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A Correlation Study of Selected Teeth by Circumferential Measurement

Steven W. Campbell

ABSTRACT

A CORRELATION STUDY OF SELECTED TEETH BY
CIRCUMFERENTIAL MEASUREMENT

by

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A correlation was established among the circumferences of teeth in a given set. This is the first step in constructing a band numbering system so that the fitting of one band (the predictor tooth) would give you the band sizes for the remaining teeth in the set. This would make possible improved efficiency for the orthodontist during band selection.

Individual sets of teeth from impressions of patients starting orthodontic treatment were measured by the use of the dentometer. The upper second bicuspid was chosen as the predictor tooth after the correlation matrices were computed.

It was concluded that 48% of the sample for males and 42.5% of the sample for females could be predicted to within one band size ($\leq$.020"). 73% (average of males and females) of the total sample size could be predicted to within two band sizes.

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Each person whose signature appears below certifies that this thesis in his opinion is adequate, in scope and quality, as a thesis for degree of Master of Science

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CHAPTER I

INTRODUCTION

Much of the time the orthodontist spends in banding is consumed in determining the correct band size for each individual tooth. Efficiency in band selection for the orthodontic patient would be greatly increased if the time spent for this procedure could be reduced and this might be done if a direct correlation between sizes of teeth in an individual could be shown. The orthodontist could then fit one band and from its size predict the band sizes of the remaining teeth.

Crown dimensions and tooth size analysis have been reported in the dental literature.[1-15] G. B. Black[1] was one of the first investigators to measure the mesiodistal diameter of the crown. His tables of mean figures are still referred to in modern dental text books.

Asymmetry in tooth size was studied by Ballard[2] using the greatest mesiodistal diameter of each tooth. He concluded that ninety percent of a sample of five hundred cases had a discrepancy of 0.25 mm or more between left and right counterparts.

In 1958 and 1962, Bolton[3,4] studied fifty-five cases with excellent occlusion. Mesiodistal diameters were recorded which compared favorably with the results of Black and Ballard. Bolton then established a ratio of the sum of the twelve mandibular teeth to the sum of the twelve maxillary teeth. A similar ratio was established relating the sum of the six mandibular anterior teeth to the sum of the six maxillary anterior teeth. Today, this ratio is used by many orthodontists as a diagnostic aid in localizing any tooth size discrepancies which may occur. Stifter[5] confirmed Bolton's analysis by doing a similar study to test its validity.

Gard, Lewis and Kerewsky[6-9] published several reports concerning size inter-relationships between buccolingual and mesiodistal tooth diameters. They concluded that higher size inter-correlations were found in teeth that were more mesial in the arch than distal. Bilateral asymmetry for both mesiodistal and buccolingual crown diameters were also measured. Their results were systematically the same for opposite sides of the arch.

Moorrees and Reed[10] established correlations of crown diameters between the deciduous and permanent dentitions of the same individuals. It was observed that the permanent first molars and deciduous second molars had the highest correlation.

Arya[11] and his associates did a study on sex differences between the mesiodistal crown diameters. The differences found were consistant with those found by other investigators. Each concluded that male teeth were consistently larger than female teeth and the deciduous dentition showed a less pronounced sex difference than the permanent dentition.

Lower mandibular crowding according to Peck and Peck[12] is significantly related to the mesiodistal and faciolingual measurement. Well-aligned mandibular incisors showed a smaller mesiodistal measurement and a larger faciolingual measurement than from a central population group which exhibited incisor crowding.

Norton and Williams[15] were the first to report using circumferential measurement for determining tooth size relationships. They hypothesized a correlation between teeth within the same arch, and suggested that the second premolar was significantly related to the lateral incisors and the canine and less significantly related to the central incisors. These results were based on simple correlations between certain teeth in the arch.

Andrews[16] has also suggested that a circumferential size relationship might exist between teeth within the same set. It is the purpose of this study to critically evaluate the results of the circumferential measurements of all teeth in the arch. If a significant statistical correlation is found, the orthodontist could benefit by having the bands categorized in sets with the same band number fitting all teeth in the arch. Thus, the fitting of one band would give the band size number of the remaining teeth; simplifying the banding procedure and leading to greater efficiency.

