Three-Dimensional Analysis of the Hyoid Bone Configuration Changes in relation to Dentoalveolar Discrepancy using CBCT.

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Abstract

Aim: to evaluate the spatial pattern of hyoid bone in relation to dimensional morphologic changes in relation to the dentofacial discrepancy.

Methods: All CBCT images of 1120 patients archive in private clinic orthodontics unit were categorized within age between 16 to 30 years old in-between normal occlusion and malocclusion. Then, every CBCT image was analyzed according to Steiner's analysis using cephalometric reference planes and points. Finally, 3D reconstructive model of hyoid bone was built up and analyzed using MIMICS 22.0V software and subsequently measured using SPSS 22v for statistical record.

Results: There was a statistically significant relationship in both dimensional changes of dentoalveolar complex and the hyoid bone configuration ($P < 0.05$). Also, there were a highly significant correlation ($p < 0.01$) in males with severe malocclusion insufficiency. The 3D reconstructive models of Hyoid bone appeared bulkier and longer forward in the severe malocclusion group to be statistically different from another normal group ($p < 0.01$).

Conclusion: This study reveals the 3D dimensional change of Hyoid bone configuration in relation to dentoalveolar discrepancy affecting in result the skeletomuscular apparatus and Obstructive Sleep Apnea (OSP) treatment plan.

Keywords: MIMICS, Dentoalveolar discrepancy, Hyoid Bone configuration, CBCT

1. Introduction

Orthopedics configuration assessment of the cartilaginous or bony part surrounding craniofacial complex is clearly determined by accurate imaging evaluation for proper treatment plan. [1] As a diagnostic tool is essential in Orthodontics to treat malocclusions comprehensively by several techniques that are available for this purpose, such as orthopantomography, radiographs, study models, photographs and recently all of these have overcame using CBCT imaging and face scanning for more predictability and accuracy [2].

The airway is bordered superiorly by the bones of the skull base, posteriorly by the spine, anterosuperiorly by the nasal septum, and anteriorly by the mandible and hyoid bone. [3] The hyoid is the only bone that does not articulate with other bones. [4] It is connected to the pharynx, mandible, and skull by muscles and ligaments. Tension generated in these structures, due to movement of the head and body and resulting from oral and tongue function, will change its position. [5-7] Changes in the positioning of mandible (physiological, surgical, or due to orthodontic treatment) are also accompanied by changes in the positioning of hyoid. [7, 8].

McNamara reported the concepts of this functional matrix and bone spatial relation appear in response to the functional behavior of an individual's craniofacial mass. In this sense, alterations in the airway and stomatognathic posture can affect maxillofacial growth and lead to dentoalveolar discrepancy. However, there is still insufficient to reveal the airflow as a determinant of craniofacial growth and development [3, 9].

Insufficient airway patency lead to breathing confusion and modifies normal craniofacial and dentofacial development. Therefore, a good diagnosis and early treatment can prevent, restore, or correct craniomaxillofacial growth [10].

This mechanism of compensation of hyoid position may result in changes in the dimension of the pharyngeal airway and may therefore have clinical implications. [11] Moreover, the close relationship between the pharynx and the hyoid bone helps to make respiration possible. The hyoid bone adjusts its orientation to the physiological requirements imposed by pharyngeal obstruction and mouth breathing. To evaluate the position of the hyoid bone, there is a set of standardized measurements known

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as the hyoid triangle method. [12].

The analysis of the hyoid bone and dentoalveolar discrepancy would indicate the treatment plan correctly and solve the malocclusion briefly in a manner. The pharyngeal airway as a complex related to hyoid bone relation with stomatognathic apparatus lead to Obstructive Sleep Apnea OSA and Its multifunctional regulating processes. It coordinates breathing, ventilation, gastric, and phonation functions [13].

