

The Effect of Age, Gender and Ethnicity on Selection of Shade and Mold of Artificial Denture Teeth: A Five-Year Retrospective Study

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Abstract

Purpose: The aim of this study was to determine the effect of the patient's age, gender and race/ethnic on the shade and mold of the maxillary anterior teeth.

Methods: After IRB approval, a computer program was written to identify a list of patients from the Electronic Health Record database and to record demographic and tooth selection information from patients treated with at least one complete maxillary denture. Data was manually collected from tooth prescription forms and confirmed with a corresponding review of the EHR for 1,265 patients. Statistically, cross tabulations were constructed and the chi square test employed. The Mann-Whitney "U" test and the Kruskal-Wallis test were used to compare groups.

Results: Chi square tests revealed significant p values for gender versus tooth form ($p < 0.001$), width ($p < 0.001$) and shade ($p < 0.001$), but not significant for gender versus facial contour. Similarly, the p value was not significant for ethnicity versus tooth contour. The Mann-Whitney "U" test revealed significant p values for gender versus width and shade. The Kruskal-Wallis test for variables ethnicity and age versus the width ($p < 0.001$) and shade ($p < 0.025$) revealed significant p values.

Conclusion: Shade selection for the maxillary denture teeth was influenced by the age, gender and ethnicity of the patient. Similarly, the age group 40 - 49 had lighter shades selected than did patients in age group > 70 . Female patients had lighter and narrower teeth selected than the males, and there was no difference in the facial contour of the teeth selected relative to age, gender or ethnicity.

Keywords: Dentures; Tooth Form; Anterior Teeth; Tooth Shade

Introduction

The selection of artificial teeth for edentulous patients can be critical to the success of treatment with complete dentures. Along with the gingiva and lips, teeth occupy the major portion of available space in an individual smile. The form, shape, size, shade, arrangement of teeth in the arch and their relationship to the surrounding structures influence the anterior esthetics of the individual. Artificial den-

ture teeth selection becomes even more complex when different demographic factors such as age, gender and ethnicity are involved. Each of these factors may influence the selection of denture teeth.

The development of dental tooth selection is founded on a protracted history in the prosthodontic literature. As early as 1884, White postulated that the patient's temperament called for a characteristic association with tooth form and facial complexion [1]. This harmony required a corresponding proportion and size of tooth to the face, and a tooth color in agreement with facial complexion. Both form and color were modified to be in accord with sex and age in an attempt to categorize denture teeth [1].

Several years later, Hall listed three classifications of denture teeth, using the terms ovoid, tapering, and square [2]. Based on the work of White [1] and later Hall [2], Berry in 1905 published the Berry's Biometric Ratio Method; whereby, the tooth was one-sixteenth of the face width and one-twentieth of the face length [3].

It was not until 1914, that Williams proposed the Law of Harmony [4]. The concept suggested that a relationship exists between the shape of the and the anatomical characteristics of the maxillary central incisor and that this relationship should be taken into account in tooth selection. Similar to the work of Hall [2], Williams' research resulted in three distinctive groups: square, tapering, and ovoid [4]. Unlike Hall's results, Williams found that tooth morphology exhibited similar characteristics and hence were grouped together. Combinations of the three basic forms eventually evolved into the additional categories of square tapering, square ovoid, tapering ovoid and square tapering ovoid that comprise modern mold selection guides [5].

It was not until the 1950s; Frush and Fisher introduced the concept of "dentogenics". The concept suggested that the factors of sex, personality and patient age should be interpreted in the denture esthetic [6-9]. This was accomplished by detailed consideration of the three equally important components of the denture: the tooth, its position and a personality matrix. The application of the dynesthetic technique to the dentogenic concept was said to enable dentists to incorporate the patient's psychologic and physiologic profile to denture esthetics [10].

In order to further enhance denture tooth selection, Bindra, *et al.* used facial photographs to assist in anterior tooth selection [11]. Using the work established by Wehner, Bindra obtained three photographic views from 30 dentate subjects [11,12]. The perspectives were full face, oblique, and reduced-size full face. The width of the maxillary right central incisor was calculated using a formula. The difference between the actual width and calculated width of MR1 was determined for each subject. The results suggested that the photographic assessment procedure was beneficial; however, it is of value only when the photograph is a full-face portrait of sufficient size [12].

