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Correlation Between Vertical Facial Patterns And Dental Arch Forms In Different Types Of Skeletal Malocclusions.

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Abstract
Introduction*: The purpose of this study was to investigate the correlation between vertical facial pattern and dental arch forms in different types of skeletal malocclusion.* ***Materials and Methods****: The study comprised of 90 pretreatment (lateral cephalogram, dental cast and photographs) aged between 11-38 years full permanent dentition without agenesis and/or tooth loss except third molar. The evaluation of the dental arch form was performed using a computer analysis (AutoCad).* ***Results****: Assessment of interexaminar reliability analysis was performed using Kappa statistic. Pearson correlation was used to analyze the dental arch form and facial vertical dimensions and the differences between the three groups were identified through an analysis of variance (ANOVA).* ***Conclusion****: As the form of dental arches is associated with the vertical growth patterns, it would be desirable to use individualized arches for each patient.*
Key Words*: Reliability, AutoCad, Photographs*

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I. Introduction

The determination of dental arch forms is an important aspect of orthodontic treatment. Arch form and arch dimensions are two important factors in case assessment, diagnosis and treatment planning.[1] The factors that affect a patient's arch form are dental perimeter, arch width, and arch depth which influence the arch form. Arch width is measured as intercanine width, interpremolar width and intermolar width. Transverse expansion can change the arch perimeter along with increase in intercanine and intermolar width.[2] The form of mandibular dental arch is considered one of the key stone during treatment and its maintenance is an important factor for the stability of orthodontic treatment. Preservation of form and dimensions of dental arches must be one of the first objectives of orthodontic problem. Arch wires are the vital components of fixed orthodontic treatment.[3] The fabrication of arch form in the canine and molar region should be planned in the proper way so as to prevent the instability of arch form.[5-6] Orthodontic manufacturer produce different arch forms as archwires and it is difficult to choose the most suitable for our patients.[7-8] Tsunori et al[9] reported that, when compared with average and long-face persons, short-face subjects had larger intermolar widths and greater buccal cortical bone thicknesses in the molar area of the mandible. Isaacson et al[10] reported that subjects with long faces showed decreased maxillary intermolar width. Clinicians often pay much attention to the inclination of the mandibular plane, because it is a major determinant of the vertical dimension of a face. Since, no study had been conducted to evaluate the correlation between vertical facial patterns and dental arch forms in different types of skeletal malocclusion.

II. Materials And Method

The present study was carried out in the department of Orthodontics and Dentofacial Orthopaedics of Himachal Dental College and Hospital, Sundernagar (H.P). The sample consisted of 90 pretreatment records (lateral cephalogram, dental cast and photographs) aged between 11-38 years and the subjects were included in the study as per the following inclusion and exclusion criteria.

INCLUSION CRITERIA

a) Full dentition except third molars.
b) Pre-treatment lateral cephalogram, dental casts and digital photographs of dental cast.
c) Individuals between 11-38 years of age.

EXCLUSION CRITERIA

a) Previous orthodontic treatment
b) Edentulous spaces
c) Malformation

MATERIALS USED FOR THE STUDY:

1. Radiographs- Lateral Cephalogram.
2. Dental casts and photographs
3. AutoCad Software

Method of tracing

The radiographic films were covered on one side with the transparent cellulose acetate sheet. The tracings of the films were done using 3H lead pencil. In the lateral cephalograms, the ANB angle was measured and divided into three groups of 30 each; skeletal Class I, Class II and Class III, according to the Steiner's[11] ANB angle (Class I- ANB 0°-4°, Class II- ANB >4°, Class III- ANB <0°). The subjects will be further divided into three subgroups according to the values of angle SN-MP according to Schudy[12]: (1) low angle (MP-SN < 27°), (2) average angle (MP-SN > 27° and < 36°), and (3) high angle (MP-SN > 36°).

DENTAL CAST ANALYSIS

Shape of dental arch measurements was performed on digital photographs of patient plaster model. All the photos were taken by a single operator based on American Board of Orthodontics instructions with and the distance from the camera lens to the dental cast was recorded 20-25cm for each cast.

The photo files were sent to AutoCad 2013 software. The evaluation of the dental arch form was performed using a computer analysis. The AutoCad software was used to draw a pentagon inscribed inside the arches as shown in figure I for maxilla and figure II for mandible.

The following dental cast landmarks were used:

1. Incisal point: The point in the midway between the incisal edges of two central incisors.
2. Canine point: The cusp tip of right and left permanent canines.
3. Mid central points of first permanent molars: by joining a line diagonally from cusp tip of mesiobuccal cusp to distopalatal cusp and a line from mesiopalatal cusp to distobuccal cusp and mid central point was made at the intersection of these two lines according to author Jucienne Salgado Ribeiro[13]

The following linear measurements were performed on maxillary and mandibular dental casts using computer analysis:

1. Intercanine width The linear distance from cusp tip of one canine to the cusp tip of the other.
2. Intermolar width The linear distance from mid central point of one permanent molar to the mid central point of other permanent molar.
3. The angular measurements were performed on maxillary (Fig. I) and mandibular dental casts (Fig. II) forming a pentagon by using computer analysis. A vertex of the pentagon was placed between the two central incisors; two other vertices lie on the cusp of the canines, and the other two are placed at the center of first molars. Internal angles of the pentagon were measured as shown in Fig I and II.

The angular measurements (Ang1, Ang2R, Ang2L) representing the anterior arch form and angular measurements (Ang3R, Ang3L), representing the posterior arch form were evaluated. The ratio between the intercanine distance and the intermolar distance was calculated. The analysis was performed on both dental arches, the upper and lower, in an independent manner. All the linear and angular measurements on the digital photographs of the plaster models and lateral cephalogram were made twice by same examiner to minimize the error of measurements. Assessment of interexaminar reliability analysis was performed using Kappa statistic. The interexaminer reliability was found to be Kappa= .80-1.00($p<0.001$) which shows perfect agreement according to Landis and Koch(1977). Pearson correlation was used to analyze the dental arch form and facial vertical dimensions in different types of malocclusions using SPSS (Statistical package for social sciences) software. The differences between the three groups were identified through an analysis of variance (ANOVA).

FIGURE 1: Shows the angular and linear measurements on the cast.

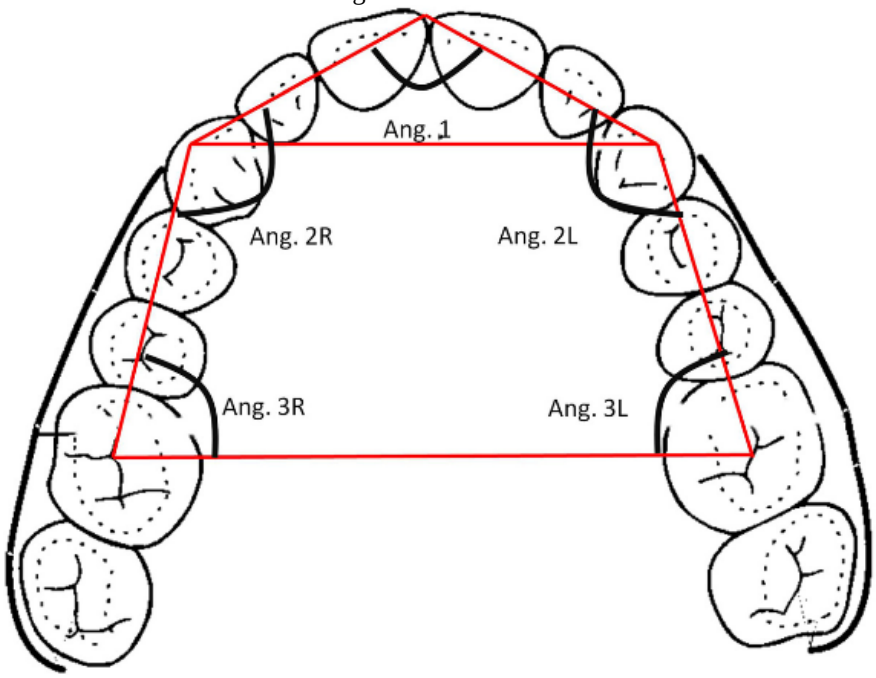


FIGURE II: Shows the angular and linear measurements using computer analysis (AutoCad software) on the maxillary arch.