Although there are various morphometric evaluation modalities for treatment of the dentoalveolar discrepancy still continues to present a great challenge. However, these studies have had several limitations either study of human cadavers or the samples were few in number and age not in adult time. [3, 9, 11-15].

This work aimed to evaluate the hyoid bone posture according to skeletal malocclusion cephalometrically to determine a connection between the three-dimensional structures of hyoid bone and dentoalveolar skeletal malocclusion using a radiological evaluation of Cone beam computed tomography (CBCT) to provide an accurate analysis with an orthographic view but required reconstruction through additional procedures.

2. Material and Methods

This is a retrospective study undertaken at the unit of Orthodontics in private clinic CBCT archives of patient cases in conjugation with the unit of Dentomaxillofacial radiology, Baghdad, Iraq. The study comprised CBCT images of 1120 patients with age between 16-30 years old for both angle class III malocclusion and normal dentofacial pattern. A comparison was made with the determination of vomer bone dimensional changes.

The CBCT image of each patient was reconstructed in three views (sagittal, coronal and axial) and on each scan cephalometric facial landmarks were determined using mimics 22.0 version analysis tool software package (Materialise, Leuven, Netherlands). A subset of these landmarks can be seen in (Table.1).

An outline border of the hyoid bone was examined, analyzed then splatted using three-dimensional key transforming tool to build up a hyoid bone model patten for analysis of volumetric change between control normal and study groups. In all subjects' images with the same set of osseous landmarks being determined on trans-sagittal view of CBCT. Shape analysis for three group of different dentofacial pattern was performed using Steiner's (ANB) angle analysis.

There were several steps performed for the hyoid outline reconstruction from surrounding hard tissue for construction for different type groups. Firstly, the skeletal bone scale threshold used. (Figure.1) Then the skeletal landmarks selected for the dentoalveolar and hyoid bone planes determination. (Figure.2).

After all plane's determination, the hyoid area cropped using growth growing tool then segmented and the hyoid bone planes outlined. (Figure.3) The conversion of the resulting vomer bone outline to the 3D analysis for each patient in all control and study group was performed. (Figure.4) all planes measurements of the shape difference of the hyoid bone described accurately with dentoalveolar malocclusions relations.

Finally, the hyoid morphometric significant differences and correlation statistically analyzed, to investigate if these measurements could be a contributory factor affecting malocclusion development.

Statistical analysis of the data was performed using SPSS statistics program for Windows (version 22.0, SPSS, Chicago, IL, USA). The Shapiro-Wilk normality test was applied. Also, Statistical Investigations NCSS (Number Cruncher Statistical System) 2007 (Kaysville, Utah, USA) program was used for statistical analysis. Student t-test was used in two group comparisons of the variables that showed normal distribution in comparison of descriptive statistical methods (mean, standard deviation, median, frequency, ratio, minimum, maximum) as well as quantitative data. Mann Whitney U test was used in two group comparisons of non-paired It was used. The Kruskal Wallis test and the Mann Whitney U test were used in the comparison of the three groups with no normal distribution. Spearman's Correlation Analysis was used to evaluate inter-variable relationships. The Fisher-Freeman-Halton Test was used for the comparison of qualitative variables. Significance was assessed at $p < 0.05$. To determine intra-observer reliability and assess cephalometric method error, duplicate 3D tracing and measurements of 25 randomly selected images were performed by the same investigator after 1 month. Random and standard errors were calculated by correlation, which showed values between 0.80 and 0.99, and paired samples t-test between first and second angular and linear measurements. No systematic errors were detected.

3. Results

The dimensional measurements according to the type of groups were examined statistically. There was no statistically significant difference between the mean ages of cases according to study groups ($p > 0.05$). Whereas; there was a statistically significant difference between groups ($p < 0.01$). There were highly significant differences ($p < 0.01$) between all skeletal parameters among different control and study groups as shown in (Table.2).