Taken together, there are numerous additional procedures to assist with anterior tooth selection. These include pre-extraction and facial guides, diagnostic casts, photographs, radiographs, the size and form of the face, the profile and cheek form. When available, pre-extraction diagnostic casts are excellent aids in both selecting and arranging anterior teeth. A photograph of a patient in which the natural anterior teeth are visible is a great help in the selection of the tooth size and the anatomical characteristics of the teeth, and in providing information for realistic modifications of artificial teeth. Furthermore, an existing or immediate denture can provide information from the natural dentition and informs the clinician about patient tolerances and preferences.

Considering that patient racial and ethnic diversity has increased in the United States, the authors of the this manuscript conducted a five-year retrospective study to determine the effect of age, gender and ethnicity on the selection of tooth shade selection using varying mold guides among a racially diverse population within an academic (dental school) environment [13,14].

Methods

Study population

This retrospective investigation qualified for Institutional Review Board exempt status according to the Code of Federal Regulations, Department of Health and Human Services and Protection of Human Subjects 45 CFR 46.101(b). The data sample included edentulous

patients treated with maxillary complete dentures in the University of Texas School of Dentistry at Houston over a five-year period. A computer program was written to acquire the list of patients treated with American Dental Association D5110 procedure code for a maxillary complete denture from the database. Other data resources included Electronic Health Record and paper copies of the tooth prescription forms. Demographic information of all patients including age, gender and ethnicity was collected and a record review performed to confirm the information on the tooth prescription forms. Tooth selection information was retrieved from the patient notes entered by the provider. No interaction occurred with study subjects directly, through phone call or by electronic means at any stage of the study.

Data collection

It is also worth noting that the providers of the treatment for this study were not calibrated and included third and final year pre-doctoral students, Advanced Education in General Dentistry residents, Graduate Prosthodontics residents and faculty at the University of Texas School of Dentistry at Houston. It was not possible to separate this knowledge from the providers as they selected denture teeth for their clinical patients or to determine if selections were based on preconceived notions based on the tenets of Fisher and Frush [6-9]. However, the foundational education of almost all providers does include some discussion of dentogenics (Fisher and Frush) concerning the selection of denture teeth based on sex, personality and age.

A Microsoft Excel spreadsheet was used to store collected data. A serial number was assigned for each subject in order to maintain patient confidentiality and to avoid data duplication.

Tooth mold types

Two brands of molds were available for selection: Type 1, Trubyte® Interpenetrating Polymer Network (IPN) Portrait mold and Type 2, BlueLine® teeth by Ivoclar Vivodent.US. A mold conversion chart provided by the manufacturer (Ivoclar Vivodent.US) was used to convert Type 2 molds to the Type 1 category, for easy comparison. For example, A13 of the BlueLine® anterior mold is 13E in the Trubyte® IPN system. The IPN mold has three characters (e.g. 21X). The first character indicates face form such as square, square tapering, square ovoid, tapering, tapering ovoid, ovoid and square tapering ovoid and is denoted by number 1 to 7 respectively. The second number is related to the facial contour and length of the teeth. In the present study, the only contours of the teeth that were evaluated were the straight and curved contours, designated by number 1 and 2 respectively. The third character represents the intercanine width, denoted by a letter B-J. A numerical value of 1 - 8 was substituted for the letter B-J to create an ordinal value to simplify the analysis, as the width increased from B-J.

Tooth shade determination

Each mold type has different shade guides available. Portrait IPN has 27 different shades available and in the Type 2 category, there are three different shade guides available. Preliminary analysis of the data revealed the use of multiple systems with Vita Classic shade guide the most commonly used. Using the Trubyte® shade conversion chart all the shades were converted to the Vita Classic® system.