CHAPTER II

METHODS AND MATERIALS

Individual models of teeth were obtained from "A" Company*. These sets of teeth were from impressions of patients beginning active orthodontic treatment and are normally used for indirect banding.

The measuring device selected to measure the circumference of the teeth is referred to as a dentometer (Figure 1). It was invented by Gerald D. Tappe[1] in Marysville, California. Normally this instrument is used to measure the circumference of teeth within the oral environment. However in this study, measurements were made on models of teeth which had been separated into individual teeth before measure ment.

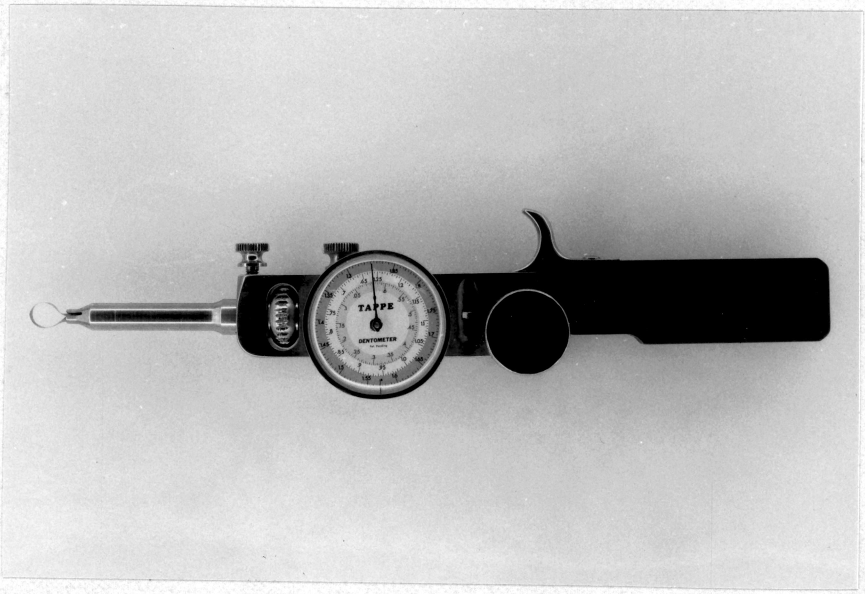

Figure 1. Dentometer used for measuring the circumference.

* "A" Company, Inc., 11436 Sorrento Valley Road, San Diego, California 92121

Measurements were made on the teeth of 61 patients (males and females being kept separately). Only sets with a full compliment of teeth which appeared normal in size and shape were measured, therefore sets containing malformed teeth (peg laterals, etc.) were excluded. Second and third molars were also excluded from the study so that twenty-four teeth were measured within each individual set. The results were computed separately for males and females with a differentiation made between maxillary and mandibular arches. In addition, each quadrant was categorized right or left.

The dentometer could be read to the nearest 0.005" and give results which were reproducible to this degree of accuracy. The dentometer was calibrated after every measurement in order to minimize errors. The band on the dentometer was positioned on the teeth approximately where band placement would occur.

Correlation coefficients were calculated for all pairs of measured teeth and a criterion was set up to rank each tooth within a given subset of teeth in terms of its usefulness as a predictor tooth.

A single predictor tooth was chosen and this tooth was then used to predict all other teeth in each set of teeth which had been measured. An analysis of the differences between measured values and predicted values was carried out.

CHAPTER III

RESULTS AND DISCUSSION

Circumferential measurements were made on sixty-one individual sets of teeth using a dentometer. The sample which was measured had values ranging from a low value of 0.450" (lower central incisor) to a high value of 1.550" (upper first molar). Tappe[17] has prepared an orthodontic band selection chart which compares several orthodontic band numbering systems according to a given size of band. This chart aids the orthodontist in interchanging bands of different brand names. The difference between sizes of orthodontic bands with adjacent numbers is usually 0.020".

Using tolerance limit tables it was determined that for a sample of size 22, there was probability .85 that 85 percent of the population of values for any given tooth would lie between the high and low values obtained in the sample. For a sample of size thirty-nine, the probability is .90 that 90% of the population values would be covered by the high and low sample values. There were 22 males and 39 females in the sample which was measured and the above tolerance table results give assurance that the prediction procedure which is outlined in this paper would be applicable to a majority of the popultion needing orthodontic treatment.

