34			

The same pairs of teeth of the left and right sides of the upper and lower jaw, respectively, were grouped together, e.g., for differences between central and lateral incisors on the right and on the left (11 and 12/21 and 22). Because of missing teeth or teeth which did not meet the inclusion criteria, the numbers of assessed tooth pairs and the numbers of patients differed between the various tooth pairs and from total *N*. The difference was assessed by subtraction of the respective L*, C*, and h* values of the teeth mentioned second from those of the teeth mentioned first in the first column. For example, the estimate ΔL*=0.43 for the comparison of upper central and lateral incisors means that the L* value of the central incisors was 0.43 higher than that of the lateral incisors, and the estimate ΔC*=−7.17 means that the chroma of the canines was 7.17 higher than that of the lateral incisors

n (t) number of tooth pairs, *n (p)* number of patients

*$p \leq 0.003$

analysis, only few significant differences in L*, C*, or h* were observed, concerning chroma in upper canines and lateral incisors and lightness and hue in upper and lower canines. Bearing the limitations of a small sample size in mind, this differs from previous results of study populations with wider age ranges [8, 12, 17]. In the YG subjects, who were approximately 20 years younger, differences in L*, C*, and h* for teeth of one patient were frequent. For practical relevance, the differences may be compared with the systematically arranged VITA 3D-Master shade guide (VITA Zahnfabrik, Bad Säckingen, Germany). The upper canines in the YG, for example, were ΔL*=2.39 (lower confidence interval (CI)) darker than the lower ones, which is approximately equivalent to half a step in lightness between two lightness groups on the 3D-Master shade guide. The maxillary canines were clearly more saturated than the lateral incisors (ΔC*=5.81 lower CI, one step on the 3D-Master is approximately ΔC*≈5), and more yellow-red than yellow-green (Δh*=1.94° lower CI, one step on the 3D-Master is approximately Δh*≈2°). Our findings in the YG are supported by previous study results, reporting significant differences, in the same direction, between the central incisors and canines of the maxilla [12]. This also applies to the small differences in color between the upper central and lateral incisors. A study using colorimetric assessment of 2,830 teeth obtained results similar to those of our YG, showing the canines of both jaws to be the anterior teeth with the lowest lightness and highest chroma [8], which is also in line with findings obtained in Japanese subjects [14]. The results of our comparison of teeth in the mandible and maxilla, however, differed from previous results showing maxillary central incisors to be lighter than mandibular incisors [8]; this difference was not observed in our analysis for the central incisors, in which no difference was measured, even when taking into account that possible edge loss may have led to

measuring errors in the lower incisors (values too dark). This also applies to the lower canines, which were found to be lighter than the upper ones, and might be associated with the age of the subjects.

Study limitations

Method—the probe tip of the Easyshade measuring device is 5 mm in diameter. Although the examiners were instructed to measure teeth only if the complete probe tip could be placed on the tooth surface, an increased edge-loss effect in the measurements of the lower central incisors and first bicuspids, which were relatively narrow and waisted, can be assumed [15]. This means that measurements for the lower central incisors and upper first bicuspids might be "too dark", and the lightness results of the comparisons of upper and lower central incisors, as well as upper canines and first bicuspids, have to be interpreted bearing this limitation in mind. Furthermore, the results are restricted to the middle third of the facial tooth surface and may be different in the incisal and cervical thirds. This assumption is supported by findings indicating relations between the colors of canines and incisors, especially in the cervical tooth region and less in other regions [12].

Participants—the sample sizes, especially in the OG, were relatively small. However, significant differences were observed despite these small samples and the stringent level of the alpha error chosen; the statistical power of the statement of no difference between tested pairs, the beta error, is probably high. Results indicating no differences between tested pairs have thus to be interpreted bearing this limitation in mind. The age range of the participants was rather small, because the original study used as the basis for this analysis was not designed for dental, but for longitudinal medical and psychological, purposes. The participants were, however, in two age groups relevant to the need for prosthodontics, and there is no bias towards dental purposes in the study design. In Germany, over 90% of the 65–74 age group have some kind of fixed or removable denture and are, therefore, potential prosthodontic patients [16]. The number of subjects available for the different comparisons varied, because, owing to the age structure of the sample, all the teeth could not always be measured.