Following shade conversion, 23 different shades were used by the providers. For further analysis, all 23 shades were arranged in descending order of value (lighter to darker) and then categorized into four groups:

1. 010, 030, BL2, BL3, PW2, PW4, PW7 (very light)
2. B1, A1, B2, D2, A2, C1, C2 (light)
3. D4, A3, D3, A3.5, B3 (medium)
4. B4, C3, A4, C4 (dark).

Further reduction of the number of shades was needed to provide a more effective analysis. The shades in Category 2 had seven shades arranged in decreasing order of value (lighter to darker within the light category) which were selected for 862 patients; this was a sufficiently large sample to be used for further analysis.

Additional variables

Further variables such as existing denture (ED) were included if the patient had a denture previously and new dentures were being fabricated. A notation was made if the same mold was repeated (denoted as 1); or not repeated (denoted as 0). Immediate denture (ID) was recorded if the patient had an existing immediate denture. If the same mold was repeated, it was noted as 1; if not 0. Mandibular denture (MD) was noted if a mandibular denture was fabricated concurrently, (denoted as 1); or if not (denoted as 0).

Data analysis

Cross tabulations of independent variables with dependent variables were constructed Chi-square analysis was used to assess the effect on age group, gender, and ethnicity on contour and tooth form. Kruskal-Wallis tests and Mann-Whitney ‘U’ tests for pairwise comparisons within age group and ethnicity were used to assess the ordinal outcomes of shade and width.

Results

Frequency distribution for demographics variables

All patients (1265) treated with a maxillary complete denture from June 2008 to May of 2013 were included in the study. The sample had an equal gender distribution, as 603 (47.7%) of the patients were males and 662 (52.3%) were females. Data for race/ethnic status was available for only 1068 patients in the EHR. Using 1068 as the denominator for the percentages, Caucasians (542) constituted 42.8%, African American patients (291) were 23.0% and Hispanics (159) were 12.6%. Additionally, there were a cohort 76 (7.1%) miscellaneous subjects, which included Asians, Native Americans and Alaskans. These individuals, due to their heterogeneity and small sample size, were statistically analyzed on a limited basis.

Age information was available for 1093 patients, 901 (82.5%) of whom were above 50 years of age with 616 (56.4%) above 60 years of age and 305 (27.9%) above 70 years of age.

Shade information for 1,076 patients was available in the EHR. One hundred and eighty nine did not have reported data. Eight hundred sixty two (68%) patients were included in the Shade Category 2, which was the only category further analyzed (Table 1). The sample size was too small in the other categories for further analyses. One hundred fifty two (12.0%) of the patients were included in Category 3. The bleach shades (Category 1) were used for only 24 (2%) of the fabricated dentures.

Shade	Frequency	%
V Light	24	1.9
Light	862	68.1
Medium	152	12
Dark	38	3
Total	1076	85.1
Not Reported	189	14.9
Grand total	1265	100

Table 1: Frequency table for shade categories.

Tooth mold information was available for 910 patients (Table 2). The most commonly used tooth form was the Square tapering tooth form; it was used in 335 (26.5%) cases. Square and square tapering tooth forms constituted 54.7% of the patients. All four types of ovoid were used for only 21.6% patients, so this seemed to be the least preferred form.

Tooth Form	Frequency	%
SQ	215	17
SQ-TA	335	26.5
SQ-OV	72	5.7
TA	163	12.9
TA-OV	52	4.1
OV	33	2.6
SQ-TA-OV	40	3.2
Not reported	355	28.1
Total	1265	100
SQ = Square, TA = Tapered, OV = Ovoid		

Table 2: Frequency table for tooth form.

Of the 910 patients for whom mold information was available, 756 (83.2%) had straight contour facial surfaces selected and the remaining patients (153; 16.8%) had curved facial contours. The most common width selected was “X” which is in the range of 49mm to 51 for width of six maxillary anterior teeth measured on a curve (Table 3).

Length (mm)	Frequency	%	Valid %	Cumulative %
< 44	25	2	2.7	2.7
44 - 45.5	83	6.6	9.1	11.9
45.6 - 48	133	10.5	14.6	26.5
48.1 - 49	184	14.5	20.2	46.7
49.1 - 51.5	218	17.2	24	70.7
51.6 - 54	180	14.2	19.8	90.4
54.1 - 56	78	6.2	8.6	99
> 56	9	0.7	1	100
Total	910	71.9	100	
Not reported	355	28.1		
Grand Total	1265	100		

Table 3: Frequency distributions for tooth width.