Table I summarizes the values of the mean, standard deviation, high and low values for the circumferences of teeth which were measured; the quadrants being separated between right and left, upper and lower. Values for males and females are summarized separately. These same subdivisions will also be noted in Tables II - VI.

Correlation coefficients were calculated for each pair of teeth in the given subset of teeth under consideration. For each tooth the mean R^2 of the squared correlations between that tooth and each of the remaining teeth was obtained.

$$R_i^{\,2} = \sum_{\substack{j=1 \\ i \neq j}}^{n} r_{ij}^{\,2} \, / \, (n-1)$$

where r_{ij} is the correlation coefficient for tooth i and tooth j and n is the number of teeth in the given subset. The tooth having the largest value for R^2 was chosen as the best predictor tooth for the given subset. $R_i^{\,2}$ can be interpreted to be the average proportion reduction in variance among the remaining teeth if tooth i is used as the predictor tooth. A summary of the results of this procedure is given in Table II.

All possible combinations of two teeth in a given subset were also considered and multiple correlation coefficients were calculated between each pair of teeth and each of the remaining teeth in the set. The average of the squares of these multiple correlation coefficients excluding the values for the two predictor teeth was calculated as in the single tooth case discussed above. The pair of teeth chosen as the best predictors was that pair having the largest value for this average. The results of these calculations are summarized in Table III.

The data in Tables II and III were used to make a choice of a single predictor tooth to be used to investigate the feasibility of the proposed prediction model. For males, the tooth showing highest single tooth correlation with the remaining teeth in the set appears to be the second bicuspid, while the best predictor tooth for the female subgroup would probably be the central or lateral. If the information from Table II is added to the picture, it appears that the central or lateral would pair with the second bicuspid if two predictor teeth were chosen.

The cuspid or first bicuspid also appear to be good predictors when males and females are grouped together (see Table II); however, they do not appear as predictors when pairs of teeth are considered (see Table III). Their absence in Table III is probably due to the high correlations between the cuspid and first bicuspid and the central, lateral and second bicuspid.

The remaining calculations and tables in this paper are based on the left upper second bicuspid used as a single predictor tooth to predict tooth circumference for all remaining teeth in the mouth for both males and females. The circumferences of the left upper bicuspid for the males in the sample ranged from 0.940" to 1.120", while those for females in the sample ranged from 0.850" to 1.060". The values in Tappe's[17] orthodontic band chart ranged from 0.820" to 1.190".

Table IV is a frequency table indicating which teeth have the largest difference between the predicted value (using linear regression with the left upper second bicuspid as predictor) and the actual measured tooth circumference. The frequency of occurrence of the teeth in each group was recorded to see if a particular pattern would be established for the given predictor tooth. The central for males, especially the left central, shows a greater frequency of having a greater maximum difference than the remaining teeth in the mouth. This indicates that the central does not correlate well with the upper second bicuspid for males. For females, the first molar does not correlate well with the second bicuspid. Table II showed a similar pattern.

Table V shows the percentage of the sample which is included for various maximum differences between predicted and measured values. The differences which are tabulated range from ≤ 0.010" to ≤ 0.060" in increments of 0.010". Again the percentages for males are slightly higher than for females.

Table VI gives the theoretical confidence levels corresponding to confidence intervals of lengths 0.040" and 0.080" (± 0.020" and ± 0.040" from the predicted value) for the prediction of an individual tooth circumference using the second bicuspid as the predictor tooth.

The differences between males and females were consistent with the findings of other investigators[10,11,13,14] who measured the mesiodistal crown diameters. Mean circumferences of teeth for males consistently exhibited higher values than for females.

There is also a high correlation (males r <.99, females r < .97) between right and left counterparts. Norton and Williams[15] also reported the right to left correlation. The low and high values for each tooth in the complete set of teeth were also very similar between right and left quadrants (see Table 1.) The central, lateral and cuspid (upper) showed identical low values for the right and left quadrants of males. The cuspid and first bicuspid had identical low values for females between right and left upper quadrants.

