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Research Article

Correlation of Condylar Morphology and Crown Inclinations of Lower Anterior Teeth in Skeletal Class III

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ABSTRACT: The current study aimed to determine the correlation between condylar morphology in skeletal Class III patterns, as determined by cone-beam computed tomography, and the crown inclination of lower anterior teeth. **Materials and Methods:** This study examined the bilateral TMJ CBCT images of 30 subjects (17 males, 13 females) with skeletal class III, average age (18–30 years), and lower cast. The TMJ's angular and linear measurements were estimated, and variances between the groups were statistically examined. The torque and angulation device TAD was used to measure the inclination of the crowns. **Results:** Regardless of the joint reference points used for measurements, there is no correlation between the position and mutual relations of the lower anterior teeth and the temporomandibular joint's structure. **Conclusion:** The mandibular condyle height was greater in Class III malocclusion. Men had larger mandibular body sizes and wider mediolateral condyles than women did.

Keywords: Cone-beam computed tomography; Temporomandibular joint; Torque and angulation device.

INTRODUCTION

The mandible is the biggest and strongest bone in the face. It has two broad rami that rise from the posterior end of the body and a horizontally curved body that is convex forwards. Coronoid and condyloid processes are present in the rami.(1)
The temporomandibular joint (TMJ), which is said to be the most complicated articular system in the human body, is situated between the glenoid fossa of the temporal bone (the superior part) and the mandibular condyle (the inferior part). The joint has a sophisticated, dynamic, and balanced mechanism that allows it to move in many orthogonal planes.(2). The TMJ is strongly linked to the mouth, teeth, and masticatory muscles that are involved. The jaw's position and function are controlled by the oral structures in conjunction with the masticatory muscles. The TMJ and all related structures are essential for mandibular movement and the redistribution of stress brought on by tasks like speaking, chewing, and swallowing.(3)

The final dimensions of the mandibular arch and the relationship between the upper and lower arches may be related to the volume and size of the TMJ. Therefore, the condylar volume and its morphology evaluation and assessment are important.(4) Variations in the normal craniofacial development in sagittal, vertical, or transverse planes may result in different malocclusions.(5)

Edward Hartley Angle, the founder of modern orthodontics, categorized malocclusions in 1899 into Class I, II, and III based on the alignment of teeth with respect to the line of occlusion and the permanent relationship between the mandibular and maxillary molars.(6). There may occasionally be a Class I dental relationship on the Class III skeletal base as a result of dental compensation. If excessive facial height does not become the problem, instead, a hypodivergent growth pattern accentuates the Class III problem because it causes more growth rotation of the mandible in the upward and forward direction. In contrast, a vertical growth pattern alleviates the problem because it causes more rotation in the downward and backward directions. Class III issues may result from either excessive forward growth or insufficient downward growth of the mandible, as well as from deficiencies in the maxilla's forward and downward growth (7). Many angular metrics have been devised to assess discrepancies in the sagittal plane of the jaw. (8) Riedel's ANB angle, which is created by joining the SNA and SNB angles, is frequently employed to assess the anteroposterior apical base relationship.

Another technique for figuring out the true sagittal apical base relationship without using the functional occlusal plane or cranial reference planes is the beta angle, which was first proposed by Baik et al. (10), It is believed that beta angles between 27° and 35° correspond to a Class I skeletal pattern. A Class II skeletal pattern is suggested if the beta angle is more acute (less than 27°), and a Class III skeletal pattern is suggested if it is more obtuse (more than 34°) (11). Later on, Neela et al. created the YEN angle without considering any reference plane. It was formed by joining points S, M (the anterior maxilla's midpoint), and G (the center at the bottom of the symphysis) (9). Skeletal class II refers to yen angles less than 117, class III refers to yen angles greater than 123°, and class I refers to yen angles between 117 and 123°.(12). With the highest sensitivity (91.67%), it is the most precise and trustworthy metric for differentiating between the Skeletal Class I and Class II Groups (13). Once active treatment is completed, having perfect axial inclinations for every tooth is one requirement for achieving a functional occlusion. The force that an orthodontist uses to manipulate a tooth's axial inclinations and shift them into a balanced position is known as torque.

The torque and angulation device (TAD), which will remove the distortion and magnification associated with panoramic images as well as the radiation exposure in CBCT, has been selected in our study as a useful instrument to measure the labiolingual inclination of the teeth. Nevertheless, testing revealed that TAD was small and easy to use, with a repeatable ±0.1° measurement accuracy.

.(7) The best diagnostic fidelity of periapical, panoramic, cephalometric, occlusal, and TMJ radiographs can be given to the orthodontist by CBCT, an exponentially advanced procedure. It also generates left and right cephalogram views..(8)

Dolphin imaging software (Dolphin Imaging and Management Solutions, Chatsworth, California, USA) is almost regarded as the gold standard in the field and has been the subject of numerous studies testing its consistency and reliability. Remarkable repeatability and reproducibility when using Dolphin imaging software to measure both hard and soft tissues. When compared to manual tracings, dolphin imaging software has been reported to produce a high degree of agreement for cephalometric measurements. Good inter-rater reliability and good intraoperater reliability are found in almost all cephalometric parameters.(9) so the aim of the current study was to assess the relation between the condylar morphology in skeletal Class III pattern by using cone-beam computed tomography and the crown inclination of lower anterior teeth.

The study aimed to determine the amount of needed torque for indirect bracketing from the measurement of condyle dimensions. The null hypothesis is that there is no correlation between condyle dimensions and lower anterior teeth inclinations.

MATERIALS AND METHODS

The samples were taken from the Al-Noor specialized dental center in Mosul, Iraq, and the study was approved by the research ethics committee of the College of Dentistry, Mosul University, Ministry of Higher Education, Iraq. The study's reference number from the Ethics Committee was UoM.Dent.23/50.

1. Sample Selection and Inclusion Criteria

Sample Selection and Inclusion Criteria:

This study depends on retrospective cross-sectional samples of a total of 60 non-orthodontically treated patients (out of 1000 cases) who suffered from class II and class III skeletal malocclusion. The patients' ages ranged from 18-30 years old. The number of females was (27 patients) (14class II,13 class III), while the number of Males was (33 patients) (16class II, 17class III)

A	**sample**	**No. of cases 60** **No. of casts 60**
B	sex	Females 27 Males 33

2. Sample size

Sample size was determined using a single mean formula (n = (z r/d)2) for a retrospective cross-sectional study involving 60 patients. (22) with n representing the sample subjects, z = 1.96 with a 95% confidence level, r = 1.11 for the standard deviation, and d = 0.4 units for precision. After making adjustments, the value that was obtained was 30 for the sample size.