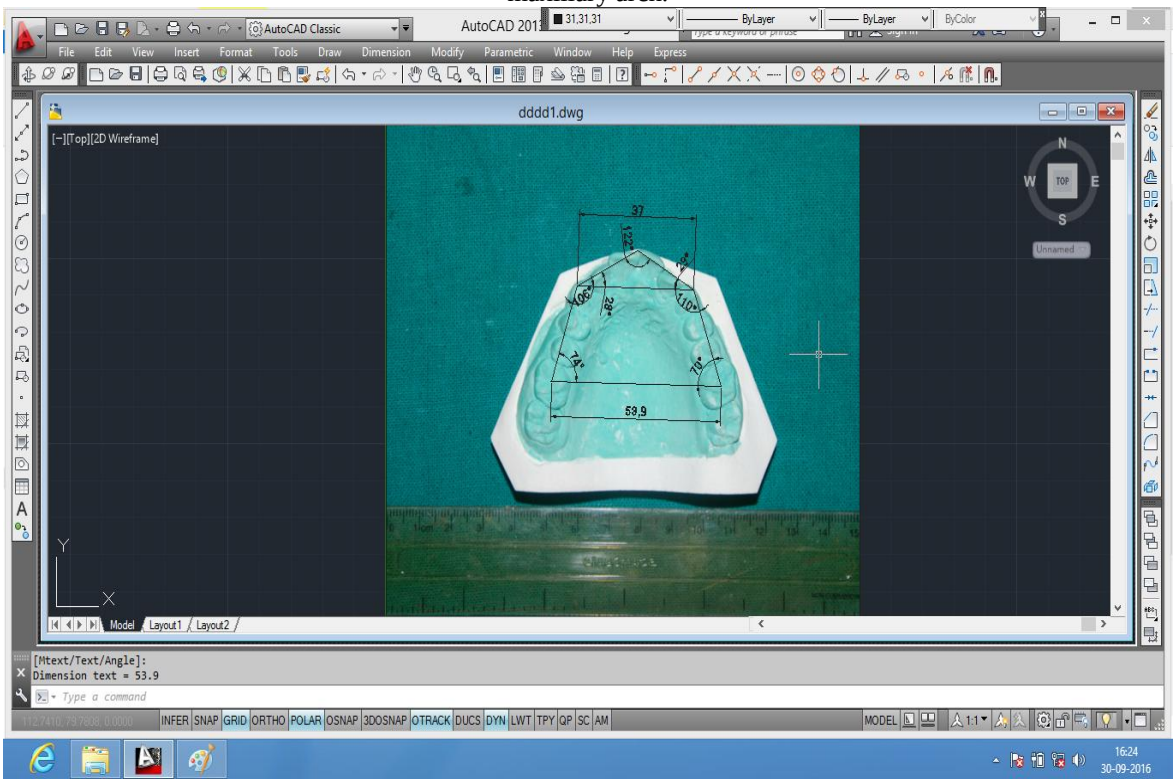


FIGURE III: Shows the angular and linear measurements using computer analysis (AutoCad software) on the mandibular arch.

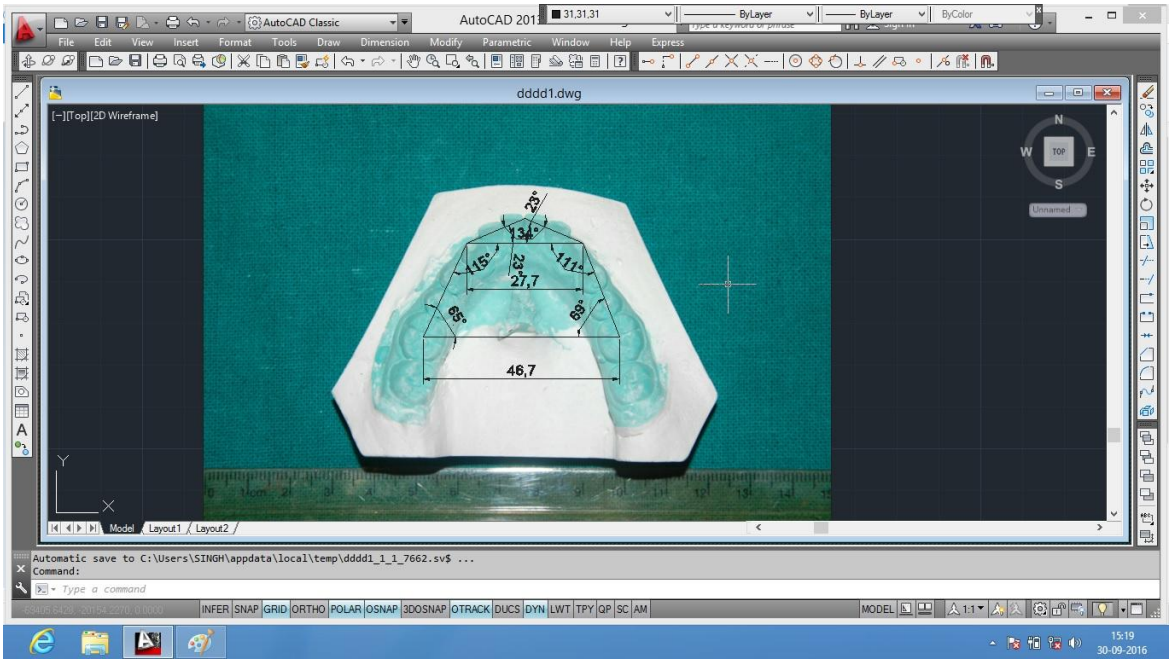


FIGURE IV. Armamentarium used for tracing.

FIGURE V: Lateral cephalogram showing ANB and SN-MP angles.

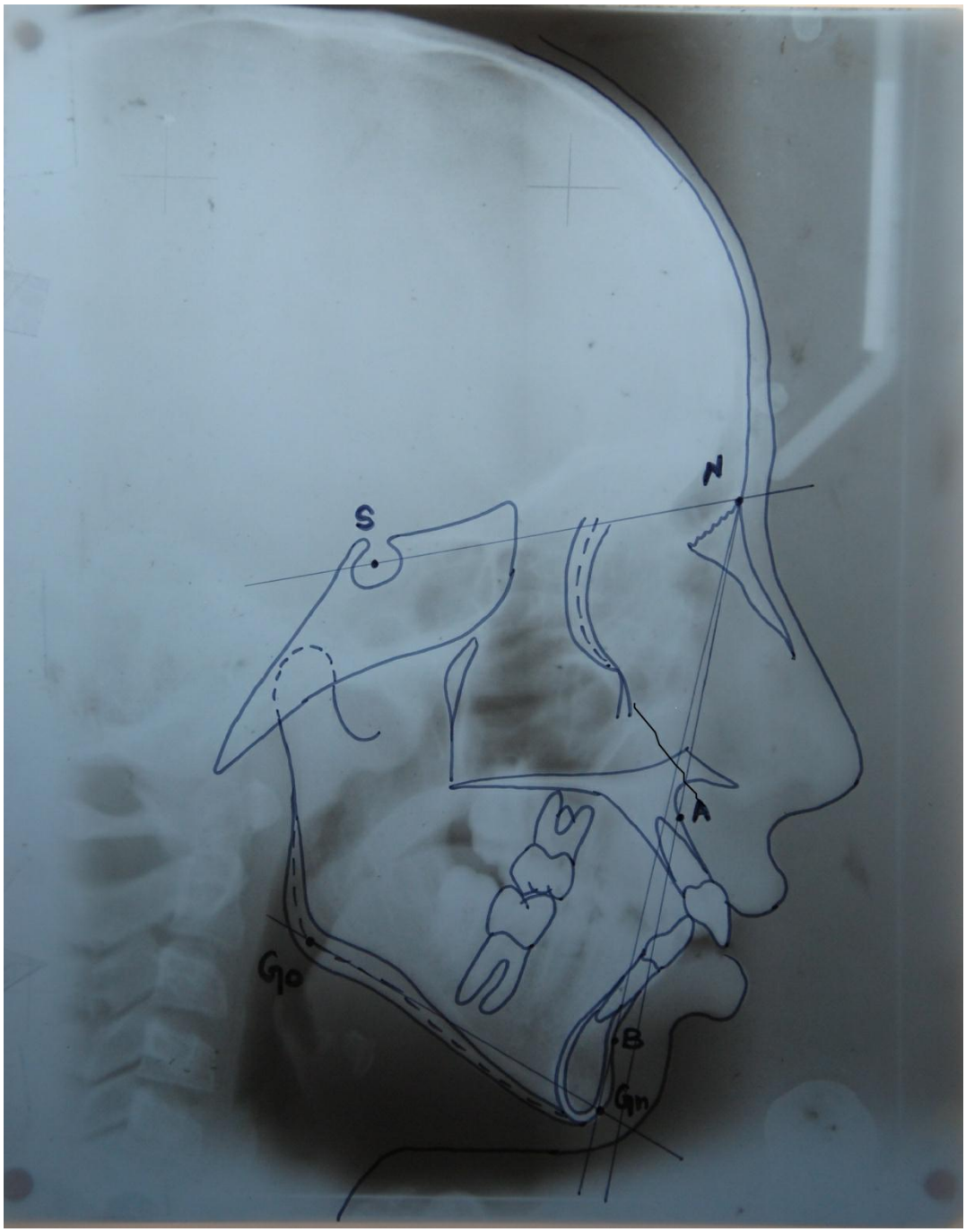


FIGURE VI: Setup for taking photograph of cast.

III. Results

The present study was conducted in the department of orthodontics and dentofacial orthopedics in Himachal Dental College, Sunder Nagar. The correlation between vertical facial pattern and dental arch form in class I, class II and class III malocclusion was investigated. The results were analyzed using ANOVA (analysis of variance). All statistical analysis was performed using the SPSS software package program.

Table I, II and graph I, II shows the mean, the standard deviation, the standard error, the minimum and maximum value of different parameters of class I malocclusion in three different groups divided based on SN-MP angle (Low, medium and high angle).