Gender versus tooth form

The Square Tapering tooth form was the most commonly selected form for both genders and included 37.9% of females and 35.2% of males (Table 4). Square and square tapering forms constituted 66% of teeth selected for males but only 56% of the teeth selected for females. Ovoid forms constituted only 11.1% of teeth selected for males but 30.1% of the teeth selected for females (Table 4). The Pearson chi square test showed a significant difference between gender and tooth form ($X^2 = 65.14$; $p < .001$).

Gender versus tooth contour

The fact that 82.3% of females and 84.2% of males had straight contoured teeth selected for their dentures demonstrated that most patients had straight profiles and that there was no significant difference between the contours of the teeth selected for males and females.

Gender	n/%	SQ	SQ-TA	SQ-OV	TA	TA-OV	OV	SQ-TA-OV	Total
Women	n	91	191	57	70	42	26	27	504
	%	18.1	37.9	11.3	13.9	8.3	5.2	5.4	100
Men	n	124	144	15	93	10	7	13	406
	%	30.5	35.5	3.7	22.9	2.5	1.7	3.2	100
Total	N	215	335	72	163	52	33	40	910
	%	23.6	36.8	7.9	17.9	5.7	3.6	4.4	100

Note 1: SQ = Square, TA = Tapered, OV = Ovoid.
 Note 2: % = Within Group Percentage.

Table 4: Cross tabulation of gender and tooth form.

Gender versus tooth shade and width

Shade Category 2 had seven different shades ranked 1 to 7 arranged in decreasing order of value. Inter-canine widths were ranked from 1 to 7 in ascending order of width.

Four hundred fifty seven female and 404 male patients had a Category 2 shade selected. With a higher mean rank of 459.95 (p < 0.001) for the males suggests that male patients had significantly darker teeth selected than female patients did. Similarly, higher mean rank of 551.44 (p < 0.001) suggests that male patients had significantly wider teeth selected than female patients did.

Ethnicity versus tooth form

The square tapering tooth form was the most common form selected for patients of all ethnicities. Forty-two percent of the African Americans had square tapered teeth selected, which was highest among all races. Ovoid forms were the least preferred among all ethnicities (Table 5). Pearson chi square test values suggest no significant association between tooth form and ethnicity.

Race	n/%	SQ	SQ-TA	SQ-OV	TA	TA-OV	OV	SQ-TA-OV	Total
AI	n	4	7	4	8	0	0	0	23
	%	17.4	30.4	17.4	34.8	0	0	0	100
AS	n	10	10	4	5	4	2	3	38
	%	26.3	26.3	10.5	13.2	10.5	5.3	7.9	100
AA	n	58	105	17	34	12	10	16	252
	%	23	41.7	6.7	13.5	4.8	4	6.3	100
HSP	n	31	44	17	20	11	4	7	134
	%	23.1	32.8	12.7	14.9	8.2	3	5.2	100
CAU	n	108	162	29	92	23	15	14	443
	%	24.4	36.6	6.5	20.8	5.2	3.4	3.2	100
Total	n	211	328	71	159	50	31	40	890
	%	23.7	36.9	8	17.9	5.6	3.5	4.5	100

Note 1: SQ = Square, TA = Tapered, OV = Ovoid
 Note 2: A-1 = Alaskans and Native American, AS = Asian, AA = African American, HSP = Hispanic, Cau = Caucasian
 Note 3: % = Within Group Percentage

Table 5: Cross-tabulations for ethnicity and tooth form.

Ethnicity versus tooth contour

Similar to the findings of gender relation to contour, about 80% of the patients among all ethnic groups studied had straight contoured teeth selected (Table 6). Pearson chi square test results showed no significant difference among different ethnic groups.