3. The inclusion criteria

Excluding the third molar, both individuals have full permanent dentition, not having had orthodontic treatment or orthognathic surgery performed in the past, not having pathologic lesions in the jaws, not being subjected to facial trauma, not suffering a history of severe distortion of the dental arches owing to a cleft lip or palate, and having high-quality study models.

4. CBCT Examination and Data Processing

Using a Carestream 8100 CBCT machine, the scanning parameters were 103 kVp, 40s, 5.0mA, a 16 x 17 cm field of view, and voxel size (150μm x 150μm}<150μm).

Anteroposterior radiographs obtained from CBCT were used for the measurements. The Dolphin 3D application was used to load all CBCT DICOM files (Dolphin Imaging, version 11).

5. Study design

The horizontal reference plane for the reconstructed images was the Frankfort horizontal (FH) plane, which was built by Orbitale on the right side and by Porion on the left. The left and right joints were assessed independently. To digitize landmarks, Dolphin Imaging Version 11.9 (Chatsworth, CA) was utilized. The TMJ's morphological assessment was carried out using both linear and angular measurements.

6. The segmentation process of the mandible:(10)

The following procedures were used to separate the mandible from each CBCT: (a) Select the facial midline in the "Orientation" module as the full-volume CBCT's midline. Verify that the left and right sides' significant ridges and cranial base structures overlap.

(b) Use the "sculpt out of shown" option in the "Sculpting tool" module to sculpt most of the cranial and maxilla structures." (Figure 1).

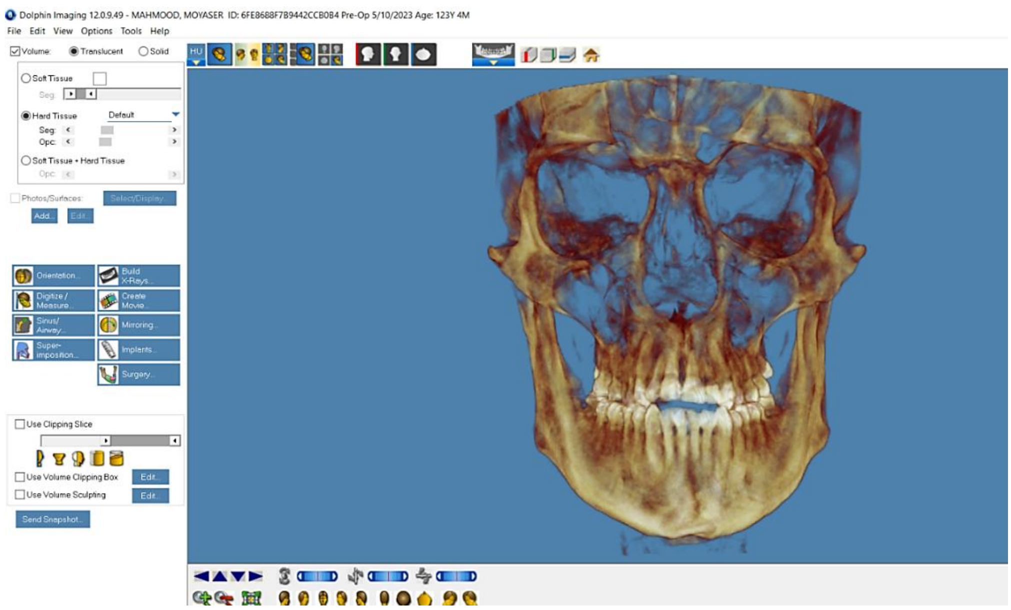


Figure (1): (choosing sculpting tool)

(c) Adjust the CBCT to the bottom view so that the edges of the condyles are visible. After sculpting the mandible's visible maxillary and cranial structures, such as the inferior border of the cervical vertebrae and the glenoid fossa (Figure 2), the mandible is prepared for "Create surface," which generates an STL file, or "Export" as DICOM files.

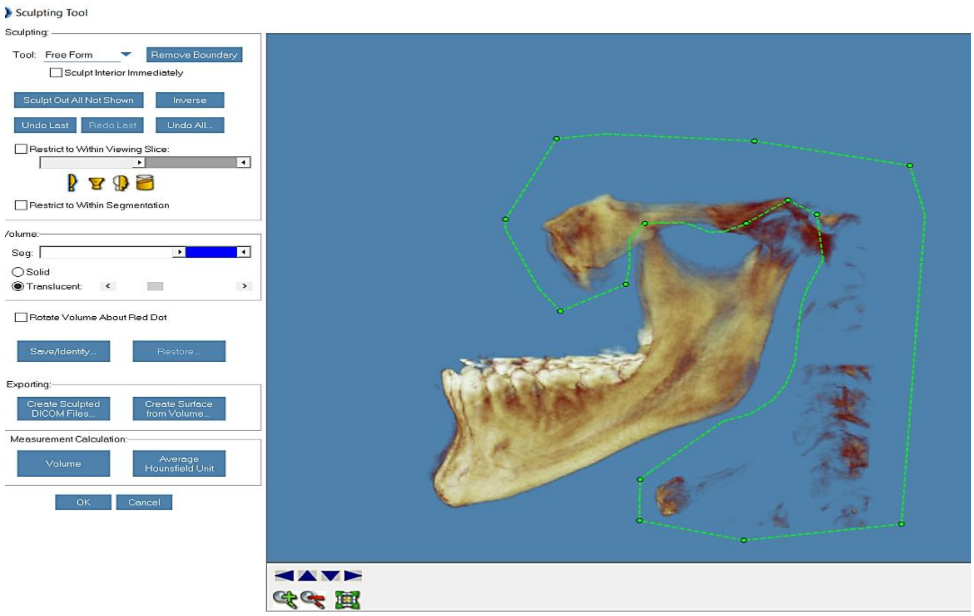


Figure (2): (sculpting cervical vertebrae and glenoid fossa with the remaining upper structure)

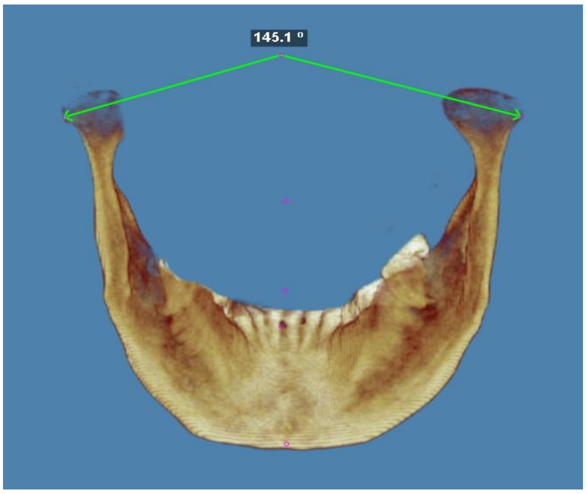
The same examiner segmented each CBCT twice, with a one-week break in between.

