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CORRELATION OF VARIOUS LINEAR AND ANGULAR MEASUREMENTS WITH DIFFERENT TYPES OF MALOCCLUSION: A MODEL ANALYSIS

Dental Science

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ABSTRACT

OBJECTIVE: The present study is a model analysis which correlates the linear and angular measurements of anterior segment with posterior segment of maxillary arch and study the intra arch discrepancy as a whole.

MATERIALS AND METHODS: Sample was divided into three groups. 51 patients belong to group 1, 70 to group 2, 55 to group 3.The study casts were analyzed for correlating the angular (ALPHAr, THETA) and linear measurement (OCI).

RESULTS: All three variables OCI, ALPHAr and THETA can be important discriminant of Class I, Class II and Class III malocclusions.A mathematical MODEL to classifythe samples in the three groups is derived.

CONCLUSION: Arch form can be predicted, whether it is constricted or expanded in anterior or posterior segment using values ALPHAr and THETA. Using the linear value OCI and angular values ALPHAr and THETA, we can classify a given case into Class I, Class II or Class III malocclusion.

KEYWORDS

Angular measurements, linear measurements, model analysis.

INTRODUCTION

Achieving proper alignment and occlusion of teeth are fundamental goals of orthodontic therapy. Man is the only example of the animal kingdom where teeth form an unbroken arch, from molar on one side to that on the opposite side. So the occlusion of man calls for a precise arrangement of the teeth. In other animals, the arches are divided into segments by diastemas, hence areas for adjustments are available. Proper diagnosis and treatment planning is necessary for successful orthodontic treatment. The major part of the diagnosis of a malocclusion is done in absence of the patient and the adjuncts which help in this, to a very great extent, are the study models and their analysis. Study models provide a three-dimensional record of the dentition. Most of the model analysis has been done on tooth-size analysis ratios. G. V. Black[1] conducted one of the first investigations to be made in the field of tooth size. Many methods have been used for easy, functional recording technique in measurement of tooth size. Ballard[2], Nance[3], Neff[4], Hixon and Oldfather[5], Moorees and Barrett[6] used basically similar methods in recording tooth dimension.

Model analyses have been either done on anterior / posterior segments of the arch. This division of the arch into segments has already been used by Cooper[7] who developed a method for assessing tooth-size disharmonies and localizing the disharmony, if it occurred in the posterior region, by dividing the region into segments and comparing maxillary to mandibular lengths. None of them have ever correlated the measurements of anterior segment with posterior segment .In this analysis we have correlated the linear and angular measurements of anterior segment with posterior segment and tried to study the intra arch discrepancy as a whole. Angular measurements form a dimension in model analysis which has been overlooked since long. Moreover there has seldom been an instance where angular measurements have been correlated with linear measurements and different form of malocclusions. This analysis will try to overcome the drawback.

OBJECTIVES:

The purpose of this study is

1. to analyse the correlation between the linear and angular measurements of anterior segment with the posterior segment in the study model and
2. to study the intra arch discrepancy as a whole.
3. This forms the baseline standard in terms of linear and angular measurements for different forms of malocclusion.

MATERIALAND METHODS

The sample size consisted of 176 patients who reported to Orthodontics department, Faculty of Dental Sciences, BHU in the duration of 3 months. It included 51 patients belonging to *group 1*, 70 patients belonging to *group 2*, 55 patients belonging to *group 3*.Age of patients in each group ranges between *14 – 16 years.* To increase accuracy in sample collection and reduce investigator bias, a panel consisting of 2 orthodontists, 1 photographer, 1 artist and a layman was formed. Groups formed were as follows:

Group 1: Class I molar relation bilaterally with straight profile and normal occlusion. This group formed the control group on whom the base line data had been calculated.

Experimental group consists of following:

Group 2: Class II div. 1 malocclusion

Group 3: Class III malocclusion

Inclusion criteria:

1. All permanent teeth present in each arch (excluding 3rd molars) and in a sufficient state of eruption to permit measurement of the mesiodistal crown dimension
2. No previous orthodontic treatment involving the deciduous, mixed, or permanent dentition in either arch
3. No large coronal restorations / RCT treated teeth that might have altered both coronal shape and size
4. No grossly decayed teeth
5. No proximal caries should be present
6. Models undamaged in areas of measurement
7. Cases with peg laterals / obvious anomalies were discarded
8. No spacing between teeth was allowed.

Exclusion criteria:

Subjects not complying with the inclusion criteria were excluded from

the sample.