Almost of the hyoid bone skeletal parameters in relation to the maxilla base plane (ANS-PNS) were decrease whereas they were increased with and mandibular base plane skeletal parameter in severe malocclusion study group by values of (44,2±-57,41, 33,21±60,98) mm respectively. While the hyoid bone (Ho-Go) subgnathic distance parameter were decreased inversely proportional with (Ho-Mo) subgnathic distance parameter that were increased. (Table.2)

There were significant differences between the Hyoid bone subgnathic distance parameter represented by (H-Mo) and another subgnathic distance (H-Go) with the severity of malocclusion were ($p < 0.01$) respectively. (Table.2)

A positive correlation was shown also between the Hyoid parameters and dentoalveolar gnathic base parameter (Go-Mo) variables (0,504/0,020*) in severe group malocclusion. In contrast, there was no correlation between other hyoid bone components in controls.

(Table.3).

The dimensional volumetric change of 3D reconstruction models of the hyoid bone appeared highly significant differences in different groups in relation to the severity of malocclusion by values of (2090,3) mm3 that the vomer bone became larger in size in severe group (Type C). (Table.4).

Table 1: The reference points of 3D facial analysis.

Landmark	Definition
Nasion (N)	The junction between the nasal and frontonasal sutures
Sella (S)	The center of the Sella turcica on the midsagittal plane
Basion (Ba)	The most anterior curve of foramen magnum
Anteriornasal spine (ANS)	The most anterior point on the floor of nose
Posterornasal spine (PNS)	The most posterior point on the floor of nose
A point (A)	The deepest point between ANS and prosthion at the midsagittal plane of upper alveolus of upper incisors
B point (B)	The deepest point between pogonion and the alveolus of the lower incisors on the midsagittal plane
H point (Ho)	The most anterior-superior and medial point at Hyoid arch in all orthopanoromic view
Menton (Mo)	The most inferior and anterior point at lowermost level of anterior mandible symphysis body.
Gnathion point (Go)	The most inferior and posterior point at lowermost level of mandible angle body.

Table.2 The Dimensional Analysis of Study Groups

plan			Type C (n=88)	S (n=322)	p
ANS	Min-Max (Median) Mean±SDs	45,42-58,79 (54,3) 53,17±4,41	41,71- 48,96±6,41	0,001**	A> C
A-ANS	Min-Max (Median) Mean±SDs	7,22-15,6 (11) 11,13±2,48	5,53-20,13 14,17±3,00	0,002**	C>A
B-ANS	Min-Max (Median) Mean±SDs	10,50±2,85 6,37-15,11 (10,1)	6,37-15,11 (10,1) 15,84±4,72	0,001**	
Ho-PNS	Min-Max (Median) Mean±SDs	6,37-15,11 (10,1) 10,50±2,85	9,9-30,21 (14,6) 15,84±4,72	0,001**	
Ho-Go	Min-Max (Median) Mean±SDs	15,24-27,66 (21,7) 21,20±3,40	18,11- 23,65±3,18	0,049*C>A	
Ho-Mo	Min-Max (Median) Mean±SDs	34,33-46,03 (41,7) 41,27±3,54	25,91- 35,22±4,45	0,001** A> C	

Table. 3 The Correlation of Vomer Bone Variables with Skeletal Parameters.

Landmarks		Type Groups			
		Type S		Type C	
Hyoid	Skeletal	r	p	r	p
Ho	A-ANS	0,457	0,056	0,125	0,589
	ANS-PNS	0,701	0,001**	0,066	0,775
	B-ANS	0,492	0,038*	0,137	0,553
Ho	Mo-ANS	0,858	0,001**	0,346	0,124
	ANS-PNS	0,695	0,001**	-0,082	0,724
	Go-PNS	0,061	0,810	0,274	0,229
Ho	Mo-A	0,259	0,299	0,131	0,571
	Mo-Go	0,917	0,001**	0,092	0,693
	Mo-B	0,129	0,610	0,504	0,020*