The difference between sizes of orthodontic bands with adjacent numbers is usually 0.020". A summary of the percentages of the total samples size included for maximum differences $\leq$ 0.020" between the predicted value and measured value shown in Table V is 48.5% for males and 42.5% for females. A two band size difference $\leq$ .040" contains 78% of the total sample for males and 69% for females. A three band size difference $\leq$ .060" covers 87% for males and 82% for females. Approximately 60% of the total sample size would be no more than one and a half band size from the predicted value to the measured value.

The values in Table V were calculated from the sample which was used in determining the prediction equations. Thus one would expect a certain amount of success in predicting these values. To determine the ability of the procedure to predict tooth circumferences for a patient from the general population, confidence intervals of lengths 0.040" and 0.080" were constructed for individual tooth prediction and the level of confidence was calculated for each tooth. The confidence interval was approximated by predicted value $\pm t_{1-\alpha/2}\sqrt{(S.D.)^2\,(1-r^2)}\;\sqrt{1+\frac{1}{n}+\frac{(x-\bar{x})^2}{(n-1)\,S_x^{\;2}}}$ where $t_{1-\alpha/2}$ is the t-value corresponding to the confidence level $1-\alpha$, S.D. the standard deviation of the predicted tooth from Table I, r the correlation coefficient for the second bicuspid and the tooth being predicted, $\bar{x}$ and S_x the mean and standard deviation of the second bicuspid from Table I and x is the measured value of the second bicuspid for the individual whose tooth circumferences are being predicted. The last factor in this equation is essentially equal to 1.1 and this value was used in the calculations. The equation $t_{1-\alpha/2}\sqrt{(S.D.)^2\,(1-r^2)}\;(1.1) = 0.020"$ determines a t-value such that the difference between the predicted value and the end of the confidence interval is approximately one band size (0.020"). The corresponding confidence level was then determined from tables of the t-statistic. Table VI gives the t-values and confidence levels for predicting tooth circumference of left maxillary and mandibular quadrants for males.

Note that the sample percentages given in Table V compare favorably with the theoretical confidence levels given in Table VI. The values in Table V for $\pm$ 0.020" range from 47% to 50%. The corresponding probabilities in Table VI range from 32% to 50%. The percentage for $\pm$ .040" is 78% and the probabilities on Table VI range from 58% to 84%.

TABLE I
SUMMARY OF VALUES FOR MALES, N = 22; FEMALES, N = 39

	MALES				FEMALES			
	Mean	S.D.	Low Value	High Value	Mean	S.D.	Low Value	High Value
Right Upper								
Central	.939	.053	.845	1.080	.875	.058	.760	.980
Lateral	.775	.055	.665	.880	.729	.050	.630	.840
Cuspid	.938	.054	.825	1.040	.890	.044	.810	.990
I Bi	1.006	.056	.890	1.120	.980	.066	.845	1.200
II Bi	1.018	.061	.910	1.150	.975	.054	.840	1.065
I Molar	1.421	.066	1.300	1.550	1.365	.060	1.230	1.495
Left Upper								
Central	.934	.053	.845	1.050	.875	.053	.740	.975
Lateral	.763	.055	.665	.860	.726	.047	.640	.860
Cuspid	.935	.050	.825	.990	.889	.045	.810	.990
I Bi	1.022	.069	.900	1.200	.981	.063	.845	1.200
II Bi	1.020	.052	.940	1.120	.984	.077	.850	1.060
I Molar	1.422	.061	1.310	1.545	1.367	.059	1.220	1.495
Right Lower								
Central	.593	.033	.525	.640	.553	.041	.450	.620
Lateral	.640	.037	.560	.700	.607	.042	.510	.690
Cuspid	.818	.055	.680	.935	.756	.040	.660	.855
I Bi	.921	.040	.865	1.010	.869	.046	.785	.990
II Bi	.980	.064	.895	1.150	.941	.045	.865	1.035
I Molar	1.389	.063	1.315	1.525	1.343	.070	1.195	1.500
Left Lower								
Central	.594	.037	.510	.645	.553	.041	.450	.625
Lateral	.641	.031	.590	.700	.612	.043	.500	.700
Cuspid	.825	.053	.710	.940	.763	.043	.670	.855
I Bi	.919	.048	.845	1.030	.870	.041	.785	.980
II Bi	.976	.056	.895	1.100	.942	.050	.860	1.050
I Molar	1.385	.057	1.295	1.530	1.341	.064	1.220	1.505