Method used in study:
Malocclusion present in the collected sample was screened through cephalometric analysis. Dental stone models obtained from candidates who passed the above mentioned criteria were included in the research. Validity of Bolton's analysis was checked in all groups. The study casts were analyzed for correlating the angular and linear measurements. The casts were trimmed and kept on a flat base. Mesio distal measurements of individual tooth size were measured using digital vernier caliper with an accuracy upto 0.005mm. The measurements of each cast were done on the standardization table whose design and method of using it were discussed below.

Design of standardization table:
A standardization table was designed for taking rest of angular and linear measurements. In the construction of the table, initially various colors such as blue, green and black had been used**.** But red color showed the best contrast and hence was used in the final table design. The table had a graph sheet of 10 mm* 10mm dimension with a 360 degree protractor placed in the centre. There were 4 diagonals of the protractor. A movable arrow head made of straight length stainless steel wire was stabilized on one of these diagonal. LED lights were placed on inner side of the table for proper illumination.

Method of using standardization table:
The study casts of the patients were placed on a flat base below the inner side of table. **Figure 1** showed standardization table with a cast placed in proper position. The cast was oriented in such a manner that a imaginary line joining canine of one quadrant and mesial pit of first molar of opposite arch lies along one of the diagonals of the protractor. The movable arrow head was oriented to join the other canine tip and mesial pit of other first molar. The various angular and linear measurements were recorded as demonstrated in **Figure 2.**

Figure 1 : standardization table with a cast placed in proper position.

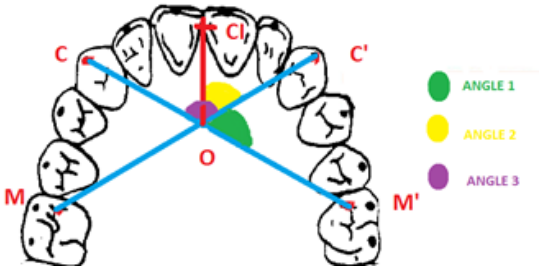


Figure 2: Various angular and linear measurements

Angle 1 = á$_r$ (right quadrant)
Angle 2 = â$_r$ (right quadrant)
Angle 3 = è

For each pair of casts, the following parameters were recorded in each arch:
1. angular measurements between the intersecting lines : angle á,â,è
2. Linear distance from the intersection point of lines CM' and C'M upto contact point of central incisors (OCI)

All models were re- measured, in a random order, in an intervening period of at least 1 week to eliminate any possibility of memory bias. Also observer bias was eradicated by being re-measured by 2 other post graduate students from Department of Orthodontics and Dentofacial Orthopedics, Faculty of Dental Sciences, Banaras Hindu University, Varanasi. The data collected, was analyzed statistically to find the correlation between the various linear and angular measurements.

RESULTS:
The first statistical analysis was carried out to rule out the significant difference between alpha angle of right (ALPHAr) and left (ALPHAl) quadrant of the maxillary arch. Paired T test was used for the analysis. Using Paired T test, it was seen that there is no significant difference between ALPHAr and ALPHAl for each group (group 1, group 2, group 3) but there is high significant correlation between ALPHAr and ALPHAl (Correlation coefficient = .987) for each group(TABLE 1).

The second analysis was done to correlate the variables ALPHAr, THETA and OCI with the three groups. One way ANOVA with Post HOC analysis was used and the results were mentioned in TABLE 2.

Results of correlation between the ratio of angles THETA / ALPHAr (denoted by RATIO) with linear measurement for each group (group 1, 2, 3)using BIVARIATE CORRELATON were depicted in TABLE 3. Group 1 is insignificant and directly correlated and group 2 and 3 are highly significant and inversely related.

TABLE 4 gives the summary of the results obtained using bivariate correlation to calculate the correlation between the variables within the three groups (group 1, 2, and 3). The results showed that the correlation between ALPHAr and THETA were highly significant and inversely related. For class II and class III, ALPHAr and OCI were highly significant and directly related and THETA and OCI were highly significant and inversely related.

MULTIPLE DISCRIMINANT ANALYSIS was done to form a model inorder to classify malocclusion into the three groups.

MODEL: $\hat{a}_0 + \hat{a}_1(OCI) + \hat{a}_2(ALPHAr) + \hat{a}_3(THETA)$

Since there are three groups so we obtain two discriminate function by stepwise method as DF-1 and DF-2. The tests of equality of means were mentioned in table 5 and group statistics were described in table 6.

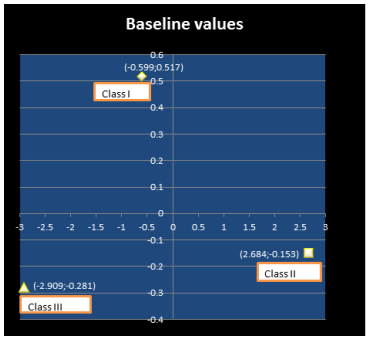
TABLE 7 revealed that both the functions are significant in predicting group membership.