The mean value of angle Ang I in class I maloclussion in different vertical facial patterns was 132 in low angle, 128 .60 in average angle and 126.60 in high angle in maxillary arch and 138 in low angle, 132 in average angle and 128.1 in high angle in mandibular arch.
The mean value of angle Ang 2R in class I maloclussion in different vertical facial patterns was 127.9 in low angle, 130 .90 in average angle and 132.1 in high angle in maxillary arch and 128.2 in low angle, 130 .70 in average angle and 133.5 in high angle in mandibular arch.
The mean value of angle Ang 2L in class I maloclussion in different vertical facial patterns was 126.5 in low angle, 132 .70 in average angle and 134.5 in high angle in maxillary arch and 126.9 in low angle, 133 .50 in average angle and 136.4 in high angle in mandibular arch.
The mean value of angle Ang 3R in class I maloclussion in different vertical facial patterns was 75.5 in low angle, 73 .50 in average angle and 79.1 in high angle in maxillary arch and 69.80 in low angle, 72 .10 in average angle and 71.1 in high angle in mandibular arch.
The mean value of angle Ang 3L in class I maloclussion in different vertical facial patterns was 76.3 in low angle, 72 .80 in average angle and 75.5 in high angle in maxillary arch and 66.90 in low angle, 71 .20 in average angle and 69.7 in high angle in mandibular arch.
The mean value of intercanine distance in class I maloclussion in different vertical facial patterns was 39.96 in low angle, 34.83 in average angle and 37.87 in high angle in maxillary arch and 28.67 in low angle, 27.72 in average angle and 26.85 in high angle in mandibular arch.
The mean value of intermolar distance in class I maloclussion in different vertical facial patterns was 51.77 in low angle, 49.93 in average angle and 49.94 in high angle in maxillary arch and 45.56 in low angle, 44.06 in average angle and 43.81 in high angle in mandibular arch.
Table III AND IV shows the comparision of mean of different parameters of class I malocclusion in three different groups divided based on SN-MP angle (Low, medium and high angle) by one way ANOVA analysis.

Table V, VI and Graph III, IV shows the mean, the standard deviation, the standard error, the minimum and maximum value of different parameters of class II malocclusion in three different groups divided based on SN-MP angle (Low, medium and high angle).
The mean value of angle Ang I in class II maloclussion in different vertical facial patterns was 124.43 in low angle, 120 .71 in average angle and 120.66 in high angle in maxillary arch and 134.29 in low angle, 131.29 in average angle and 134.71 in high angle in mandibular arch.
The mean value of angle Ang 2R in class II maloclussion in different vertical facial patterns was 123.14 in low angle, 130 .57 in average angle and 132.57 in high angle in maxillary arch and 138.57 in low angle, 123 .43 in average angle and 132.43 in high angle in mandibular arch.
The mean value of angle Ang 2L in class II maloclussion in different vertical facial patterns was 112.14 in low angle, 128 .86 in average angle and 133.43 in high angle in maxillary arch and 138.86 in low angle, 131 .14 in average angle and 127.29 in high angle in mandibular arch.
The mean value of angle Ang 3R in class II maloclussion in different vertical facial patterns was 76 in low angle, 79.29 in average angle and 74.29 in high angle in maxillary arch and 68.29 in low angle, 72 .43 in average angle and 69.29 in high angle in mandibular arch.
The mean value of angle Ang 3L in class II maloclussion in different vertical facial patterns was 80.14 in low angle, 79 .14 in average angle and 77.86 in high angle in maxillary arch and 69.29 in low angle, 73 in average angle and 74.86 in high angle in mandibular arch.
The mean value of intercanine distance in class II maloclussion in different vertical facial patterns was 38.07 in low angle, 35.28 in average angle and 34.77 in high angle in maxillary arch and 26.02 in low angle, 27.25 in average angle and 28.41 in high angle in mandibular arch.
The mean value of intermolar distance in class II maloclussion in different vertical facial patterns was 47.72 in low angle, 44.87 in average angle and 46.67 in high angle in maxillary arch and 41.38 in low angle, 40.67 in average angle and 43.74 in high angle in mandibular arch.
Table VII AND VIII shows the comparison of mean of different parameters of class II malocclusion in three different groups divided based on SN-MP angle (Low, medium and high angle) by one way ANOVA analysis
Table IX, X and Graph V, VI shows the mean, the standard deviation, the standard error, the minimum and maximum value of different parameters of class III malocclusion in three different groups divided based on SN-MP angle (Low, medium and high angle).
The mean value of angle Ang I in class III maloclussion in different vertical facial patterns was 140.6 in low angle, 136.6 in average angle and 132.8 in high angle in maxillary arch and 140.38 in low angle, 135.88 in average angle and 134.62 in high angle in mandibular arch.
The mean value of angle Ang 2R in class III maloclussion in different vertical facial patterns was 128.60 in low angle, 129.70 in average angle and 129.90 in high angle in maxillary arch and 130.12 in low angle, 136.38 in average angle and 138.50 in high angle in mandibular arch.

The mean value of angle Ang 2L in class III maloclussion in different vertical facial patterns was 125.40in low angle, 138 .40 in average angle and 131.30 in high angle in maxillary arch and 133.38 in low angle, 133 .75 in average angle and 136.62 in high angle in mandibular arch.
The mean value of angle Ang 3R in class III maloclussion in different vertical facial patterns was 77.20 in low angle, 72.2 in average angle and 73.80 in high angle in maxillary arch and 68.62 in low angle, 64 .0 in average angle and 76.25 in high angle in mandibular arch.
The mean value of angle Ang 3L in class III maloclussion in different vertical facial patterns was 79.10 in low angle, 69.20 in average angle and 75.90 in high angle in maxillary arch and 70.12 in low angle,62.12 in average angle and 72.75 in high angle in mandibular arch.
The mean value of intercanine distance in class III maloclussion in different vertical facial patterns was 39.39 in low angle, 32.97 in average angle and 38.96 in high angle in maxillary arch and 29.69 in low angle, 27.51 in average angle and 25.03 in high angle in mandibular arch.
The mean value of intermolar distance in class III maloclussion in different vertical facial patterns was 51.51 in low angle, 49.11 in average angle and 50.07 in high angle in maxillary arch and 48.46 in low angle, 46.88 in average angle and 42.03 in high angle in mandibular arch.

Table XI AND XII shows the comparison of mean of of different parameters of class III malocclusion in three different groups divided based on SN-MP angle (Low, medium and high angle) by one way ANOVA analysis.

Table XIII shows the pearson correlation between the dental arch form and vertical facial pattern in skeletal class I, class II and class III malocclusions.
In class I malocclusion the angle that express the anterior arch form in maxillary arch Ang 1was correlated with the vertical facial pattern. The value of Ang 1 was significant with negative relationship showing r = -844 and p-value .002. The value of Ang 2R was also highly significant with positive relationship showing r = .852 and p value .002. The value of Ang 2L was also significant with possitive relationship showing r = .791 and p value .003. The value of Ang 3R and 3L were insignificant with positive relationship showing r = .691 and p value .052 and r = .586 and p value .186. The value of intercanine and intermolar distance ratio was insignificant with negative relationship showing r = -510 and p .129.
In class II malocclusion the angle that express the anterior arch form in maxillary arch Ang 1was correlated with the vertical facial pattern. The value of Ang 1 was significant with negative relationship showing r = -816 and p-value .003. The value of Ang 2R was also highly significant with positive relationship showing r = .837 and p value .003. The value of Ang 2L was also significant with positive relationship showing r = .860 and p value .001. The value of Ang 3R and 3L were insignificant with positive relationship showing r = .643 and p value .056 and r = .570 and p value .132 respectively. The value of intercanine and intermolar distance ratio was significant with negative relationship showing r = -864 and p .012.
In class III malocclusion the angle that express the anterior arch form in maxillary arch Ang 1was correlated with the vertical facial pattern. The value of Ang 1 was insignificant with negative relationship showing r = -650 and p-value .051. The value of Ang 2R was also insignificant with positive relationship showing r = .587 and p value .121. The value of Ang 2L was insignificant with positive relationship showing r = .362 and p value .304. The value of Ang 3R and 3L were insignificant with positive relationship showing r = .359 and p value .370 and r = .304 and p value .472 respectively. The value of intercanine and intermolar distance ratio was insignificant with negative relationship showing r = -441 and p .202.
In mandible when the when angular(Ang 1, Ang 2R, Ang 3R and Ang 3L) and intercanine to intermolar distance ratio values were correlated with the vertical facial patterns in class I, class II and class III malocclusion, the value of Ang 1 was significant with negative relationship showing r = -710 and p-value .023, r = -790 and p-value .003, r = -629 and p-value .013 respectively. The value of Ang 2R, Ang 2L, Ang 3R, Ang 3L and intercanine to intermolar distance ratio were statistically insignificant.