7. Condyle height, depth, and width measurements (Table 1)24, as shown in Figures 3 and 4.

Figure (3): (Condyle width) **Figure (4)**: (Condyle height and depth)

Measurement	Definition
Condylar depth	The condylar head's shortest distance between its anterior and posterior points
Condylar width	The condylar head's shortest distance between its medial and lateral points
Condylar heigh	The shortest distance is found between the mandi notch's most caudal point and a plane parallel to the condylar head's most cranial point.

8. Measurement of intercondyle distance and angle as in (Figure 5,6) (11).



Figures (5,6): (Intercondyle distance and angle)

9. Measurement of mandibular divergence angle as in (Figure)

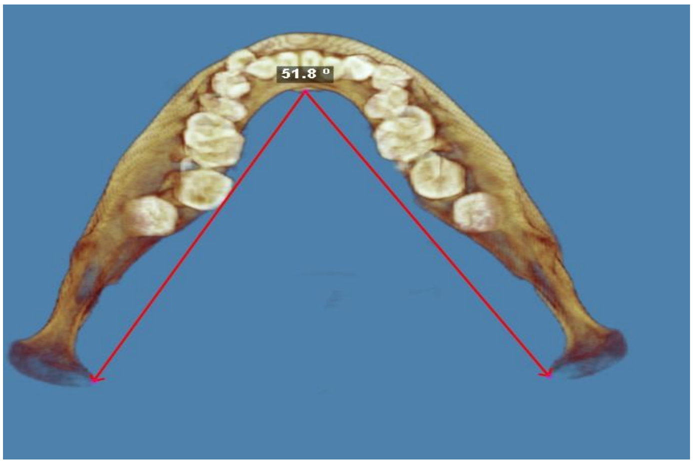


Figure (7): measurement of mandible divergence angle (Mandibular divergence angle)

10. Building x-ray: By this option in Dolphin software 11, to build a lateral x-ray for cephalometric tracing, this facility reduces the need for taking another 2-dimensional x-ray; the image will be saved as a JPG on our computer after choosing the snapshot option from Dolphin software (figure 8)

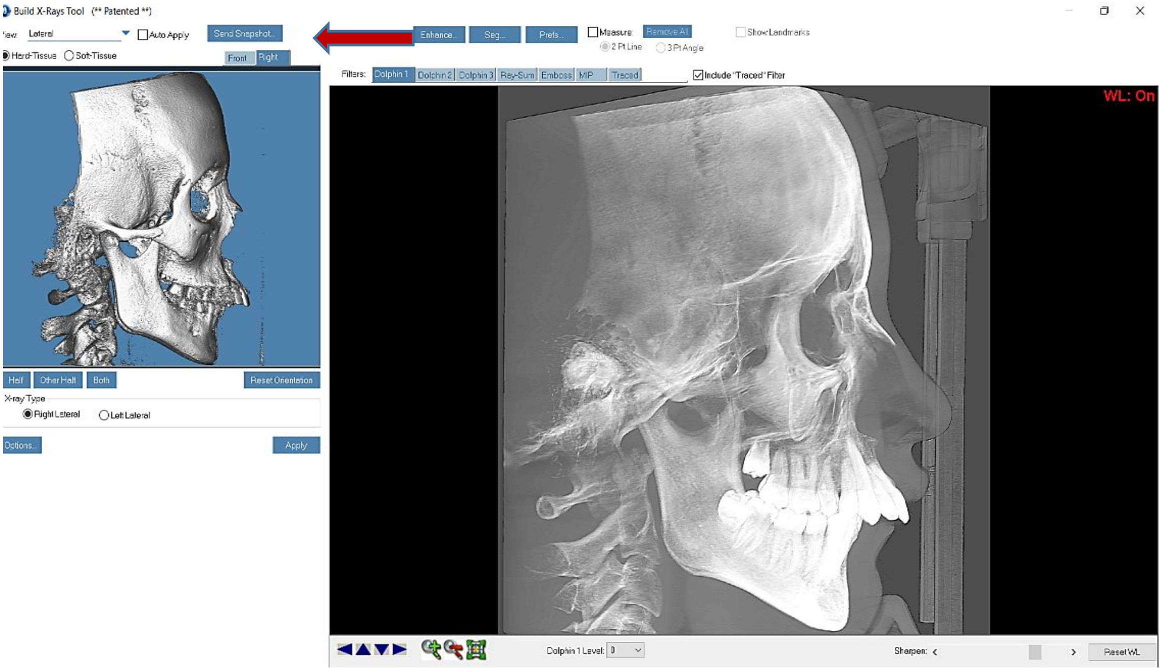


Figure (8): (Building x-ray picture)

11. cephalometric tracing: after importing the cephalometric picture into Dolphin software, from the digitize option, choosing lateral ceph (digital x-ray), select (Steiner\tweed\wits)

The program allows users to enlarge any specific area and displays all points along with their tracing sequence (Figure 9). Digital tracings were performed, and by connecting the previously mentioned points, linear and angular values were obtained.

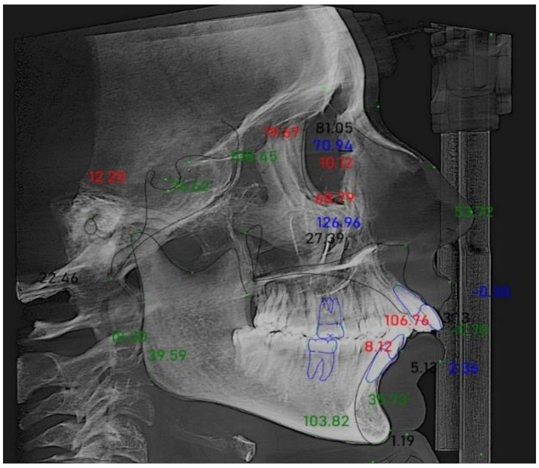


Figure (9): (Digital tracing)

Measure the inclination of the teeth

The Methodology:

The casts of each of the selected patients were turned into uniform, trimmed orthodontic dental models using blue hard orthodontic stone.

Measuring Device:

In accordance with (26), a manual protractor was provided utilizing the torque angulation apparatus (IN-tendo, Chiang Mai, Thailand).