TABLE II

SUMMARY OF THE SINGLE TOOTH CORRELATIONS

(U=Upper, L=Lower, Lf=Left, Rt=Right)

Male	Female	Max.	Mand.	Rt.	Lf.	Central	Lateral	Cuspid	I Bi	II Bi	I Molar
X		X			X			.49		.53	.57
X			X		X				.42	.44	.38
X		X	X		X					.52U.49L	.55U
X		X		X				.54	.48	.44	
X			X	X			.40		.46	.45	
X		X	X	X				.51U	.48L	.48	
X		X		X	X			.57Rt		.52Lf	.58Lf
X			X	X	X				.50Rt.47L.49Rt		
	X	X			X	.35		.29	.38		
	X		X		X	.36	.39		.34		
	X	X	X		X	.36U	.36L		.34U		
	X	X		X		.30	.33		.32		
	X		X	X		.34	.44	.39			
	X	X	X	X		.35U	.40L	.37L			
	X	X		X	X	.41Lf			.41Rt.40Lf		
	X		X	X	X		.48Rt.45Lf	.43Rt			
X	X	X			X	.43		.42	.41		
X	X		X		X		.42	.43	.45		
X	X	X	X		X	.45U		.43L	.44L		
X	X	X		X		.37	.39	.41			
X	X		X	X			.47	.47	.47		
X	X	X	X	X			.44L	.44L	.44L		
X	X	X		X	X	.48Lf		.46Rt.45Lf			
X	X		X	X	X		.50Rt		.50Rt.50Lf		
X		X						.54		.55	.55
X			X				.42		.48	.47	
X		X	X						.52L	.53U.52L	
	X	X				.34	.32		.38		
	X		X			.36	.44	.38			
	X	X	X			.37U	.39L	.36L			
X	X	X				.42		.43	.42		
X	X		X				.47	.46	.48		
X	X	X	X			.46U		.46L	.47L		

TABLE III

SUMMARY OF THE MULTIPLE CORRELATION ANALYSIS

(U=Upper, L=Lower, Rt=Right, Lf=Left)

Male	Female	Max.	Mand.	Rt.	Lf.	Central	Lateral	Cuspid	I Bi	II Bi	I Molar	R^2*
X		X			X		U			U		.70
X			X		X	L			L			.55
X		X	X		X	U				U		.65
X		X		X			U				U	.64
X			X	X			L			L		.66
X		X	X	X			L				U	.65
X		X		X	X	LfU				RtU		.73
X			X	X	X		RtL			RtL		.67
	X	X			X	U			U			.58
	X		X		X		L			L		.58
	X	X	X		X	U				L		.53
	X	X		X		U				U		.46
	X		X	X			L			L		.63
	X	X	X	X			L			U		.56
	X	X		X	X	LfU			LfU			.62
	X		X	X	X		RtL			RtL		.67
X	X	X			X	U				U		.62
X	X		X		X	L			L			.60
X	X	X	X		X	U				L		.59
X	X	X		X		U				U		.54
X	X		X	X			L			L		.67
X	X	X	X	X			L			U		.59
X	X	X		X	X	LfU			LfU			.66
X	X		X	X	X		RtL			RtL		.70
X		X				U				U		.73
X			X			L			L			.63
X		X	X			L				U		.69
	X	X				U				U		.56
	X		X				L			L		.64
	X	X	X				L			U		.57
X	X	X				U				U		.63
X	X		X				L			L		.66
X	X	X	X			U				U		.62

* Average of squares of multiple correlation coefficients excluding values for predictor teeth.