Table 1: Distribution of mean & Standard deviation of different parameters of a class I malocclusion on maxillary arch in three types of vertical facial patterns. (Low, Average & High)

Parameters	Vertical Facial Patterns	N	Mean	Std. Deviation	Std. Error	Minimum	Maximum
Ang1	Low Angle	10	132.00	6.880	2.176	122	145
	Average Angle	10	128.60	5.777	1.827	118	133
	High Angle	10	126.60	14.167	4.480	115	147
	Total	30	129.40	10.237	1.869	115	147
Ang2R	Low Angle	10	127.90	8.006	2.532	120	148
	Average Angle	10	130.90	4.954	1.567	124	137

	High Angle	10	132.10	12.360	3.909	110	137
	Total	30	129.97	9.419	1.720	110	148
Ang2L	Low Angle	10	126.50	6.096	1.928	116	139
	Average Angle	10	132.70	3.433	1.086	132	142
	High Angle	10	134.50	6.852	2.167	116	137
	Total	30	131.23	6.927	1.265	116	142
Ang3R	Low Angle	10	75.50	2.799	.885	72	80
	Average Angle	10	73.50	2.593	.820	71	77
	High Angle	10	79.10	7.125	2.253	69	88
	Total	30	76.03	5.082	.928	69	88
Ang3L	Low Angle	10	76.30	3.368	1.065	70	80
	Average Angle	10	72.80	4.131	1.306	67	77
	High Angle	10	75.50	2.718	.860	73	82
	Total	30	74.87	3.665	.669	67	82
Inter canine distance	Low Angle	10	39.960	2.9098	.9202	35.8	43.2
	Average Angle	10	34.830	1.0414	.3293	33.3	36.6
	High Angle	10	37.870	3.3059	1.0454	35.3	44.2
	Total	30	37.887	3.3754	.6163	33.3	44.2
Inter molar distance	Low Angle	10	51.770	2.4980	.7899	47.5	55.5
	Average Angle	10	49.930	2.1380	.6761	46.0	52.0
	High Angle	10	49.940	2.2292	.7049	47.9	54.3
	Total	30	50.213	2.7772	.5070	46.0	55.5
Intercanine Intermolar distance ratio	Low Angle	10	.758	.0475	.0150	.7	.8
	Average Angle	10	.713	.0343	.0109	.7	.8
	High Angle	10	.749	.0665	.0210	.7	.9
	Total	30	.740	.0532	.0097	.7	.9

Table II: Distribution of mean & Standard deviation of different parameters of a class I malocclusion on mandibular arch in three types of vertical facial patterns. (Low, Average & High)

Parameters	Vertical Facial Patterns	N	Mean	Std. Deviation	Std. Error	Minimum	Maximum
Ang1	Low Angle	10	138.30	4.572	1.446	128	145
	Average Angle	10	132.60	3.950	1.249	127	138
	High Angle	10	128.10	4.909	1.552	133	145
	Total	30	136.33	5.101	.931	127	145
Ang2R	Low Angle	10	128.20	4.849	1.533	124	140
	Average Angle	10	130.70	8.616	2.725	126	150
	High Angle	10	133.50	4.882	1.544	126	139
	Total	30	134.13	8.055	1.471	124	150
Ang2L	Low Angle	10	126.90	3.178	1.005	131	140
	Average Angle	10	133.50	1.080	.342	132	136
	High Angle	10	136.40	6.059	1.916	117	134
	Total	30	132.27	5.889	1.075	117	140
Ang3R	Low Angle	10	69.80	.789	.249	68	71
	Average Angle	10	72.10	5.744	1.816	58	76
	High Angle	10	71.40	3.893	1.231	65	75
	Total	30	71.10	4.012	.732	58	76
Ang3L	Low Angle	10	66.90	2.234	.706	65	72
	Average Angle	10	71.20	4.104	1.298	68	77
	High Angle	10	69.70	1.703	.539	68	74
	Total	30	69.27	3.311	.604	65	77
Inter canine distance	Low Angle	10	28.670	2.6949	.8522	23.6	29.4
	Average Angle	10	27.720	1.4490	.4582	25.8	29.7

	High Angle	10	26.851	2.0002	.6325	25.8	31.8
	Total	30	27.747	2.2288	.4069	23.6	31.8
Inter molar distance	Low Angle	10	45.560	2.1246	.6718	43.4	47.8
	Average Angle	10	44.060	1.9546	.6181	42.6	48.9
	High Angle	10	43.810	2.2781	.7204	40.7	48.7
	Total	30	45.810	2.1812	.3982	40.7	48.9
Intercanine Intermolar distance ratio	Low Angle	10	.784	.0352	.0111	.5	.6
	Average Angle	10	.616	.0376	.0119	.6	.7
	High Angle	10	.606	.0270	.0085	.6	.7
	Total	30	.605	.0359	.0065	.5	.7

Table III: Comparison of mean of different parameters of a class I malocclusion on maxillary arch in three types of vertical facial patterns (Low, Average & High) by one way ANOVA.

ANOVA						
		Sum of Squares	Df	Mean Square	F	Sig.
Ang1	Between Groups	506.400	2	253.200	2.699	.035*
	Within Groups	2532.800	27	93.807		
	Total	3039.200	29			
Ang2R	Between Groups	400.267	2	200.133	2.487	.102
	Within Groups	2172.700	27	80.470		
	Total	2572.967	29			
Ang2L	Between Groups	528.267	2	264.133	8.263	.042*
	Within Groups	863.100	27	31.967		
	Total	1391.367	29			
Ãng3R	Between Groups	161.067	2	80.533	3.699	.038*
	Within Groups	587.900	27	21.774		
	Total	748.967	29			
Ang3L	Between Groups	67.267	2	33.633	2.818	.077
	Within Groups	322.200	27	11.933		
	Total	389.467	29			
Inter canine distance	Between Groups	146.089	2	73.044	10.700	.000**
	Within Groups	184.326	27	6.827		
	Total	330.415	29			
Inter molar distance	Between Groups	81.649	2	40.824	7.761	.002*
	Within Groups	142.026	27	5.260		
	Total	223.675	29			
Intercanine Intermolar distance ratio	Between Groups	.011	2	.006	2.150	.136
	Within Groups	.071	27	.003		
	Total	.082	29			

p<0.05 and p<0.01 (significant); p<0.01 (highly significant); p>0.05 (not significant)

Table IV: Comparison of mean of different parameters of a class I malocclusion on mandibular arch in three types of vertical facial patterns (Low, Average & High) by one way ANOVA.

ANOVA						
		Sum of Squares	Df	Mean Square	F	Sig.
Ang1	Between Groups	509.267	2	104.633	9.180	.001*
	Within Groups	545.400	27	20.200		
	Total	1054.667	29			
Ang2R	Between Groups	787.267	2	393.633	4.713	.121
	Within Groups	1094.200	27	40.526		
	Total	1881.467	29			
Ang2L	Between Groups	274.067	2	287.033	7.948	.012

	Within Groups	431.800	27	15.993		
	Total	1005.867	29			
Ang3R	Between Groups	27.800	2	13.900	.855	.436
	Within Groups	438.900	27	16.256		
	Total	466.700	29			
Ang3L	Between Groups	95.267	2	47.633	5.778	.118
	Within Groups	222.600	27	8.244		
	Total	317.867	29			
Inter canine distance	Between Groups	23.795	2	11.897	2.671	.087
	Within Groups	120.265	27	4.454		
	Total	144.060	29			
Inter molar distance	Between Groups	16.250	2	8.125	1.802	.184
	Within Groups	121.717	27	4.508		
	Total	137.967	29			
Intercanine Intermolar distance ratio	Between Groups	.007	2	.003	3.011	.066
	Within Groups	.031	27	.001		
	Total	.037	29			

p<0.05 and p<0.01 (significant); p<0.01 (highly significant); p>0.05 (not significant)

Table V: Distribution of mean & Standard deviation of different parameters of a class II malocclusion on maxillary arch in three types of vertical facial patterns. (Low, Average & High)

Parameters	Vertical Facial Patterns	N	Mean	Std. Deviation	Std. Error	Minimum	Maximum
Ang1	Low Angle	10	124.43	9.589	3.624	127	146
	Average Angle	10	120.71	19.172	7.246	102	144
	High Angle	10	120.66	17.141	6.479	96	133
	Total	30	125.67	16.614	3.626	96	146
Ang2R	Low Angle	10	123.14	11.187	4.228	110	134
	Average Angle	10	130.57	12.660	4.785	115	146
	High Angle	10	132.57	10.706	4.046	124	148
	Total	30	128.76	11.717	2.557	110	148
Ang2L	Low Angle	10	112.14	1.676	.634	110	114
	Average Angle	10	128.86	13.031	4.925	112	141
	High Angle	10	133.43	11.058	4.180	116	147
	Total	30	124.81	13.280	2.898	110	147
Ang3R	Low Angle	10	76.00	5.831	2.204	69	84
	Average Angle	10	79.29	2.563	.969	77	82
	High Angle	10	74.29	3.147	1.190	72	81
	Total	30	76.52	4.434	.968	69	84
Ang3L	Low Angle	10	80.14	5.699	2.154	68	84
	Average Angle	10	79.14	2.116	.800	77	82
	High Angle	10	77.86	5.398	2.040	75	90
	Total	30	79.05	4.555	.994	68	90
Inter canine distance	Low Angle	10	38.071	.4786	.1809	37.6	38.7
	Average Angle	10	35.286	1.5646	.5914	32.9	37.1
	High Angle	10	34.771	3.1090	1.1751	33.3	41.8
	Total	30	36.043	2.4310	.5305	32.9	41.8
Inter molar distance	Low Angle	10	47.729	.9945	.3759	44.5	46.8
	Average Angle	10	44.871	2.2904	.8657	42.4	47.9
	High Angle	10	46.671	.8538	.3227	45.4	47.6
	Total	30	45.757	1.6299	.3557	42.4	47.9
Intercanine	Low Angle	10	.843	.0535	.0202	.8	.9