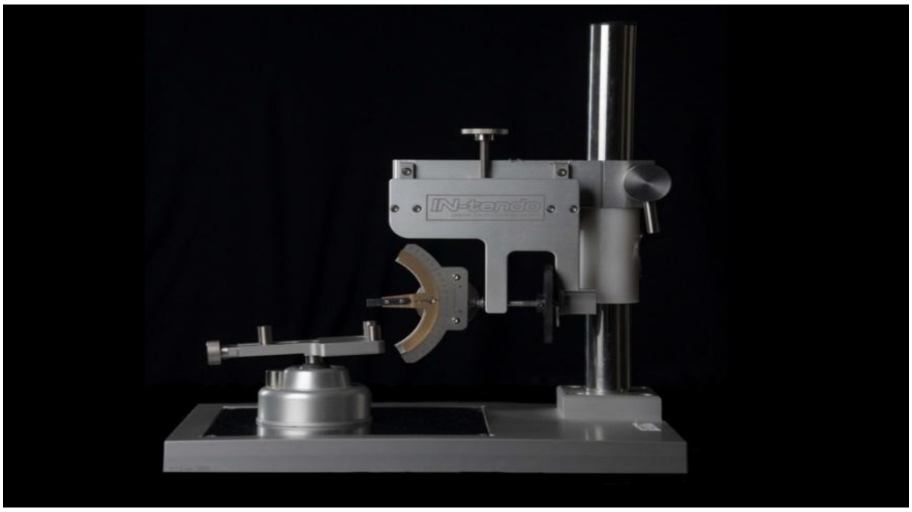


Figure (10): (The torque angulation device (IN-tendo device))

Method of Measurements

The long axis of the clinical crown (LACC) and midpoint of the clinical crown (LA) of each tooth were marked with a hard pencil on the dry lower standardized orthodontic dental models. The occlusal plane of the teeth ran parallel to the metal base's working surface, with their occlusal surfaces pointing upward. The measurement compartment was then filled with the model holder. After that, as shown in Figure 11.

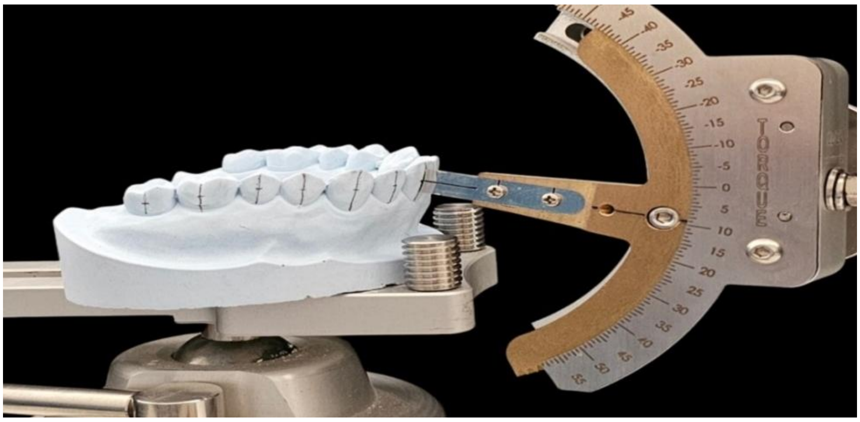


Figure (11): (Dental models displaying the LACC and LA point)

The measurement has to be done on a level plane to avoid any rise or fall in the torque values. The palatal torque of the crown is represented by a negative value, and the facial torque is represented by a positive value.

Statistical Analysis

Data analysis was conducted using IBM SPSS Statistics Version 25.0 software. An evaluation of the method's error was performed using the coefficient of reliability.

1. Descriptive statistics for variables were expressed as mean, SD, min, and max. One could define statistical significance as a value of less than 0.05.
2. Based on the results of the normality test, the Shapiro-Wilk test was used, which indicated that the variables were not normally distributed.
3. t-test, Mann-Whitney U test for two independent samples, Spearman's correlation coefficient

RESULTS

It was done for all variables, including total males and females. Minimum, Maximum, Mean, and SD were shown in the table (2)

Table (2): (Descriptive statistics of total class, II patients)

Variable	SD±	Mean	Minimum _ Maximun
Beta angle	9.833563	43.70333	26.3_76.4
Yen angle	6.776922	133.2767	121.3_153.1
Interincisal angle	8.131251	136.3	114_150.8
Gonial angle	4.654455	130.6467	121.8_140.3
Intercondyle angle	5.077311	79.57667	67.8_89.5
Intercondyle distance	6.148025	140.62	128.5_154.5
Mandibular divergence a	5.128402	46.71333	34.6_61.3
Menton deviation	1.645474	1.9	0.5_9.5
Collum angle incisor	6.428117	2.7	-11_13
Collum angle canine	8.623678	0.666667	-11_11
Condyle height right	2.826931	20.11333	16.9_26.9
Condyle height left	2.482122	19.39	15.3_25.9
Condyle depth right	1.498156	8.963333	6.7_12.9
Condyle depth left	1.240245	8.48	5.7_10.8
Condyle width right	1.963579	17.05667	14.2_21.2
Condyle width left	1.59341	16.80333	14.1_19.6
Ramus length right	5.690655	58.07	49.8_69.7
Ramus length left	6.376321	57.43333	47.5_71.3
Mandible length right	6.51944	81.53667	72.1_98.7

Mandible length left	7.418359	80.63667	67.9_96.1
Torque 1 right	5.932668	-14.9	-23_2
Torque 1 left	6.642254	-17.1333	-30_-5
Torque 2 right	6.640523	-15.2	-24_5
Torque 2 left	5.992716	-21.1333	-30_-8
Torque 3 right	6.979444	-19.3333	-28_-1
Torque 3left	5.014327	-18.7356	-27_-9

Comparison between groups
As indicated in Tables 3 and 4, the variables for both sexes show no significant differences between right and left values, except male torque for the lower central incisors and lower lateral incisors, and canines.

Table (3): (Comparison of Right and Left males)

Right Male			**left Male** **No. 17**		
Variable	**Mean**	**SD**	**Mean**	**SD**	**P Value**
Condyle height	20.6059	3.32368	19.7412	2.93067	0.469
Condyle depth	9.2176	1.78299	8.5471	1.47314	0.241
Condyle width	18.1882	1.81793	17.6765	1.42983	0.368
Ramus length	59.8882	6.25409	59.4471	5.58918	0.830
Mandible length	84.6412	6.96205	84.6059	6.46021	0.988
Torque 1	-13.6471	6.39278	-16.4706	6.64377	0.341
Torque 2	-14.1176	6.81801	-20.6471	7.07055	0.014**
Torque 3	-18.0588	7.10168	-19.8235	5.89741	0.397

Table (4): (Comparison of Right and Left females)

Right Female			**left Female** **NO:13**		
Variable	**Mean**	**SD**	**Mean**	**SD**	**P Value**
Condyle height	19.4692	1.94696	18.9308	1.74183	0.465
Condyle depth	8.6308	0.98690	8.3923	0.89950	0.526
Condyle width	15.5769	0.85162	15.6615	0.95790	0.814
Ramus length	55.6923	3.91162	54.8000	6.58382	0.343
Mandible length	77.4769	2.56520	75.4462	5.08357	0.215
Torque 1	-16.5385	5.04340	-18.0000	6.80686	0.540
Torque 2	-16.6154	6.38407	-21.7692	4.39988	0.025**
Torque 3	-21.0000	6.72062	-17.8462	3.99679	0.061*

The comparison between male and female disclose that there are no significant differences for all variables except Condyle width, Ramus length and Mandible length; On the other hand, the evaluation of single variables between male and female shows that there is no significant difference between them at all except Yen angle, Gonial angle, Intercondylar angle and intercondylar distance as shown in table (5,6).