TABLE IV

SUMMARY OF MAXIMUM DIFFERENCE BETWEEN PREDICTED
VALUE AND ACTUAL VALUE

(Numbers indicate which tooth has the highest difference using II Bi as the predictor)

				Central	Lateral	Cuspid	I Bi	II Bi	I Molar
Male	Left	Upper and Lower	Upper	7	6	3	2	0	3
			Lower	6	2	6	2	2	3
Male	Right	Upper and Lower	Upper	5	6	2	6	0	3
			Lower	3	3	3	2	5	5
Female	Left	Upper and Lower	Upper	7	9	8	3	0	13
			Lower	4	6	6	1	5	14
Female	Right	Upper and Lower	Upper	10	8	5	3	0	13
			Lower	5	6	4	3	2	19

TABLE V

PERCENTAGE OF THE SAMPLE BETWEEN PREDICTED AND MEASURED VALUES FOR VARIOUS MAXIMUM DIFFERENCES

			≤ 0.010"	≤ 0.020"	≤ 0.030"	≤ 0.040"	≤ 0.050"	≤ 0.060"
Male	Left	Upper and Lower	32%	50%	66%	78%	84%	89%
Male	Right	Upper and Lower	27%	47%	63%	78%	82%	85%
Female	Left	Upper and Lower	27%	41%	56%	70%	77%	82%
Female	Right	Upper and Lower	27%	44%	56%	68%	76%	82%

TABLE VI

THEORETICAL PROBABILITIES FOR MALE LEFT UPPER AND LOWER TEETH USING THE MAXILLARY SECOND BICUSPID AS THE PREDICTOR

MAXILLARY	r	S.D.	*t-value	Confidence level	**t-value	Confidence level
Central	.563	.054	.471	.32	.834	.59
Lateral	.590	.056	.411	.32	.823	.58
Cuspid	.727	.050	.542	.41	1.085	.72
I Bi	.819	.070	.463	.35	.926	.64
I Molar	.896	.061	.687	.50	1.374	.85
MANDIBULAR						
Central	.391	.038	.532	.40	1.064	.71
Lateral	.592	.031	.745	.54	1.490	.86
Cuspid	.683	.054	.473	.36	.946	.65
I Bi	.842	.049	.705	.52	1.410	.84
I Molar	.787	.058	.520	.40	1.040	.70

* $t_{1-\alpha/2} \sqrt{(S.D.)^2 (1-r^2)}$ (1.1) = 0.020" is essentially half the length of the confidence interval for the predicted value when the confidence coefficient is $1-\alpha$.

** Same as * except half interval length = 0.040".

CHAPTER IV

SUMMARY

The purpose of this study was to see if a statistical correlation exists between the circumference of teeth within the same set. A desirable goal would be to standardize the numbers of the bands using their circumferential correlation with each other so that the circumference of the predictor tooth or teeth would give you the size of the bands of all remaining teeth in the set, thus decreasing the number of band trial fittings. Packages of the same numbered band would properly fit all the teeth in the same set so this would increase the orthodontist's efficiency and simplify the band inventory.

The sample studied consisted of sixty-one sets of teeth. Males and females were separated in order to evaluate any significant differences between them. The right and left quadrants and maxillary and mandibular arches were also kept separate.

Correlation matrices were computed for each of the various subsets indicated above. Each tooth was correlated with the remaining teeth in the set. These results were used in establishing the predictor tooth.

The upper second bicuspid was chosen as the predictor tooth because it showed consistently high correlations with the remaining teeth in the same set for males and was one of the teeth having high multiple correlations when pairs of teeth were considered. Therefore, the results of this study were based on the upper second bicuspid as the predictor tooth.

There is a high correlation between right and left counterparts with no significant difference in correlation between the maxillary and mandibular arches. The central for males and first molar for females showed the lowest correlation with the predictor tooth. 48% of the sample for males and 42.5% of the sample for females could be predicted to within one band size ($\leq$ 0.020"). 73.5% (average of males and females) of the total sample could be predicted to within two band sizes.

The results of this study are significant enough to warrant further investigation. Further study is being done to determine whether the second bicuspid is the best predictor tooth. A possible alternative predictor tooth would be the upper central, which showed a high R^2 value for the subset of females. The upper central has the advantages of greater accessibility for measurements and earlier erruption which would make the use of this procedure possible for patients with mixed dentition.

It would be of value to determine whether the use of a pair of predictor teeth would significantly increase the accuracy of prediction. The results of this study should be validated by using the regression equations calculated on the basis of the given sample of 61 individuals to predict tooth circumferences for patients not included in the original sample.

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