Intermolar distance ratio	Average Angle	10	.786	.0900	.0340	.7	.9
	High Angle	10	.729	.0756	.0286	.7	.9
	Total	30	.786	.0854	.0186	.7	.9

Table VI: Distribution of mean & Standard deviation of different parameters of a class II malocclusion on mandibular arch in three types of vertical facial patterns. (Low, Average & High)

Parameters	Vertical Facial Patterns	N	Mean	Std. Deviation	Std. Error	Minimum	Maximum
Ang1	Low Angle	7	134.29	1.604	.606	117	122
	Average Angle	7	131.29	14.244	5.384	113	147
	High Angle	7	134.71	9.087	3.435	120	145
	Total	21	128.43	11.505	2.511	113	147
Ang2R	Low Angle	7	138.57	2.070	.782	136	141
	Average Angle	7	123.43	3.207	1.212	119	126
	High Angle	7	132.43	5.855	2.213	126	144
	Total	21	131.48	7.434	1.622	119	144
Ang2L	Low Angle	7	138.86	.900	.340	138	140
	Average Angle	7	131.14	12.130	4.585	120	145
	High Angle	7	127.29	4.536	1.714	122	136
	Total	21	132.43	8.652	1.888	120	145
Ang3R	Low Angle	7	68.29	.756	.286	67	69
	Average Angle	7	72.43	5.028	1.901	65	80
	High Angle	7	69.29	1.496	.565	66	70
	Total	21	70.00	3.421	.746	65	80
Ang3L	Low Angle	7	69.29	.756	.286	68	70
	Average Angle	7	73.00	5.568	2.104	66	79
	High Angle	7	74.86	4.220	1.595	72	81
	Total	21	72.38	4.522	.987	66	81
Inter canine distance	Low Angle	7	26.029	.4821	.1822	25.3	26.8
	Average Angle	7	27.257	3.0843	1.1658	23.1	30.6
	High Angle	7	28.414	1.5214	.5750	25.9	30.3
	Total	21	27.233	2.1481	.4688	23.1	30.6
Inter molar distance	Low Angle	7	41.386	.8611	.3255	40.1	42.2
	Average Angle	7	40.671	2.2269	.8417	37.8	43.7
	High Angle	7	43.743	.7678	.2902	42.5	44.5
	Total	21	41.933	1.9223	.4195	37.8	44.5
Intercanine Intermolar distance ratio	Low Angle	7	.600	.0000	.0000	.6	.6
	Average Angle	7	.686	.0690	.0261	.6	.8
	High Angle	7	.629	.0488	.0184	.6	.7
	Total	21	.638	.0590	.0129	.6	.8

Table VII: Comparison of mean of different parameters of a class II malocclusion on maxillary arch in three types of vertical facial patterns (Low, Average & High) by one way ANOVA.

		Sum of Squares	df	Mean Square	F	Sig.
Ang1	Between Groups	1000.667	2	500.333	1.992	.015*
	Within Groups	4520.000	18	251.111		
	Total	5520.667	20			
Ang2R	Between Groups	345.524	2	172.762	1.296	.298
	Within Groups	2400.286	18	133.349		
	Total	2745.810	20			
Ang2L	Between Groups	1757.810	2	878.905	8.941	.142
	Within Groups	1769.429	18	98.302		
	Total	3527.238	20			
Ang3R	Between Groups	90.381	2	45.190	2.686	.095

	Within Groups	302.857	18	16.825		
	Total	393.238	20			
Ang3L	Between Groups	18.381	2	9.190	.417	.665
	Within Groups	396.571	18	22.032		
	Total	414.952	20			
Inter canine distance	Between Groups	44.134	2	22.067	5.364	.015*
	Within Groups	74.057	18	4.114		
	Total	118.191	20			
Inter molar distance	Between Groups	11.349	2	5.674	2.444	.115
	Within Groups	41.783	18	2.321		
	Total	53.131	20			
Intercanine Intermolar distance ratio	Between Groups	.046	2	.023	4.114	.034
	Within Groups	.100	18	.006		
	Total	.146	20			

p<0.05 and p<0.01 (significant); p<0.01 (highly significant); p>0.05 (not significant)

Table VIII: Comparison of mean of different parameters of a class II malocclusion on mandibular arch in three types of vertical facial patterns (Low, Average & High) by one way ANOVA.

		Sum of Squares	df	Mean Square	F	Sig.
Ang1	Between Groups	1000.667	2	500.333	1.992	.045*
	Within Groups	4520.000	18	251.111		
	Total	5520.667	20			
Ang2R	Between Groups	345.524	2	172.762	1.296	.298
	Within Groups	2400.286	18	133.349		
	Total	2745.810	20			
Ang2L	Between Groups	1757.810	2	878.905	8.941	.142
	Within Groups	1769.429	18	98.302		
	Total	3527.238	20			
Ang3R	Between Groups	90.381	2	45.190	2.686	.095
	Within Groups	302.857	18	16.825		
	Total	393.238	20			
Ang3L	Between Groups	18.381	2	9.190	.417	.665
	Within Groups	396.571	18	22.032		
	Total	414.952	20			
Inter canine distance	Between Groups	44.134	2	22.067	5.364	.015*
	Within Groups	74.057	18	4.114		
	Total	118.191	20			
Inter molar distance	Between Groups	11.349	2	5.674	2.444	.115
	Within Groups	41.783	18	2.321		
	Total	53.131	20			
Intercanine Intermolar distance ratio	Between Groups	.046	2	.023	4.114	.034
	Within Groups	.100	18	.006		
	Total	.146	20			

p<0.05 and p<0.01 (significant); p<0.01 (highly significant); p>0.05 (not significant)

Table IX: Distribution of mean & Standard deviation of different parameters of a class III malocclusion on maxillary arch in three types of vertical facial patterns. (Low, Average & High)

Parameters	Vertical Facial Patterns	N	Mean	Std. Deviation	Std. Error	Minimum	Maximum
Ang1	Low Angle	10	140.60	10.341	3.270	120	144
	Average Angle	10	136.60	7.662	2.423	119	137
	High Angle	10	132.80	13.406	4.239	109	143
	Total	30	128.33	10.393	1.898	109	144
Ang2R	Low Angle	10	128.60	7.442	2.353	119	138
	Average Angle	10	129.70	6.308	1.995	118	136
	High Angle	10	129.90	8.987	2.842	116	141
	Total	30	129.40	7.412	1.353	116	141
Ang2L	Low Angle	10	125.40	7.749	2.450	114	133
	Average Angle	10	138.40	3.688	1.166	132	144
	High Angle	10	131.30	9.190	2.906	117	143
	Total	30	131.70	8.848	1.615	114	144
Ang3R	Low Angle	10	77.20	3.824	1.209	67	80
	Average Angle	10	72.20	2.573	.814	68	75
	High Angle	10	73.80	3.293	1.041	69	80
	Total	30	74.40	3.802	.694	67	80
Ang3L	Low Angle	10	79.10	5.322	1.683	70	86
	Average Angle	10	69.20	1.874	.593	67	72
	High Angle	10	75.90	3.178	1.005	73	84
	Total	30	76.73	5.533	1.010	67	86
Inter canine distance	Low Angle	10	39.390	2.0030	.6334	36.2	41.9
	Average Angle	10	32.970	.4165	.1317	32.4	33.6
	High Angle	10	38.960	.9958	.3149	35.5	38.2
	Total	30	37.107	2.6549	.4847	32.4	41.9
Inter molar distance	Low Angle	10	51.510	1.0104	.3195	50.2	52.8
	Average Angle	10	49.110	1.2423	.3928	47.1	50.5
	High Angle	10	50.070	2.7479	.8690	46.1	52.1
	Total	30	49.930	2.1050	.3843	46.1	52.8
Intercanine Intermolar distance ratio	Low Angle	10	.745	.0289	.0091	.7	.8
	Average Angle	10	.672	.0201	.0064	.6	.7
	High Angle	10	.714	.0498	.0158	.7	.8
	Total	30	.724	.0506	.0092	.6	.8

Table X: Distribution of mean & standard deviation of different parameters of a class III malocclusion on mandibular arch in three types of vertical facial patterns. (Low, Average & High)

Parameters	Vertical Facial Patterns	N	Mean	Std. Deviation	Std. Error	Minimum	Maximum
Ang1	Low Angle	10	140.38	5.153	1.822	134	149
	Average Angle	10	135.88	12.171	4.303	113	144
	High Angle	10	134.62	10.649	3.765	128	150
	Total	30	136.96	10.084	2.058	113	150
Ang2R	Low Angle	10	130.12	1.246	.441	128	132
	Average Angle	10	136.38	2.326	.822	133	139
	High Angle	10	138.50	5.732	2.027	123	138
	Total	30	131.67	4.914	1.003	123	139
Ang2L	Low Angle	10	133.38	2.200	.778	130	136
	Average Angle	10	133.75	3.495	1.236	141	149
	High Angle	10	136.62	12.478	4.412	114	139
	Total	30	134.58	10.215	2.085	114	149