Table (5): (comparison of class II Males and Females)

Class III Male No.17			**Class III Female No.13**		
Variable	**Mean**	**SD**	**Mean**	**SD**	**P Value**
Condyle height	20.1735	3.11655	19.2000	1.83063	0.136
Condyle depth	8.8824	1.64602	8.5115	0.93309	0.275
Condyle width	17.9324	1.63127	15.6192	0.88905	0.00**
Ramus length	59.6676	5.84469	55.2462	5.32520	0.004**
Mandible length	84.6235	6.61330	76.4615	4.07863	0.00**
Torque 1	-15.0588	6.57793	-17.2692	5.91647	0.143
Torque 2	-17.3824	7.59990	-19.1923	5.98010	0.322
Torque 3	-18.9412	6.48981	-19.4231	5.65100	0.970

Table (6): (Comparison of single variables class II Males and Females)

Male III			**Female class III**		
Variable	**Mean**	**SD**	**Mean**	**SD**	**P Value**
Beta angle	44.2000	12.79131	43.0538	3.83745	0.730
Yen angle	135.2059	7.69224	130.7538	4.46404	0.074*
Interincisal angle	135.8176	7.88600	136.9308	8.72376	0.717
Gonial angle	132.0882	4.80011	128.7615	3.85217	0.051*
Intercondyle angle	81.4294	4.93885	77.1538	4.30748	0.023 *
Intercondyle distance	142.3529	6.87760	138.3538	4.29644	0.077*
Mandibular divergence angle	45.8882	6.17514	47.7923	3.23895	0.322
Menton deviation	1.7941	0.88351	2.0385	2.33793	0.476
Collum angle incisor	1.5294	6.49151	4.2308	6.26038	0.214
Collum angle canine	0.3529	8.73170	1.0769	8.81723	0.673

The Spearman's correlation:

It (r) determines the possibility of a significant degree of association between two variables studied. However, trying to assign a cause-and-effect relationship.

It can range from -1 to +1, where -1 indicates a perfect negative correlation, +1 indicates a perfect positive correlation, and a value of 0 indicates no correlation at all.

The Spearman's correlation coefficient can be interpreted as follows: 00–0.19 = very weak; 0.20–0.39 = weak; 0.40–0.59 = moderate; 0.60–0.79 = strong; 0.80–1.0 = very strong.(12)

CL.III

From table (7), we can see a strong positive correlation between Torque 1 and each of Torque 2(R and L) and Torque 3, with a highly significant (0.00), and a weak positive correlation with Remus length (sig.=0.018). Another strong positive correlation appears between Torque L2 and Torque 3, with a significant (0.00), but a moderate positive correlation with Remus length (sig.=0.004).

For Torque R2, a highly significant, moderately positive correlation was found between Torque R2 and each of Torque 3, Torque L2. On the other hand, a weakly positive correlation with Remus length (sig.= 0.23)
Also, we can see a moderate positive correlation with Yen A and Mandible length, with a significant 0.004.

Another significant correlation, but weak between Beta A and Torque L2, Yen A and each of Torque 3, Mandible divergence A, Torque L2, Torque 1, and +ve weakly with Gonial A.

Finally, between Mandible divergence A and Mandible length significant –ve weakly correlation, and between Mandible divergence A and Torque 3 significant +ve weakly correlation.

Table (7): (Spearman's correlation)

Correlations[a]