Race	n/%	Contour 1	Contour 2	Total
A-I	n	21	2	23
	%	91.3	8.7	100
AS	n	31	7	38
	%	81.6	18.4	100
AA	n	205	46	251
	%	81.7	18.3	100
His	n	110	24	134
	%	82.1	17.9	100
Cauc	n	370	73	443
	%	83.5	16.5	100
Total	n	737	152	889
	%	82.9	17.1	100

Note 1: A-1 = Alaskan and Native American, AS = Asian, AA = African American, HSP = Hispanic, Cau = Caucasian
 Note 2: % = Within Group Percentage

Table 6: Cross tabulation for ethnicity and contour.

Ethnicity versus tooth width and shade

The p values of for shade ($X^2 = 11.15$; $p < 0.025$) and for width ($X^2 = 29.06$; $p < 0.001$) indicate that there is a significant difference between shades and widths of the teeth selected for different ethnic groups, but this test does not provide enough information about the differences between the ethnic groups. Hence, these two tooth variables were further analyzed by pairwise comparison between the ethnic groups.

Mann-Whitney “U” test was performed for pairwise comparison of Group 2 (Asian) and Group 3 (African-Americans). The lower mean rank for shade of Group 3 (129.82) compared with Group 2 (160.00) and a p value 0.021 indicate that significantly lighter shades were selected for African American patients than for the Asian patients. The difference in mean ranks of the width for African American and Asian patients was not significant ($p < 0.069$). When Group 3 (African-American) was compared with Group 4 (Hispanic), the mean rank of shade for Group 3 (165.99) was significantly lower than that of Group 4 (192.42) and $p < 0.015$. This indicates that African American patients had significantly lighter teeth selected than Hispanic patients did. The mean rank width for the African American group (212.70) was higher than the mean rank width for the Hispanic group (157.40). The p value of 0.001 indicates that the African American group had significantly wider teeth selected than the Hispanic group. Pairwise comparison of Group 3 (African American) and Group 4 (Caucasian) showed that the mean ranks for shade were 317.40 and 330.70 respectively, with a $p < 0.368$. This finding indicates that there was no significant difference between the shades of teeth selected for the African American and Caucasian groups. However, the mean ranks for width of the African American group (391.66) and the Caucasian group (323.17) with $p < 0.001$ suggest that the African American group had significantly wider teeth selected than the Caucasian group.

Age cohort and shade

Cross tabulation for age groups versus shade showed the median ranks for shade increased from 2.00 for Age Group < 30 to 5.00 for Age Group >70 suggesting that increasingly darker teeth (the lower the rank the higher the value) were selected as age increased. The Kruskal Wallis test confirmed that there was a significant ($p < 0.002$) (Table) difference in the value of shades selected between the age groups. Further analysis by pair wise comparisons between the age groups was performed based on the median ranks from a preliminary report. Higher mean rank of shade for Age Group 60 - 69 (143.21) than that for Age Group 30 - 39 (99.88) and a $p < 0.003$ suggest that darker shades (low in value) were selected for age group 60 - 69 than for Age Group 30 - 39. Comparison of Age Group 30 - 39 (mean rank - 95.58) to Age Group 50 - 59 (mean rank- 137.23) revealed significantly lighter ($p < 0.003$) teeth were selected for Age Group 30 - 39 than age group 50 - 59. When Age Group 30 - 39 was compared with Age Group > 70, the mean ranks were higher for Group > 70 (126.40) than for Group 30 - 39 (79.20). The $p < 0.001$ suggests that significantly lighter teeth were selected for Group 30 - 39 than Group > 70. Similar results were found when Group 40 - 49 was compared with Group > 70. Mean ranks for shade were 148.05 and 178.98 respectively and with a significant $p < 0.003$.

Discussion

The results of this study indicate that gender affects the form, width and the shade of the artificial teeth selected. However, no specific form can be attributed to either male or females. Both genders seem to have square forms (all types) used more frequently - as high as 69.7% of the males and 57.3% of the females. Only 11.2% of ovoid forms were used for males but about 30.1% of the teeth selected were ovoid for females. A similar observational study done in South Africa [13], comparing 100 natural dentitions and 100 dentures with similar demographic distribution, found that providers selected narrower teeth for dentures than their natural counter parts. A tapering form of denture tooth was more commonly used in males and the most common shape of natural teeth was tapering. These findings are in agreement with observations made in the current study in which 47% square tapering teeth were chosen for African Americans and narrower teeth were more commonly selected for females [13].