ANS-PNS: Maxilla base plane, A-ANS: Anterior maxilla plane, B-ANS: Anterior mandibular plane, Mo-ANS: Anterior subgnathic bimaxillary relation bone, Go-ANS: posterior subgnathic bimaxillary relation, Mo-A: Maxilla dentoalveolar interrelation, Mo-Bo: Mandible base plane, Mo-B: Mandible dentoalveolar interrelation

r: Spearman's Correlation Coefficient *p<0,05 **p<0,01

4. Discussion

Orthopedic dentofacial harmony is an essential topic in the treatment of the malocclusion with surprising concept because of its interrelationships with the various distinct anatomical architectures. [15, 16] Recently, an affordable use of CBCT is not worthy applied in craniofacial applications [14, 17] but it wisely and widely applied for analysis of a broad spectrum of dentofacial discrepancy like dentofacial malocclusion complex. [18].

Conventional cephalometric 2D imaging gives a general idea about the patient problem in most cases. However, negative merits of craniofacial deformities are not clearly diagnosed and treated alone to suffice the defects. In Orthognathic/Orthodontics procedure planning, the position, size and relationships of craniofacial structures need to be determined accurately. These malocclusion confusing problems, although many investigators try to make three-dimensional reconstructions based on using two-dimensional posteroanterior and lateral cephalograms easier, but the reproducibility of measurements and sensitization has not been adequately used [19].

In this study, unlike previous studies that used a 2D conventional cephalometries alone or CBCT 3D image analysis with misdiagnosed Hyoid bone. Firstly, the parameter measured by using 2D cephalometries landmarks and planes determination then after the Hyoid bone posture and shape observed for the reconstruction of the 3D models without errors using algorithmic tools of Mimics 19.0 version software [20].

Superposition of anatomical structures or different magnifications in different regions, have not been observed frequently in the examining of the skeletal craniofacial structures. By that method facilities, the analyzing of the dentofacial complex revealed a clear accurate image in three-dimensional reality. Therefore, before orthodontic and orthognathic surgery procedures; The CBCT analysis can be used to evaluate incoming changes that might be reported with no complication and with steady treatment's outcome later [21].

When the dimensional changes of skeletal parameters evaluated, the Hyoid bone components (subgnathic distances, Supragnathic height relations) (Ho-Mo/ Ho-Go and Ho-PNS) shown with values (53,81±5,90, 42,94±5,92, 23,65±3,18, and 35,22±4,45) respectively highly proportional and significant differences with maxillary base length (ANS-PNS) and mandibular base length (Mo-Go) parameters among different study groups. However, The anterior maxilla plane (A-ANS) (B-ANS) were appeared the dentoalveolar impaction plane anteriorly (A-B) parameters decreased inversely but still the posterior plane obscure with OSA confusion analysis (14,17±3,00), (15,84±4,72) when the Hyoid bone forward displaced and elongated in the sever group malocclusion (TypeS).

Thus, a new finding of this study emphasized a strong correlation of the anterior impaction dentoalveolar profile with hyoid bone pattern with under the biodynamic effect of the skeletal dimensional changes. The displacement range of all hyoid bone parameters were between [3-5] mm in all planes with near value of (±4,72) mm. [13, 22] That results appeared to be parallel with the Da Costa's study with confidential evidence to the anatomical feature of anterior portion of maxilla segments. [23] (Table 3) (Figure 3).

Due to the hyoid bone morphology of the "U" shape, the anterior proximal segments have a close relation to the inframandibular masticatory structure that stretching anterior segment of hyoid bone arch and horns in a medial directional displacement toward mandibular base line. These observational findings appeared clearly with highly significant increase and positive correlation in the anterior maxilla region (ANS-PNS), (Ho-PNS), (Ho-Go) and (Ho-Mo) parameters in relation to the full length of Hyoid bone and mandibular base plane parameters were displaced in forward direction toward to relieve the severity of malocclusion. [24, 25] (Table.2, 3) (Figure 4).