Summary and conclusion

The results showed that gender does not significantly affect ΔL^*, ΔC^*, and Δh^* for neighboring teeth or the corresponding teeth in the mandible and maxilla and need therefore not be considered in this context. In both age groups, the lightness and hue of upper and lower canines and the chroma of maxillary canines and lateral incisors differed significantly. Furthermore, in the YG, differences were observed for the hue of central incisors in the upper and lower jaws, and for the lightness and hue of lateral incisors/canines and first bicuspids/canines in the maxilla. If these nongender-specific color differences are considered in denture tooth production, the appearances of dentures may be closer to the natural ideal.

Acknowledgments We would like to thank Vita Zahnfabrik H. Rauter GmbH, Bad Säckingen, Germany, for the financial support of this study.

This publication is based on data from the Interdisciplinary ILSE (AZ: 301-1720-295/2), funded by the Federal Ministry of Family Affairs, Senior Citizens, Women, and Youth.

We would like to thank all project members for their contributions. Particular thanks are extended to Dr. Marina Schmitt, who organized the ILSE study.

Conflict of interests The authors declare that they have no conflict of interests.

References

1. Hasegawa A, Ikeda I, Kawaguchi S (2000) Color and translucency of in vivo natural central incisors. J Prosthet Dent 83:418–423
2. O'Brien WJ, Hemmendinger H, Boenke KM, Linger JB, Groh CL (1997) Color distribution of three regions of extracted human teeth. Dent Mater 13:179–185
3. Kim J, Paravina R, Chen JW (2007) In vivo evaluation of color of primary teeth. Pediatr Dent 29:383–386
4. Paravina RD, Majkic G, Imai FH, Powers JM (2007) Optimization of tooth color and shade guide design. J Prosthodont 16:269–276
5. Yuan JC, Brewer JD, Monaco EA Jr, Davis EL (2007) Defining a natural tooth color space based on a 3-dimensional shade system. J Prosthet Dent 98:110–119
6. Dozic A, Kleverlaan CJ, Aartman IH, Feilzer AJ (2004) Relation in color of three regions of vital human incisors. Dent Mater 20:832–838
7. Goodkind RJ, Keenan KM, Schwabacher WB (1985) A comparison of chromascan and spectrophotometric color measurements of 100 natural teeth. J Prosthet Dent 53:105–119
8. Goodkind RJ, Schwabacher WB (1987) Use of a fiber-optic colorimeter for in vivo color measurements of 2830 anterior teeth. J Prosthet Dent 58:535–542
9. Brodbelt RH, O'Brien WJ, Fan PL, Frazer-Dib JG, Yu R (1981) Translucency of human dental enamel. J Dent Res 60:1749–1753
10. Burchett PJ Jr, Christensen LC (1988) Estimating age and sex by using color, form, and alignment of anterior teeth. J Prosthet Dent 59:175–179
11. Solheim T (1988) Dental color as an indicator of age. Gerodontics 4:114–118
12. Dozić A, Kleverlaan CJ, Aartman IH, Feilzer AJ (2005) Relations in color among maxillary incisors and canines. Dent Mater 21:187–191
13. Martin M, Grunendahl M, Martin P (2001) Age differences in stress, social resources, and well-being in middle and older age. J Gerontol B Psychol Sci Soc Sci 56:214–222
14. Hasegawa A, Motonomi A, Ikeda I, Kawaguchi S (2000) Color of natural tooth crown in Japanese people. Col Res Appl 25:43–48
15. Bolt RA, Bosch JJ, Coops JC (1994) Influence of window size in small-window color measurement, particularly of teeth. Phys Med Biol 39:1133–1142
16. Micheelis W, Schiffner U (2006) Vierte Deutsche Mundgesundheitsstudie. Deutscher Zahnärzte Verlag, Colone, p 362

Copyright of Clinical Oral Investigations is the property of Springer Science & Business Media B.V. and its content may not be copied or emailed to multiple sites or posted to a listserv without the copyright holder's express written permission. However, users may print, download, or email articles for individual use.