Variable		Beta A	Yen A	Interincisal A	Gonial A	Intercondyle A	Mandible divergance A	Collum incisor A	Collum canine A	Torque 1	Torque 2	Torque L2	Torque 3	Intercondyle D	Condyle height	Condyle depth	Condyle width	Ramus length	Mandible length	deviation
Beta A	corr.	1	0.178	0.264	0.030	-0.096	-0.240	-0.098	0.057	-0.198	-0.171	-0.361	-0.204	0.175	-0.143	0.064	0.013	-0.404	0.281	-0.028
	sig.		0.346	0.159	0.874	0.615	0.201	0.606	0.765	0.295	0.366	0.050	0.280	0.354	0.450	0.738	0.946	0.027	0.133	0.883
Yen A	corr.	0.178	1	0.330	0.475	-0.036	-0.415	-0.137	-0.045	-0.376	-0.301	-0.401	-0.495	0.357	-0.066	-0.120	0.212	0.034	0.508	
	sig.	0.346		0.075	0.008	0.851	0.023	0.472	0.815	0.041	0.106	0.028	0.005	0.053	0.728	0.527	0.260	0.857	0.004	
Interincisal A	corr.	0.264	0.330	1	-0.211	-0.140	-0.043	0.368	-0.107	-0.387	-0.493	-0.274	-0.378	0.345	-0.140	-0.033	-0.146	-0.258	0.152	
	sig.	0.159	0.075		0.264	0.459	0.821	0.045	0.574	0.034	0.006	0.143	0.040	0.062	0.461	0.862	0.441	0.168	0.423	
Gonial A	corr.	0.030	0.475	-0.211	1	-0.212	-0.483	-0.335	-0.030	-0.203	-0.055	-0.193	-0.275	0.094	0.084	-0.324	0.213	0.051	0.216	
	sig.	0.874	0.008	0.264		0.260	0.007	0.070	0.876	0.283	0.772	0.307	0.141	0.622	0.658	0.080	0.259	0.791	0.253	
Intercondyle A	corr.	-0.096	-0.036	-0.140	-0.212	1	0.105	-0.250	-0.238	0.232	0.145	0.186	0.192	0.092	0.303	0.335	0.278	0.105	0.328	
	sig.	0.615	0.851	0.459	0.260		0.581	0.183	0.205	0.217	0.444	0.325	0.309	0.627	0.104	0.070	0.137	0.579	0.076	
Mandible divergance A	corr.	-0.240	-0.415	-0.043	-0.483	0.105	1	0.078	0.080	0.360	0.329	0.228	0.422	-0.156	-0.149	0.162	-0.237	-0.113	-0.460	
	sig.	0.201	0.023	0.821	0.007	0.581		0.681	0.675	0.050	0.076	0.225	0.020	0.411	0.432	0.391	0.207	0.554	0.011	
Collum incisor A	corr.	-0.098	-0.137	0.368	-0.335	-0.250	0.078	1	-0.312	-0.218	-0.270	-0.040	-0.166	0.133	-0.170	0.143	-0.304	-0.091	0.045	
	sig.	0.606	0.472	0.045	0.070	0.183	0.681		0.093	0.247	0.148	0.836	0.380	0.485	0.370	0.451	0.103	0.632	0.815	
Collum canine A	corr.	0.057	-0.045	-0.107	-0.030	-0.238	0.080	-0.312	1	0.199	0.251	0.111	0.231	-0.154	-0.076	0.145	-0.001	0.140	-0.151	
	sig.	0.765	0.815	0.574	0.876	0.205	0.675	0.093		0.293	0.181	0.561	0.219	0.418	0.691	0.444	0.995	0.460	0.426	
Torque 1	corr.	-0.198	-0.376	-0.387	-0.203	0.232	0.360	-0.218	0.199	1	0.829	0.804	0.899	-0.079	-0.118	0.211	0.231	0.428	-0.194	
	sig.	0.295	0.041	0.034	0.283	0.217	0.050	0.247	0.293		0.000	0.000	0.000	0.678	0.536	0.262	0.219	0.018	0.306	
Torque 2	corr.	-0.171	-0.301	-0.493	-0.055	0.145	0.329	-0.270	0.251	0.829	1	0.617	0.770	-0.192	0.046	0.138	0.316	0.413	-0.166	
	sig.	0.366	0.106	0.006	0.772	0.444	0.076	0.148	0.181	0.000		0.000	0.000	0.309	0.811	0.467	0.089	0.023	0.379	
Torque L2	corr.	-0.361	-0.401	-0.274	-0.193	0.186	0.228	-0.040	0.111	0.804	0.617	1	0.839	-0.270	-0.175	0.046	0.150	0.509	-0.316	
	sig.	0.050	0.028	0.143	0.307	0.325	0.225	0.836	0.561	0.000	0.000		0.000	0.150	0.356	0.809	0.430	0.004	0.089	
Torque 3	corr.	-0.204	-0.495	-0.378	-0.275	0.192	0.422	-0.166	0.231	0.899	0.770	0.839	1	-0.181	-0.211	0.106	0.109	0.265	-0.349	
	sig.	0.280	0.005	0.040	0.141	0.309	0.020	0.380	0.219	0.000	0.000	0.000		0.339	0.263	0.577	0.566	0.158	0.059	
Intercondyle D	corr.	0.175	0.357	0.345	0.094	0.092	-0.156	0.133	-0.154	-0.079	-0.192	-0.270	-0.181	1	-0.342	0.298	0.159	-0.189	0.266	
	sig.	0.354	0.053	0.062	0.622	0.627	0.411	0.485	0.418	0.678	0.309	0.150	0.339		0.064	0.110	0.402	0.317	0.155	
Condyle height	corr.	-0.143	-0.066	-0.140	0.084	0.303	-0.149	-0.170	-0.076	-0.118	0.046	-0.175	-0.211	-0.342	1	0.094	0.206	0.193	0.464	
	sig.	1.000	0.728	0.461	0.658	0.104	0.432	0.370	0.691	0.536	0.811	0.356	0.263	0.064		0.622	0.276	0.308	0.010	
Condyle depth	corr.	0.064	-0.120	-0.033	-0.324	0.335	0.162	0.143	0.145	0.211	0.138	0.046	0.106	0.298	0.094	1	0.063	0.188	0.286	
	sig.	0.738	0.527	0.862	0.080	0.070	0.391	0.451	0.444	0.262	0.467	0.809	0.577	0.110	0.622		0.743	0.320	0.125	
Condyle width	corr.	0.013	0.212	-0.146	0.213	0.278	-0.237	-0.304	-0.001	0.231	0.316	0.150	0.109	0.159	0.206	0.063	1	0.575	0.461	
	sig.	0.946	0.260	0.441	0.259	0.137	0.207	0.103	0.995	0.219	0.089	0.430	0.566	0.402	0.276	0.743		0.001	0.010	0.974
Ramus length	corr.	-0.404	0.034	-0.258	0.051	0.105	-0.113	-0.091	0.140	0.428	0.413	0.509	0.265	-0.189	0.193	0.188	0.575	1	0.229	-0.034
	sig.	0.027	0.857	0.168	0.791	0.579	0.554	0.632	0.460	0.018	0.023	0.004	0.158	0.317	0.308	0.320	0.001		0.224	0.858
Mandible length	corr.	0.281	0.508	0.152	0.216	0.328	-0.460	0.045	-0.151	-0.194	-0.166	-0.316	-0.349	0.266	0.464	0.286	0.461	0.229	1	0.048
	sig.	0.133	0.004	0.423	0.253	0.076	0.011	0.815	0.426	0.306	0.379	0.089	0.059	0.155	0.010	0.125	0.010	0.224		0.800
Mandibe deviation	corr.	-0.028	0.056	-0.426	0.237	-0.077	-0.149	-0.140	0.136	0.197	0.266	0.134	0.274	0.123	-0.014	0.045	-0.006	-0.034	0.048	1
	sig.	0.883	0.770	0.019	0.206	0.685	0.431	0.460	0.475	0.296	0.156	0.479	0.142	0.518	0.939	0.812	0.974	0.858	0.800	

Canonical correlation analysis (CCA)

It is a statistical method that is used to explore and assess the relationship between two sets of variables. It was used in this study to investigate the relationship between the face's (DISTANCE versus ANGLES). P < 0.05 was chosen as the significance level.

Set 1 (angles variables) –Beta angle, Yen angle, Interincisal angle, Gonial angle, Intercondylar angle, Mandibular divergence angle-Collum angle-Torque angle of lower anterior teeth.

Set 2 (distance variables) –Intercondylar distance-Condylar height-Condylar depth-Condylar width-Ramus length-Mandible body length-menton deviation from midline. Table (8) shows the canonical correlation result, which indicates that the correlation values ranged from 0.939 to 0.358, from tests of significance: **Wilks Statistic** and **F-ratio**, just the first canonical correlation was significant.

Table (8): (Canonical Correlations and test of significance level)

Number	Canonical correlation	tests of significance			
		Wilks Statisti	F- ratic	D.F	Sig.
1	**0.939**	0.003	1.444	84	**0.04** *
2	0.845	0.024	1.065	66	0.397
3	0.784	0.084	0.907	50	0.638
4	0.677	0.217	0.758	36	0.810
5	0.667	0.400	0.682	24	0.841
6	0.416	0.721	0.405	14	0.962
7	0.358	0.872	0.415	6	0.859

* Statistically significant at *P*<0.05.

Thus, indicating that the - DISTANCE versus ANGLES are positively correlated.