Ang3R	Low Angle	10	68.62	1.923	.680	65	71
	Average Angle	10	64.00	2.204	.779	62	69
	High Angle	10	76.25	7.126	2.520	70	87
	Total	30	69.62	6.684	1.364	62	87
Ang3L	Low Angle	10	70.12	1.642	.581	68	73
	Average Angle	10	62.12	6.512	2.302	55	73
	High Angle	10	72.75	6.798	2.403	65	82
	Total	30	68.33	7.007	1.430	55	82
Inter canine distance	Low Angle	10	29.612	1.2029	.4253	27.1	30.2
	Average Angle	10	27.512	2.4585	.8692	22.2	28.3
	High Angle	10	25.037	2.3207	.8205	26.6	32.0
	Total	30	27.721	2.5485	.5202	22.2	32.0
Inter molar distance	Low Angle	10	48.462	2.3360	.8259	46.0	52.8
	Average Angle	10	46.888	3.8331	1.3552	40.3	52.1
	High Angle	10	42.038	3.2941	1.1646	38.8	46.3
	Total	30	45.796	4.1516	.8474	38.8	52.8
Intercanine Intermolar distance ratio	Low Angle	10	.591	.0160	.0057	.6	.6
	Average Angle	10	.546	.0599	.0212	.5	.7
	High Angle	10	.693	.0548	.0194	.6	.8
	Total	30	.610	.0775	.0158	.5	.8

Table XI: Comparison of mean of different parameters of a class III malocclusion on maxillary arch in three types of vertical facial patterns (Low, Average & High) by one way ANOVA.

ANOVA						
		Sum of Squares	df	Mean Square	F	Sig.
Ang1	Between Groups	24.267	2	12.133	.105	.012*
	Within Groups	3108.400	27	115.126		
	Total	3132.667	29			
Ang2R	Between Groups	9.800	2	4.900	.084	.920
	Within Groups	1583.400	27	58.644		
	Total	1593.200	29			
Ang2L	Between Groups	847.400	2	423.700	8.040	.002*
	Within Groups	1422.900	27	52.700		
	Total	2270.300	29			
Ang3R	Between Groups	130.400	2	65.200	6.096	.007*
	Within Groups	288.800	27	10.696		
	Total	419.200	29			
Ang3L	Between Groups	510.467	2	255.233	18.260	.000**
	Within Groups	377.400	27	13.978		
	Total	887.867	29			
Inter canine distance	Between Groups	157.805	2	78.902	45.722	.000**
	Within Groups	46.594	27	1.726		
	Total	204.399	29			
Inter molar distance	Between Groups	37.464	2	18.732	5.555	.010*
	Within Groups	91.039	27	3.372		
	Total	128.503	29			
Intercanine Intermolar distance ratio	Between Groups	.041	2	.020	16.389	.000**
	Within Groups	.034	27	.001		
	Total	.074	29			

$p<0.05$ and $p<0.01$ (significant); $p<0.01$ (highly significant); $p>0.05$ (not significant)

Table XII: Comparison of mean of different parameters of a class III malocclusion on mandibular arch in three types of vertical facial patterns (Low, Average & High) by one way ANOVA.

		Sum of Squares	df	Mean Square	F	Sig.
Ang1	Between Groups	322.333	2	161.167	1.678	.001**
	Within Groups	2016.625	21	96.030		
	Total	2338.958	23			
Ang2R	Between Groups	276.583	2	138.292	10.418	.101
	Within Groups	278.750	21	13.274		
	Total	555.333	23			
Ang2L	Between Groups	1190.583	2	595.292	10.338	.100
	Within Groups	1209.250	21	57.583		
	Total	2399.833	23			
Ang3R	Between Groups	612.250	2	306.125	15.477	.102
	Within Groups	415.375	21	19.780		
	Total	1027.625	23			
Ang3L	Between Groups	490.083	2	245.042	8.050	.453
	Within Groups	639.250	21	30.440		
	Total	1129.333	23			
Inter canine distance	Between Groups	59.243	2	29.622	6.901	.005**
	Within Groups	90.136	21	4.292		
	Total	149.380	23			
Inter molar distance	Between Groups	179.423	2	89.712	8.682	.002**
	Within Groups	217.006	21	10.334		
	Total	396.430	23			
Intercanine Intermolar distance ratio	Between Groups	.090	2	.045	19.748	.000**
	Within Groups	.048	21	.002		
	Total	.138	23			

p<0.05 and p<0.01 (significant); p<0.01 (highly significant); p>0.05 (not significant)

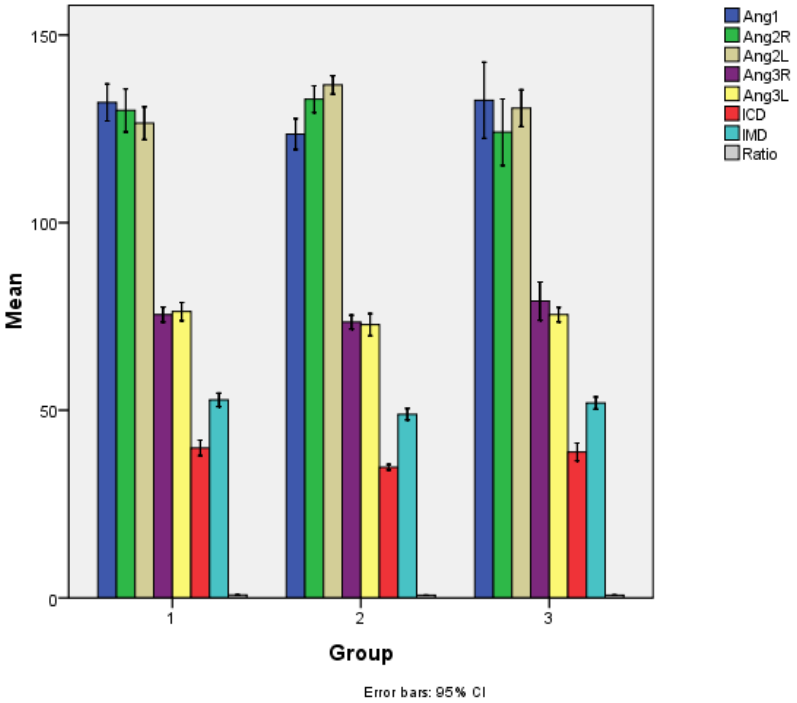
Table XIII: Showed the correlation between dental arch form and vertical facial pattern.

		MAXILLA			MANDIBLE		
SN/MP	Pearson Correlation P value N	Class I	Class II	Class III	Class I	Class II	Class III
Ang1	Pearson Correlation	-.844	-.816	-.750	-.770	-.710	-.613
	P value	.002*	.010*	.032	.019*	.045*	.145
	N	10	10	10	10	10	10
Ang2R	Pearson Correlation	.852	.837	.587	.230	-.281	.277
	P value	.002*	.003*	.121	.523	.541	.507
	N	10	10	10	10	10	10
Ang2L	Pearson Correlation	.791	.860	.362	.356	.531	.176
	P value	.019*	.003*	.304	.312	.062	.676
	N	10	10	10	10	10	10
Ang3R	Pearson Correlation	.691	.643	.359	.394	-.661	.268
	P value	.052	.056	.370	.261	.106	.521
	N	10	10	10	10	10	10
Ang3L	Pearson Correlation	.586	.570	.304	.374	.737	-.016
	P value	.186	.132	.472	.339	.059	.971
	N	10	10	10	10	10	10
Intercanine Intermolar	Pearson Correlation	-.864	-.810	-.641	-.513	-.565	.179
	P value	.012*	.019*	.202	.129	.186	. 671

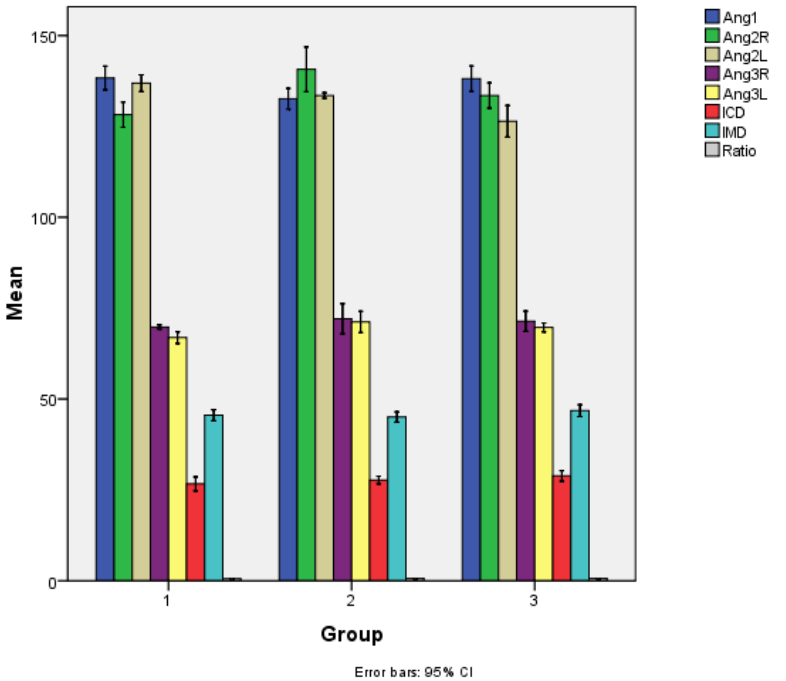
distance ratio	N	10	10	10	10	10	10

p<0.05 and p<0.01 (significant); p<0.01 (highly significant);
p>0.05 (not significant)