TABLE 8 provided Discriminant Function Coefficients and table 9 provided functions at group centroids.

On the basis of above coefficients we can formulate our predictive model DF-1 and DF-2 as:
- DF_1= -35.634 +0.443 * OCI + 0.265 * ALPHAr + 0.102 * THETA
- DF_2 = -166.583 + 0.917 * OCI + 0.469 * ALPHAr +0.997 * THETA

DF_1 gives the value of X coordinate while DF_2 gives the value of Y coordinate.

Bolton's analysis was conducted on all three groups. In Class II and Class III malocclusion, it was seen that the cases with the mean value of angle THETA similar to that of Class I malocclusion had Bolton discrepancy which was insignificant (TABLE 10 and 11).



Graph 1: Fit of Model: To check the fit of proposed discriminant model we run the model on our data set and following results were obtained.

Table -1: Paired Samples Statistics

		Mean	N	Std. Deviation	Std. Error Mean	t-test
Pair 1	ALPHAr	55.0876	177	4.03950	0.30363	t=1.597 p=0.112
	ALPHAl	55.1667	177	4.06295	0.30539	

* P=.05

Table- 2: Correlation of variables ALPHAr, THETA and OCI within group 1 and 2, group 1 and 3, group 2 and 3.

Variables	Sig (2 tailed)	Inference	Sig (2 tailed)	Inference	Sig (2 tailed)	Inference
ALPHAr	0.000	HS	Sig. =0.044	S	0.507	I
THETA	0.000	HS	Sig. =0.011	HS	0.704	I
OCI	0.003	HS	Sig. =1.000	I	0.001	HS
** P=0.05; HS= High Significantly; S= Significant; I= Insignificant*						

Table-3: Correlation of the ratio of angles THETA / ALPHAr (denoted by RATIO) with linear measurement for each group (group 1, 2, 3).

Group	Significance	Correlation coefficient
Group 1	Insignificant (Directly correlated)	0.263
Group 2	High significance (Inversely related)	-0.603
Group 3	High significance (Inversely related)	-0.605

Table 4: Summary

Group	Variables	THETA	OCI
Class I	ALPHAr	Highly significant {Sig. (2-tailed) = 0.000}	Insignificant {Sig. (2-tailed) = 0.117}
		Inversely related (Pearson Correlation = -1.000)	Inversely related (Pearson Correlation = -0.222)
	THETA	----	Insignificant {Sig. (2-tailed) = 0.117}
			Directly related (Pearson Correlation = 0.222)
Class II	ALPHAr	Highly significant {Sig. (2-tailed) = 0.000 }	Highly significant {Sig. (2-tailed) = 0.000 }
		Inversely related (Pearson Correlation =-1.000)	Directly related (Pearson Correlation =0.597)
	THETA	----	Highly significant {Sig. (2-tailed) = 0.000 }
			Inversely related (Pearson Correlation = -0.597)
Class III	ALPHAr	Highly significant {Sig. (2-tailed) = 0.000}	Highly significant {Sig. (2-tailed) = 0.000 }
		Inversely related (Pearson Correlation = -1.000)	Directly related (Pearson Correlation =0.617)
	THETA	----	Highly significant {Sig. (2-tailed) = 0.000 }
			Inversely related (Pearson Correlation = -0.617)

* P= 0.05

Table- 5: Tests of Equality of Group Means

	Wilks' Lambda	F	df1	df2	Sig.
OCI	0.168	430.416	2	174	0.000
ALPHAr	0.180	397.653	2	174	0.000
THETA	0.177	403.275	2	174	0.000

* P= 0.05

Table-6: Group statistics

Group		Mean	Std. Deviation
Class I	OCI	17.632	1.29037
	ALPHAr	54.0196	2.90854
	THETA	1.26E+02	2.90854
Class II	OCI	21.8679	1.49795
	ALPHAr	62.6549	2.39731
	THETA	1.17E+02	2.39731
Class III	OCI	14.2135	1.56695
	ALPHAr	49.2455	2.90414
	THETA	1.31E+02	2.75112
Total	OCI	18.2689	3.54981
	ALPHAr	56	6.36686
	THETA	1.24E+02	6.28578

Table -7:

Test of Function(s)	Wilks' Lambda	Chi-square	df	Sig.
DF-1 through DF-2	0.134	348.094	6	0.000
DF-2	0.899	18.509	2	0.000