In a multicenter center study done by Owens and Goodacre, significant gender differences were noted with African American, Hispanic, and Caucasian males exhibiting wider central incisors than their female counterparts [14]. The current study agrees with the findings in which significantly wider teeth were selected for males when compared to females.

The finding in the current study in which females had lighter shades chosen for anterior teeth and increasingly darker shades (gradual increase in median values) selected for the older age group patients is in agreement with a study done by Gozalo-Diaz., *et al.* where age and gender were found to be statistically significant determinants in predicting the natural color of central incisors [15]. Over time, the natural central incisor becomes darker, more reddish, and more yellow. The female subjects in this study had lighter and less yellow central incisors than the men.

Subjective variability of identification of face forms among providers and the consistency with which an operator can identify a facial form or contour of the patient has never been studied. With the amount of variation in the facial features of humans, it is often hard to fit them into the seven available facial forms. The current study was influenced by the variability of over 100 providers in their selection of the shade, mold and arrangement of anterior teeth appropriate for the age and sex of the individual. Sellen surveyed fifty dentists to determine the variability of dental staff in their selection of anterior teeth appropriate for the age and sex of the individual [16]. This study concluded that there was little consistency in the selection of the shade, mold and arrangement of anterior teeth appropriate for the individual by qualified dental practitioners. The development and implementation of an aesthetic proforma to guide dental staff, dental undergraduates and patients through the process of choosing the tooth mold, shade and arrangement based on age and sex may be helpful. Dental specialists had comparatively better understanding and knowledge about the principles of tooth shade selection compared with dental students, interns and general dentists.

In the current study, only 2% of the patients treated had bleach shades selected. This is not consistent with the current trend of esthetic dentistry. A2 was the most common shade used. Lighter shades (B1 and A1) were also quite common. This is confirmed by the reference list of popular molds and shades arranged according to product sales data provided by Trubyte® system. This may represent a comfort level of providers and patients with particular shades and molds. A study done by Hirsch and Levin [17] suggested that the crucial variable in the patient's acceptance of their dentures was their involvement in the process of denture tooth selection and not the esthetic quality of the dentures they received.

An observational study of natural teeth by Jahangiri [18] found that the relationship between tooth shade value and skin color is inversely related, suggesting patients with darker skin had lighter teeth. Our results (in which there was no difference in shade selected found in Caucasian and African American populations) did not agree with the Jahangiri study of the natural dentition [18].

Individuals of an ethnic group cannot be generalized to have a singular skin color, as Hispanics include different nationalities, and skin tones. Similarly, Asian populations include different nationalities, such as people from the Indian subcontinent. Thus, the results of this study cannot be extrapolated to skin color but only ethnicity itself. Further prospective studies could be accomplished by dental specialists in a controlled environment to reduce operator variability. The study of natural dentitions of similar population groups to compare and validate the current technique of teeth selection for complete dentures, may provide additional information since the main goal of esthetics in denture treatment is to mimic nature.

Conclusion

The results of this study indicate the following conclusion:

1. Shade selection for the maxillary denture teeth is influenced by the age, gender and ethnicity of the patient.
2. The younger age group 30 - 39 had significantly lighter shades selected than patients in age group 60 - 69 did and > 70. Likewise, age group 40 - 49 had lighter shades selected than patients in age group did > 70.
3. Women selected lighter and narrower teeth than the males.
4. There was no difference in the selected tooth contour relative to age, gender or ethnicity.
5. African American and Caucasian patients selected lighter teeth as compared to other ethnic groups.
6. African Americans and Caucasians had selected significantly lighter (higher value) and wider teeth than Hispanic patients had.
7. Caucasians and African-Americans selected significantly lighter shades (higher values) than Asian cohort did.
8. Asian and African American patients had significantly wider teeth than other ethnic groups.

Conflict of Interest

The authors report no conflict of interest with respect to this manuscript.

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