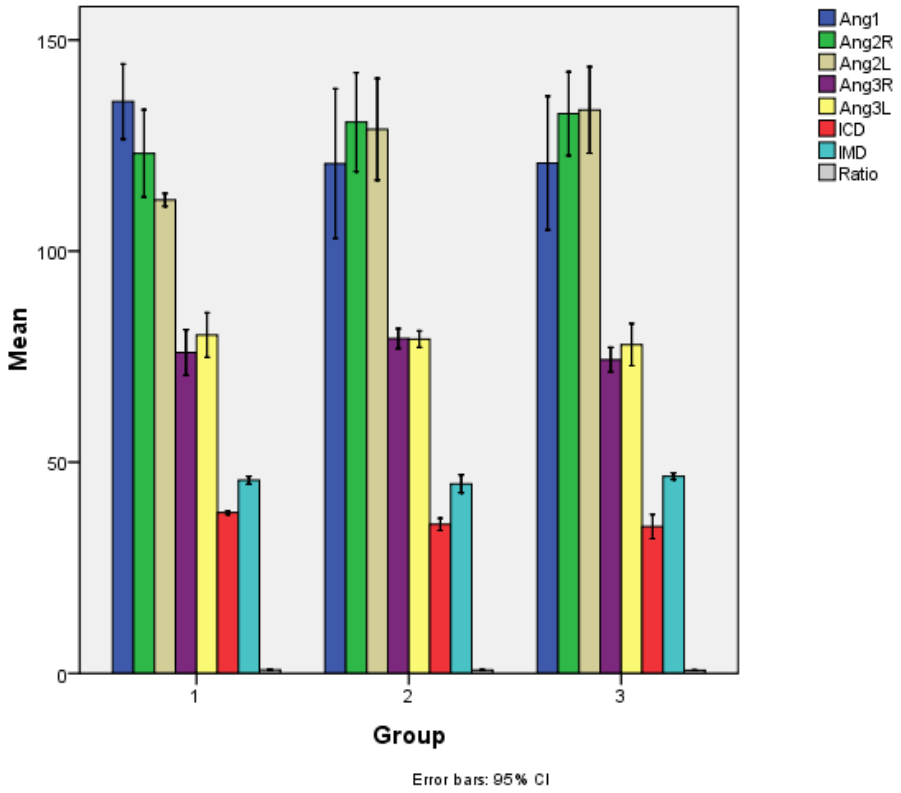
Graph I: Distribution of Mean ± 95% C.I. of different parameters in three groups of Maxilla teeth in Class 1



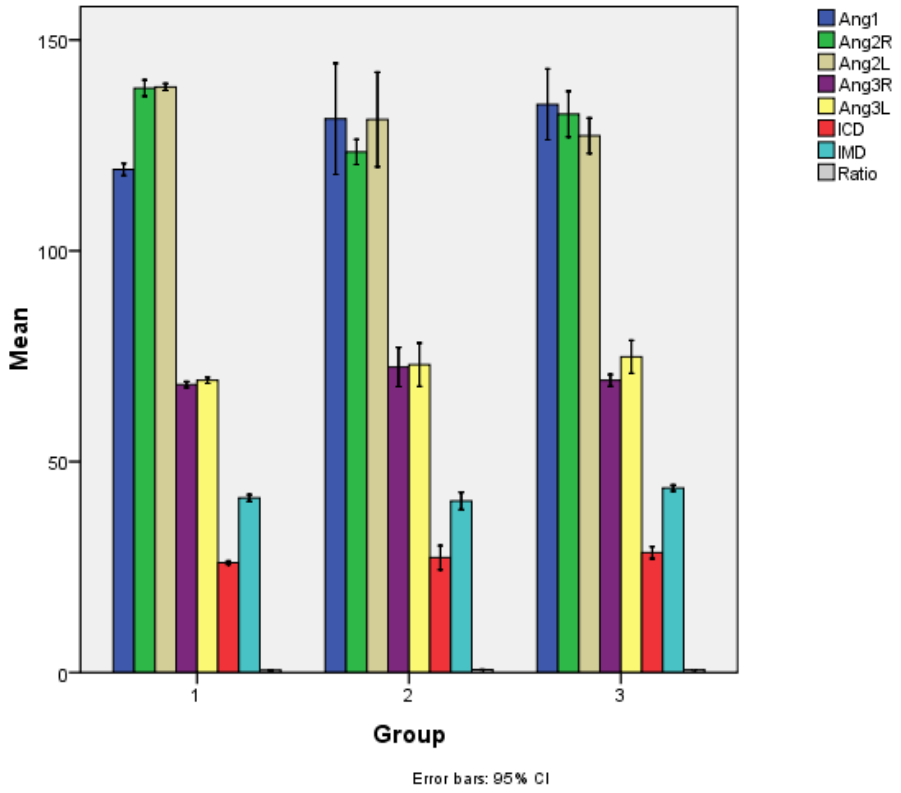
Graph 2: Distribution of Mean ± 95% C.I. of different parameters in three groups of Mandible teeth in Class 1



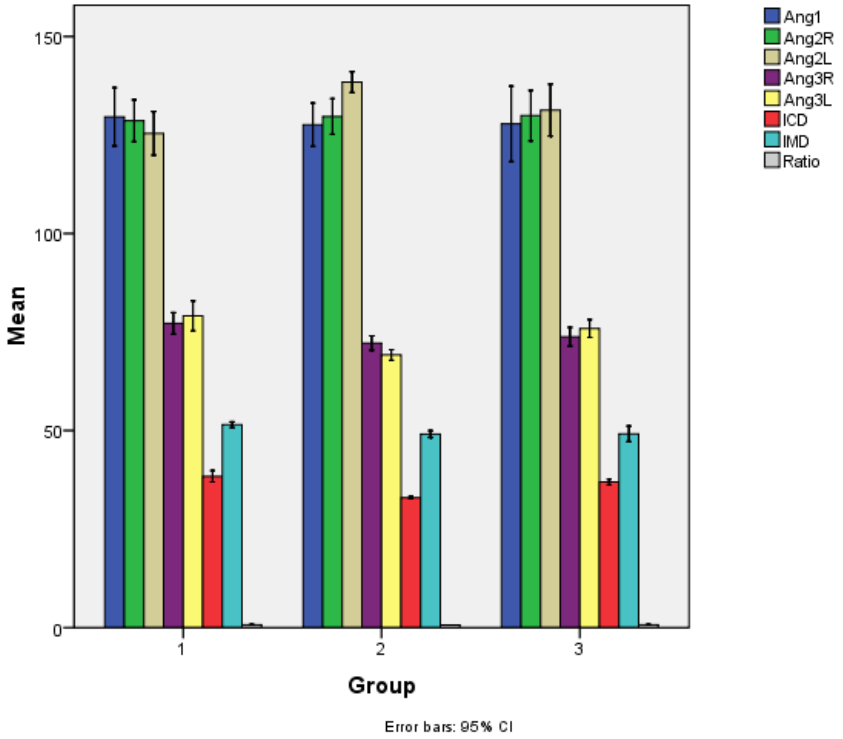
Graph 3: Distribution of Mean ± 95% C.I. of different parameters in three groups of Maxilla teeth in Class 2



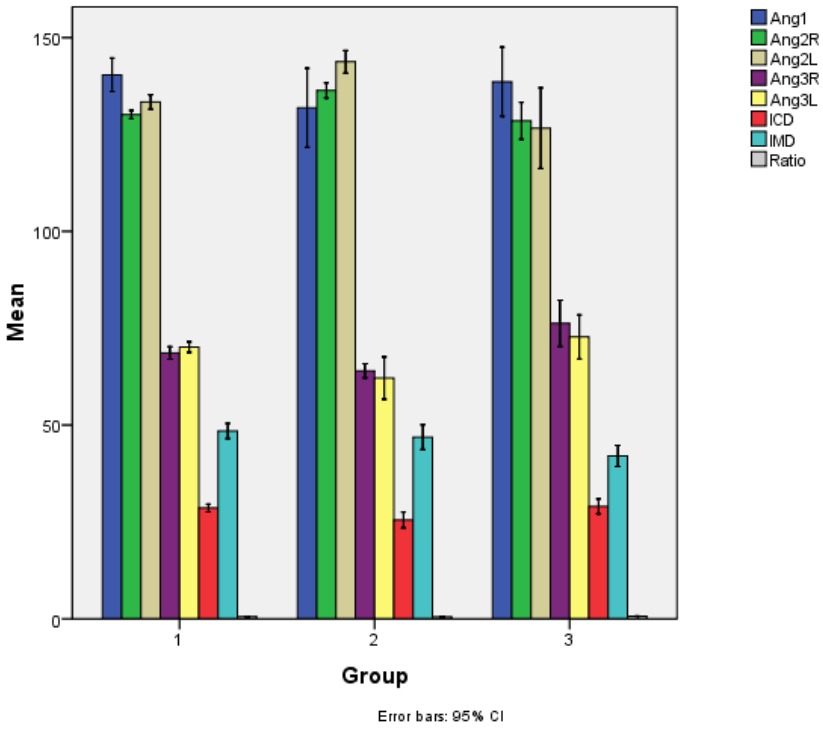
Graph 4: Distribution of Mean ± 95% C.I. of different parameters in three groups of Mandible teeth in Class 2



Graph 5: Distribution of Mean ± 95% C.I. of different parameters in three groups of Maxilla teeth in Class 3



Graph 6: Distribution of Mean ± 95% C.I. of different parameters in three groups of Mandible teeth in Class 3.