Tables (2a and 2b) loading canonical coefficients between Angles - set 1 - and Distance-set 2- variables for the canonical in CL III

Tables (9): (a and b): loading canonical coefficients between Angles and Distance variables for the canonical in CL III

a1): Set 1 Canonical Loadings

Variable	1
Beta A	0.036
Yen A	**-0.679**
Interincisal A	-0.586
Gonial A	**0.694**
Intercondyle A	0.628
Madible divergance A	**0.728**
Collum incisor A	-0.106
Collum canine A	-0.210
Torque1	-0.199
Torque2	-0.061
Torque 3	-0.012

a2): Set 2 Canonical Loadings

Variable	1
Intercondyle distance	-0.352
Condyle height	**-0.604**
Condyle depth	0.165
Condyle width	0.062
Ramus length	**-0.837**
Mandible length	-0.207
Menton deviation	0.235

The first canonical varieties for **ANGLE** variables ranged from moderate negative loading with **Torque L2** (-0.669), **to** moderate positive loading with **Beta Angle** (0.560). The first canonical varieties for **DISTANCE** variables ranged from moderate negative loading with **Ramus length** (-0.463), to moderate positive loading with **Intercondylar distance** (0.595).

Finally, figure 12 demonstrates the result of application of the idea of canonical correlation between variables So, holding the influence of all other angles constant, the angles with the greatest influence are **Beta Angle, Yen Angle, inter incisal angle** respectively, on the other hand, the distance with the greatest influence are **mandible length, inter condyle distance** respectively. It is illustrated how to reduce the dimensions of the study by grouping the study variables in each set into one group DISTANCE versus ANGLES by linear combination, and this combination give us the sub correlations as well as a canonical correlation with value 0.939

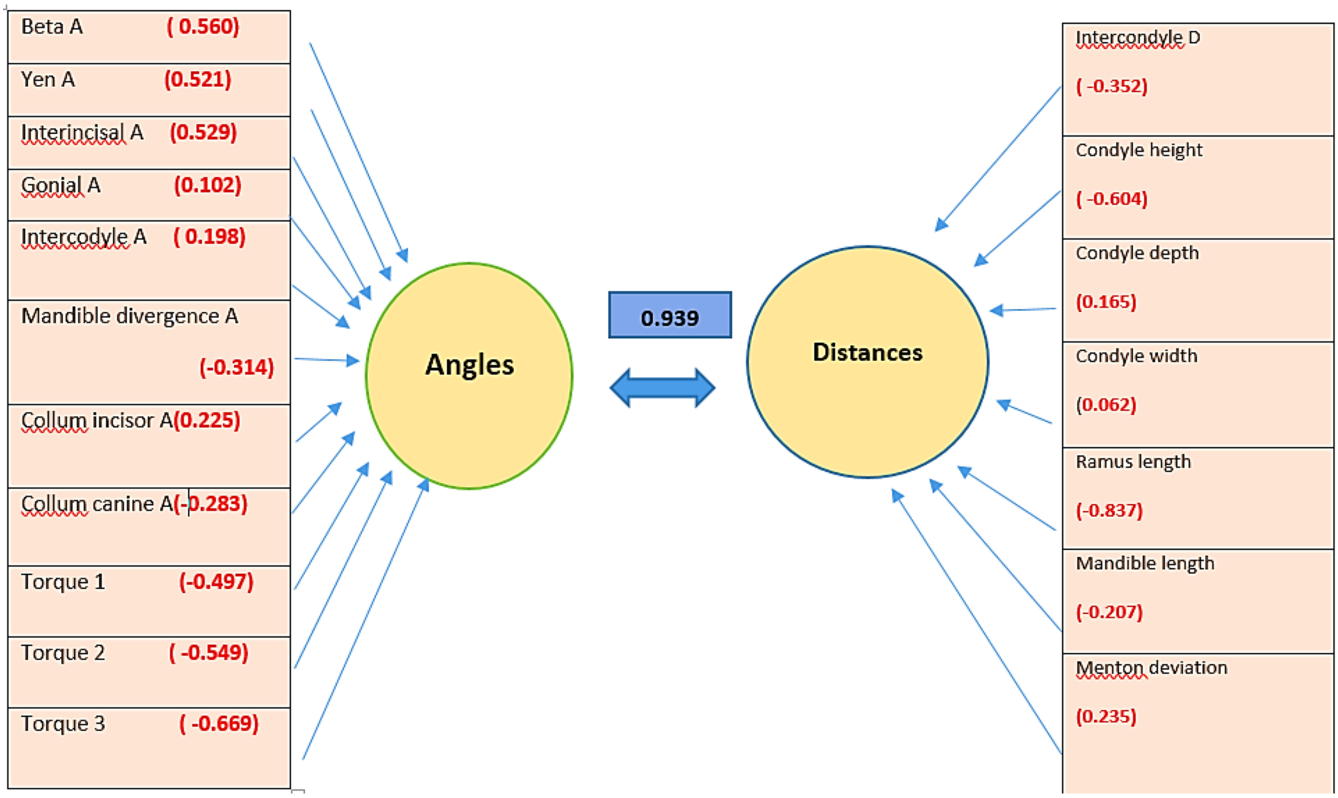


Figure (12): Relationship of Angles and Distance variables

It illustrates how to reduce the dimensions of the study by grouping the study variables in each set into one group, DISTANCE versus ANGLES by linear combination, and this combination gives us the sub-correlations as well as a canonical correlation with a value of 0.939

DISCUSSION

Cone Beam Computed Tomography (CBCT)

Many investigations by Kobayashi et al. (29), Lascala et al. (27), Soumalainen et al. (28), and others have validated the accuracy of CBCT for linear measurements. Furthermore, Soumalainen et al. found that the CBCT technique produced a lower error in linear measurement and evaluation than multislice CT. According to Lascala et al. (27), CBCT images are accurate for linear measurements of these structures but underestimate the actual distances between different points on the base of the skull. The most effective method for determining both linear and volumetric measurements of the TMJ's bony structures at this time is computed tomography (CBCT), which agrees with (30).