Table- 8: Discriminate Function Coefficients

	Function	
	DF-1	DF-2
OCI **(β1)**	0.443	0.917
ALPHAr **(β2)**	0.265	0.469
THETA **(β3)**	0.102	0.997
(Constant) **(β0)**	-35.634	-166.583

Table- 9: Functions at Group Centroids

Group	Function	
	DF-1	DF-2
Class-I	-0.599	0.517
Class-II	2.684	-0.153
Class-III	-2.909	-0.281

Table- 10: Classification Statistics

		Group	Predicted Group Membership			Total
			Class I	Class II	Class III	
Original	Count	Class I	45	5	1	51
		Class II	1	69	1	71
		Class III	4	0	51	55
	%	Class I	88.2	9.8	2.0	100.0
		Class II	1.4	97.2	1.4	100.0
		Class III	7.3	0.0	92.7	100.0
Cross-validateda	Count	Class I	45	5	1	51
		Class II	1	69	1	71
		Class III	5	0	50	55
	%	Class I	88.2	9.8	2.0	100.0
		Class II	1.4	97.2	1.4	100.0
		Class III	9.1	.0	90.9	100.0

Table- 11: Mean, SD, SE of mean for Class I, Class II, Class III malocclusions with respect to Bolton's analysis

		Anterior C 1	Anterior C 2	Anterior C 3
N	Valid	50	71	55
	Missing	1	1	1
Mean		77.21	72.01	80.82
Std. Error of Mean		0.07	0.53	0.36
Std. Deviation		0.47	4.47	2.68

DISCUSSION

The present era is an era of dramatic progress in the field of clinical orthodontics. This is particularly true with respect to the mechanical phase of our treatments, and of course many of the mechanical advances are dependent upon the development of new materials. Improvements are so numerous that at times it seems as though changes occur almost daily. Advances in the diagnostic phase of treatment have also been plentiful, particularly with respect to the use of cephalometric head films as a pretreatment guide. They seem to have the glamour and appeal to cause one perhaps to ignore one of the most basic of fundamentals-use of three dimensional model analysis to confirm differential diagnosis[9].

Since the inception of orthodontics, many researchers had tried to identify "ideal arch form" which will be suitable for the large part of the population. According to the investigators, the shapes of the arch form included the ellipse, parabola, and catenary curve as well as mathematic formulas such as the cubic spline, conic section, and polynomial function. These shapes proposed by different people have been questioned for their validity and stability.In the present study, it has been assumed that the maxillary arch is in form of semicircle in the

anterior region and the posterior teeth are in a straight line for premolars and molars, with the second and third molars turned toward the centre[11,12].This structure of arch form was established by Hawley C.[9] who modified the Bonwill[9]approach by combining the width of six anterior teeth to serve as the radius of a circle determined by combined width of the lower incisors and canines, with the premolars and molars aligned, with the second and third molars turned toward the centre. From this circle he constructed an equilateral triangle, with base representing the intercondylar width. The radius of the arch varied on the size of the anterior teeth, so that arch dimensions differed as a function of tooth size, but arch form was constant for all individuals. This construction is what is popular to this day as the Bonwill-Hawley arch form. The arch form used in present study is exactly similar to what was used by Weinberger BW.[14]who stated that the dental arches of normal individuals presented the anterior region in the form of semicircle and the posterior teeth in straight-line, while the malocclusion arches were represented by four distinct forms.

Further, this study divides the maxillary arch into anterior and posterior segment by joining the two corner stones of dentition: canine tip of one side of arch with the mesial molar pit [15]of other side of arch. This division of the arch into segments has already been used by Cooper[7] who developed a method for assessing tooth-size disharmonies and localizing the disharmony, if it occurred in the posterior region, by dividing the region into segments and comparing maxillary to mandibular lengths.

In this study, it was seen that there was asymmetry in mesio distal tooth size within the maxillary arch. Ballard[16] studied asymmetry in tooth size. This discrepancy in size hardly affected the angular measurement ALPHA and THETA and the linear measurement OCI (TABLE 1).