On the other hand, the interesting interrelations of the hyoid bone with dentofacial architecture using 3D CBCT analysis has not revealed accurately in all previous studies and reviews such using linear triangular approach. In this study, by the application of creating 3D reconstruction model of the full skull and hyoid bone models provide the opportunity to analyze the hyoid bone with great accuracy and reproducibility.

The analysis of this study 3D models was developed by defining landmarks and planes initially then converted from 2D to 3D masks for accurate finding analysis. As a result, the hyoid bone seemed to be significantly larger in relation to the increase of severity among different study groups [26]. (Figure 1, 2).

That hyoid bone components analysis was reported with a meaningful limitation of this study retrospectively and less sample account. However, that study fact has an important orthodontic and surgical implementation because the pattern of anomalies and facial disharmony appeared almost varied between individuals even though a little dentofacial difference may be seen between each other's.

According to the findings of this study, the dimensional change and 3D pattern variations of hyoid bone were shown to be highly significant and correlated with a meaningful displacement to the skeletal dentofacial discrepancy by using 3D CBCT image analysis.

5. Conclusion

Under the limits of this study it can be concluded that: Three-dimensional analysis of the hyoid bone segments provide the clear evidence of the dentofacial pattern discrepancy related to malocclusion. To create an ideal treatment, plan the morphometric analysis for malocclusion with different dentofacial pattern should be evaluated.

In order to evaluate a more reliable relationship of hyoid bone with midface hypoplasia and dentofacial pattern discrepancy, further studies are still needed to be conducted.

Ethics Committee Approval: This study was approved by Clinical Researches Ethic Committee of Alfarahidi University, Faculty of Dentistry.

Informed Consent: Written informed consent was obtained from patients who participated in this study.

Author contributions: Concept - A.M., K.B., Ş.E.Y.; Design - A.M., K.B., Ş.E.Y.; Supervision A.M., K.B., Ş.E.Y.; Materials – A.M., K.B., Ş.E.Y.; Data Collection and/or Processing - A.M., K.B., Ş.E.Y.; Analysis and/or Interpretation - A.M., K.B., Ş.E.Y.; Literature Search A.M., Ş.E.Y.; Writing A.M., K.B., Ş.E.Y.; Critical Reviews - A.M., K.B., Ş.E.Y.

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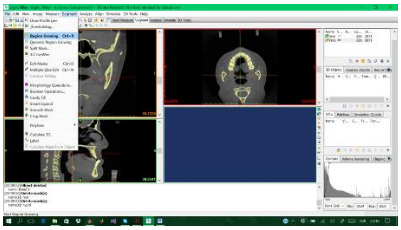

Figure 1. Landmarking and Dimensional Determination.

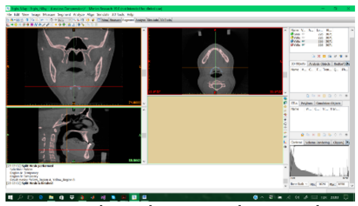

Figure 2. Horizontal and Vertical Coordination Planes.

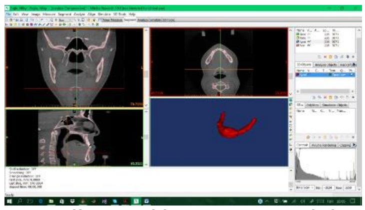

Figure 3. Full Hyoid bone 3D model analysis.

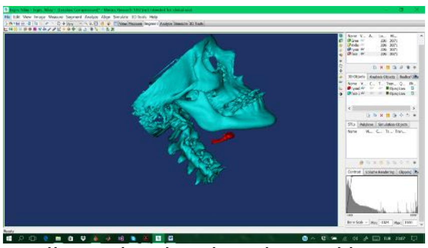

Figure 4. Full Head with splitted Hyoid bone 3D model Reconstruction.

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