Dolphin software

These days, the preferred technique for taking cephalometric measurements is to digitize X-rays. Professionals find it easier and easier to adjust to the numerous repetitive tasks involved in clinical practice as technology advances. This study assessed the accuracy of linear and angular measurements made using Dolphin Imaging® 11.0 software in computerized cephalometric tracings. More research should be done with this computer program because it includes additional tools for cephalometric tracing, such as overlays, profile manipulation, and predictive tracings for orthognathic surgery, even though it offers more options than just the 3D program itself. Based on the techniques used in this study and the outcomes of comparing angular and linear measurements of manual and digital tracings, we can reasonably conclude that the cephalometric program Dolphin Imaging® 11.0 can be used with reliability to assist in the diagnosis, planning, monitoring, and evaluation of orthodontic treatment in both clinical and research settings (19)

Comparison between Male and Female in Torque Values

A relationship between two variables can be briefly described by Spearman's Rank correlation coefficient, which indicates whether the relationship is positive or negative. The range of responses will always be a perfect positive correlation (1.0) or a perfect negative correlation (-1.0). Instead of using Pearson's correlation coefficient, we used Spearman's correlation coefficient because most of the study's parameters were not usually disturbed. Males have more upright mandibular canines than females; this is supported by Ferrario's research, which found a gender difference in the torque of teeth. However, there was There is no discernible difference in torque between males and females. (20). The lingual inclination of labio-lingual teeth in the maxillary and mandibular arches started positively in the incisor regions before starting to incline lingually from the canine; this finding is consistent with Saudi population data from Andrews and Bukhary. (13)

Each tooth in the lower arch that was farther away from the central incisor typically had a greater lingual inclination than its neighbor. In comparison to the male group, the females exhibited a greater lingual inclination of the lower canine, which is consistent with the findings by(14).

Comparison between Male and Female in condyle dimensions Values:

Males have an upright mandibular canine, and the asymmetry in torque between the two sides in males may be due to a preferred chewing side in malocclusion subjects, which may result in changes to volume and morphology. This result is in line with the research conducted by (23)

Comparison between Male and Female in condyle dimensions values:

Males had significantly larger mandibular condyles on both sides in terms of length, width, and height. This was consistent with Tadej et al.'s findings (36). Measurement differences between the two sides are caused by the type of diet and parafunctional habits, claim Enomoto et al(37). The morphological differences in TMJ between male and female individuals can be attributed to variations in sex hormones and metabolic activity, which is consistent with research by (25), which found differences in condyle dimensions between genders. When comparing the mandibular body's size to the right, no noticeable variations were found, and the left side, suggesting a generally symmetric mandibular body. This is in line with studies done by (24). Males had more pronounced mandibular condyle width and height than females did. Class III malocclusion was associated with greater condylar height and width, which was consistent with (25). These results might suggest that patients with Class III malocclusion have an excessive amount of vertical development in their mandibular ramus. Although it does not affect vertical skeletal malocclusions, condylar height most likely plays a crucial role in the development of Class III malocclusions. The load placed on a bone affects its internal structure and morphology. Hypodivergent patients have higher maximum bite forces, according to earlier research, which is consistent with findings by (26).

Correlation between condyle dimensions and lower teeth inclinations:

While there is a strong correlation between the mid facial structures and the soft tissue chin, and upper and lower incisor inclination (15). Nevertheless, regardless of the joint reference points used for measurements, the situation and mutual relationships of the front teeth do not correlate with the structure of the temporomandibular joint. Our findings also support a study by Lassmann et al. that found no correlation between the interincisal overbite, overjet, and interincisal angle of permanent teeth in relation to the anatomy of the temporomandibular joint(16).

The Limitations of the study, that there aren't many samples in our society that have a Class III malocclusion, making it challenging to determine prevalence accurately without large sample sizes. We believe that additional studies with larger sample sizes are required to clarify the relationship between the general population's lower anterior teeth morphology and inclinations. The current study primarily relied on retrospective data, and we eliminated many cases from our research sample due to the fact that the field of view was insufficient to reveal all the necessary details. For example, in certain cases, the field of view was small, resulting in only the maxilla and mandible being included in the DICOM images; a larger FOV was required. The density of the hard tissue and noise in the 3D radiograph may affect some fine details that are so important in the segmentation, cephalometric tracing, and 3D measurement.

CONCLUSIONS

Within the limitations of the current study, it is possible to conclude that:
Class III malocclusions had a higher mandibular condyle height. The male mandibular condyle was wider than the female one. The mandibular body size, position, and morphology of the condyles on the left and right sides did not exhibit any discernible directionality, according to the results of the current investigation. In terms of the size of the left and right condyles in the mandible, as well as mediolateral width, men were larger than women.

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Authors' Contribution

Mohammed HB., and Al-Dewachi ZB contributed to conceptualization, validation, and writing the original draft. Mohammed HB. was responsible for formal analysis, methodology, and project administration. Al-Dewachi ZB is responsible for the supervision, review & editing of the manuscript. Mohammed HB., and Al-Dewachi ZB contributed to the investigation, software, validation, and visualization. Mohammed HB was involved in data curation, resources, and review & editing. All authors have read and approved the final manuscript.

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Ethical statement: The protocol of this study was approved by the Local Ethics Committee (Uom. Dent. 23/50), Research Ethics Committee of the College of Dentistry, University of Mosul, Mosul, Iraq. Informed consent was obtained from all participants. The participants in the current study gave their verbal and written agreement. The research goal was explained to the participants, and they were assured of the privacy and confidentiality of their data.

Conflict of interest

The authors declare that there are no conflicts of interest regarding the publication of this manuscript.

Availability of data and materials: The data supporting the findings of this study are available from the corresponding author upon reasonable request.

Declaration of Generative AI and AI-assisted technologies

No artificial intelligence tools were used. The authors reviewed and edited the content as needed and take full responsibility for the content of the publication.

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العلاقة بين مورفولوجيا اللقمة وميلان التاج للأسنان الأمامية السفلية في الفئة الهيكلية الثالثة

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الملخص

الاهداف: هدفت الدراســة الحالية إلى تحديد العلاقة بين مورفولوجيا اللقمة في نمط الهيكل العظمي من الفئة الثالثة باســتخدام التصـوير المقطعي المحوسب ذي الحزمة المخروطية وميل تاج الأسـنان الأمامية السفلية. **المواد وطرائق العمل**: فحصـت هذه الدراسة صور CBCT الثنائية للمفصل الصدغي الفكي لـــ 30 شخصًا (17 ذكرًا و13 أنثى) من الفئة الهيكلية الثالثة ومتوسط العمر (18-30 عامًا) والجبيرة السفلية. تم تقدير القياسات الزاوية والخطية للمفصل الصـدغي الفكي، وتم فحص التباينات بين المجموعات إحصـــائيًا. تم اســـتخدام جهاز عزم الدوران والزاوية TAD لقياس ميل التيجان. **النتائج**: بغض النظر عن نقاط مرجع المفصـل المستخدمة للقياسات، لا يوجد ارتباط بين موضـع الأسـنان الأمامية السفلية والعلاقات المتبادلة وبنية المفصل الصـدغي الفكي. **الاستنتاجات**: كان ارتفاع اللقمة السفلية أكبر في سوء الإطباق من الفئة الثالثة. كان لدى الرجال أحجام أجسـام الفك السفلي وأطراف الفك الوسطى الجانبية أوسع من النساء.

الكلمات المفتاحية: التصوير المقطعي المحوسب باستخدام الأشعة المخروطية؛ المفصل الصدغي الفكي؛ جهاز عزم الدوران والزاوية