There is a strong correlation between the maxillary arch shapes and Class I, Class II and Class III malocclusions. This has formed the basis for choosing the maxillary arch as the area of concern. A similar finding was reported by Braun et al.,[17] in which he showed that the human arch form could be represented by a complex mathematical formula,known as beta function. This was calculated by entering measurements of dental landmarks on orthodontic models into a computer curve fitting program. In addition, it will be an excellent generalized equation of the maxillary and mandibular arch shapes for each of the Angle classification of occlusion. They compared maxillary arch shapes and concluded that arch depths for all Angle classifications are essentially the same. However, the Class III maxillary arch widths were greater from the lateral incisor canine area distally compared with the Class I maxillary arch, and the Class IImaxillary arch form was narrower than the Class I arch form from the lateral incisor-canine area distally. Their finding has been supported by the findings of this study where it was seen that the mean value of ALPHAr for Class III malocclusion is less than Class I malocclusion which in turn is less than Class II malocclusion (TABLE 6) indicating that the posterior segment of the arch is expanded in case of Class III malocclusion while it is constricted in case of Class II malocclusion as compared to Class I malocclusion. The arch is expanded anteriorly in case of class III malocclusion but in case of class II malocclusion, it is constricted as compared to class I malocclusion, indicated by the mean value of THETA(TABLE 6),

It was found that for Class II and Class III malocclusions, the ratio (THETA / ALPHAr)was inversely related and this relation is highly significant. This means that when the ratio of anterior and posterior angle increases (as in case of increase in anterior angle or decrease in posterior angle or both), there will be a decrease in value of anterior linear measurement. Thus, if in both Class II and Class III malocclusion, there is widening of arch transversely in anterior segment or narrowing of arch in posterior segment or both, then there will be constriction of arch anteroposteriorly. But for Class I malocclusion this relation is directly correlated but insignificantly related.

The main aspect of the present study is to find the correlation of angular measurements, ALPHAr (posterior angle of right side of maxillary arch) THETA (anterior angle of the arch) and linear measurement OCI (for anterior segment) with Class I, Class II and Class III malocclusions and to classify a given case on the basis of these measurements. For Class I malocclusion posterior angle, ALPHAr and anterior linear measurement OCI had a significant correlation while anterior angle THETA had a highly significant correlation. For Class II malocclusion also, similar findings were seen. In case of Class III malocclusion, posterior angle ALPHAr had NO significant correlation with malocclusion while anterior angle THETA and linear measurement OCI had significant correlation (TABLE 4).

It was seen that ALPHAr and THETA can be important discriminant of Class I, Class II and Class III malocclusions (TABLE 5). Using their values for a given case and placing them on the formed model, the patient can be classified into Class I, Class II and Class III malocclusion.

For Class II malocclusion, anterior segment of arch is linearly displaced in a forward direction while for Class III malocclusion it is displaced linearly in a backward direction anteroposteriorly(TABLE 6).

The model to classify malocclusion into Class I, II and III malocclusion is denoted as follows:

$Df_1 = -35.634 + 0.443 * OCI + 0.265 * ALPHAr + 0.102 * THETA$

$Df_2 = -166.583 + 0.917 * OCI + 0.469 * ALPHAr + 0.997 * THETA$

Df_1 gives the value of X coordinate while DF_2 gives the value of Y coordinate. WE can correlate the calculated values of DF_1 and DF_2 with functions at group centroid and classify into respective groups (TABLE 9).93.2% of original grouped cases are correctly classified.88.2% of original grouped cases correctly classified into Class I malocclusion 97.2% of original grouped cases correctly classified into Class II malocclusion. 92.7% of original grouped cases correctly classified into Class III malocclusion (TABLE 10).

The variation in angle THETA was due to the Bolton discrepancy existing in cases. Thus, angle THETA can be an important predictor of maxillary or mandibular anterior tooth material discrepancy (TABLE 11).

CONCLUSION

Using the present study, it is possible to predict the arch form, whether it is constricted or expanded in anterior or posterior segment. Main goal of orthodontic treatment is to preserve the original arch form for stability and so analyzing the pretreatment arch form we can customize the arch wires to maintain the pretreatment arch form at the end of treatment. The value of OCI shows if the anterior segment of the arch is too forwardly or too backwardly placed sagittally. Correlating the mid treatment values with the mean values of Class I, it can be predicted how much retraction or protraction of anterior teeth need to be done. The degree of retraction or protraction of anterior teeth mostly affects the soft tissue profile of an individual. Hence, entire treatment outcome relies on this decision. So; the value of OCI can be of great help in forming of treatment plan. Using the linear value OCI and angular values ALPHAr and THETA, it is possible to classify a given case into Class I, Class II or Class III malocclusion.

The arches in which the value of anterior angle THETA is already greater than the mean value in Class I ideal cases along with reduced value of OCI , cannot go for an extraction pattern where more amount of tooth material may be lost which in turn will result in concave profile. Exact prediction of extraction pattern is the limitation of this study.

To further improve the accuracy of this study, research can be continued with a larger sample size. A mathematical model of the human dental arch using the linear and angular measurements can be formulated as a further continuation of the study.

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