IV. Discussion

Information regarding arch dimensions in human populations is important to clinicians in most of the dental specialties including orthodontics. Arch dimensions are also modified by the various arch wires used during treatment affecting the stability of the results achieved. Stability of arch form is one of the most desirable goals of orthodontics, yet unfortunately it is the least understood goal. The size and shape of arches have a

considerable clinical implication in orthodontics specially during diagnosis and treatment planning, as it affects the space available, dental esthetics and stability of dentition. Information regarding arch dimensions in human populations is important to clinicians in most of the dental specialties including orthodontics.

Arch dimensions are also modified by the various arch wires used during treatment affecting the stability of the results achieved. Stability of arch form is one of the most desirable goals of orthodontics, yet unfortunately it is the least understood goal. The size and shape of arches have a considerable clinical implication in orthodontics specially during diagnosis and treatment planning, as it affects the space available, dental esthetics and stability of dentition.

In the present study, the shape of dental arch was measured on the digital photographs of the patient plaster model by drawing a pentagon inscribed inside the arches. The various internal angles inside the maxillary and the mandibular arches of pentagon (Ang 1, Ang 2R, Ang 2L, Ang 3R and Ang 3L) and the ratio between the intercanine and intermolar distance was calculated to evaluate the form of dental arch in different types of skeletal malocclusion.

In present study, value of Ang1in skeletal class I malocclusion was decreased from low angle to high angle **(TABLE I, TABLE II and GRAPH I, II)**. This is in accordance with the study conducted by Al-Taee and Al-Joubori.[14] When angle Ang 2R, Ang 2L, Ang 3R and Ang 3L were evaluated in skeletal class I malocclusion, it was found that the angular values were increased from low to high angle cases. This is in accordance with the study conducted by Tsunori M, Mashita M, Kasai K[15] (1998) who evaluate the comparison between average, short and long-face persons. It was concluded that short-face subjects had larger intercanine and intermolar widths and this was the reason that the value of Ang 2R, Ang 2L, Ang 3R and Ang 3L increases from low to high angle case. Also **Isaacson et al.[16]** reported that subjects with long faces showed decreased maxillary intermolar width. This is also with accordance with **Nasby et al.[17]** who noted increased mandibular molar diameters and length of maxillary and mandibular arches in subjects with reduced Sella-nasion/mandibular plane angle (SN-MP).

In present study value of Ang1in skeletal class II malocclusion was decreased from low angle to high angle cases **(TABLE V, TABLE VI and GRAPH II, GRAPH III)**. This is because of downward and backward rotation of the mandible in hyperdivergent facial patterens. This is also in accordance with the study conducted by **Kou Xi H[18]** who found that the upper and lower incisors of class II, Division 1 malocclusion were labially inclined in vertical growth pattern. When angle Ang 2R, Ang 2L, Ang 3R and Ang 3L were evaluated in skeletal class I malocclusion, it was found that the angular values were increased from low to high angle cases. This may be because as the value of angle Ang 1 decreases, the value of Ang 2R, Ang 2L, Ang 3R and Ang 3L increases shown in **figI**.

In this study when the internal angles in the maxillary arch were evaluated in different types of skeletal malocclusion, it was found that the value of Ang1was highest in class III malocclusion followed by class I and least in class II malocclusion **(TABLE IX, TABLE X and GRAPH V, GRAPH VI)**. This is because of square arch form in class III malocclusion and narrower arch form in class II malocclusion. This is in accordance with the study conducted by Ricketts et al[19] who believed that the brachyfacial hypodivergent face have relatively broader dental arches. The result of present study is in the favour of study conducted by Kageyama et al[20] who also found narrow arches in hyperdivergent facial pattern.

When angle Ang 2R, Ang 2L, Ang 3R and Ang 3L were evaluated in different types skeletal malocclusion, it was found that the angular values was highest in class III malocclusion and least in class II malocclusion. This is because as value of Ang 1 increases in class III malocclusion results in decreased value of other angles(Ang 2R, Ang 2L, Ang 3R and Ang 3L). Similarly when value of Ang 1 decreases in class II malocclusion results in increased value of other angles(Ang 2R, Ang 2L, Ang 3R and Ang 3L). Only the mandibular arch angular value Ang 1 showed a statistical significant value ($p<0.05$), while values Ang 2R, Ang 2L, Ang 3R, and Ang 3L were not significant in the lower jaw. When different types of vertical facial growth pattern was compared between different skeletal malocclusion, it was found that angular value increased from low to high angle group irrespective of skeletal malocclusion.

The intercanine and intermolar width was found to be increased in skeletal Class III malocclusion followed by class I and least in class II malocclusion. This is in accordance with the study conducted Braun et al[4] who found that class III maxillary dental arch widths were an average of 5.1 mm wider (begins in lateral incisor-canine area) and mandibular dental arch width on an average 2.1 mm greater (begins in premolar area) than the arch widths of class I malocclusion. This is in accordance with the study conducted by **Staley et al[21]** who also reported that subjects with normal occlusion had larger maxillary molar widths and intermolar widths differences than subjects with class II malocclusion. The increase in intermolar width in class III malocclusion is due to lingual tipping of the anterior teeth in class III development and flattening of the anterior area besides the lateral growth of tongue due to decrease of molar depth. Also this might be due to the anteroposterior skeletal discrepancy and the fact that the mandibular arch is advanced relative to the maxillary arch. The

possible reason for the narrower arches in class II may be due to palatal movement of maxillary posterior teeth which were needed to compensate for the increased overjet and to have good posterior interdigitation.

When different types of vertical facial growth pattern was compared between different skeletal malocclusion, it was found that the intercanine and intermolar width and ratio value decreased from low to high angle group irrespective of skeletal malocclusion. This is in accordance with the study conducted by **Ricketts et al**[18] who believed that the brachyfacial hypodivergent face have relatively broader dental arches. **Khera AK et al**[22] who also found that the maxillary intercanine width, mandibular intercanine width and first interpremolar width were higher in the hypodivergent as compared with hyperdivergent in males.

When dental arch forms were correlated with different vertical facial patterns the result analysis showed a change in upper arch shape with an intercanine diameter proportionately smaller in patients with high angles and greater in patients with low angles ($P < 0.05$) irrespective of malocclusion. There was no statistically significant difference in mandibular arch forms between the three groups with the exception of the angle value Ang. 1. The bigger the SN-MP angles were, the narrow is the form of the upper arches. Although the data from the present study showed an inverse trend between SN-MP angle and dental arch widths and it seems that the SN-MP angle might be only one of the contributing factors. The decrease of this value from low- to high-angle groups should be interpreted as the prevalence of 'V' shapes arch form in subjects with high angle and of ovoid arch forms in low angle patients. The data from this study showed an inverse relationship between MP-SN angle and it seems the MP-SN angle might be only one of the contributing factors.

The relationships between the vertical facial morphology and dental arch widths in untreated Himachali adults have an inverse relationship as in Caucasian population. Hence, irrespective of ethnicity and race of the population group, SN-MP and inter-arch widths can be used as a valuable tool in assessing the vertical and transverse craniofacial and dentoalveolar morphology. Hence, the prediction of dental arch width is generalized and can be influenced by other factors.

This highlights the importance of using individualized archwires according to pretreatment arch form and width for each patient during orthodontic treatment. Since the wide variations in patient arches cannot be met by the few preformed archwire shapes and sizes available, the concept of individualization of archwires is strongly suggested.

V. Conclusion

The conclusions drawn from the study were as follows:

1. When correlation was done between dental arch form and vertical facial pattern in different types of sagittal skeletal malocclusion, it was found to be highest in class I malocclusion followed by class II and least in class III malocclusion.
2. Inverse correlation was found between dental arch form and vertical facial pattern indicating narrower arch form in high angle cases and wider arch form in low angle cases.
3. Intercanine and intermolar distance was found to be highest in class III malocclusion and least in class II malocclusion.
4. As the form of dental arches is associated with the vertical growth patterns, it would be desirable to use individualized arches for each patient.

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