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Analysis of upper airway measurements and cephalometric measurements using two-dimensional Cephalometry and three-dimensional Computed Tomography in patients with skeletal Class III malocclusion.

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Abstract

Introduction and Objective. Skeletal Class III malocclusion, characterized by complex craniofacial irregularities, often necessitates orthognathic interventions for its resolution. The aims of the study were 1) to comprehensively assess the dimensions of the upper airway and cephalometric measurement, 2) to evaluate the values of upper airway dimensions in a three-dimensional context, in correlation with cephalometric measurements acquired in a two-dimensional format among patients afflicted with skeletal Class III malocclusion.

Materials and Method. Medical records were analysed of 18 patients diagnosed with skeletal Class III malocclusion undergoing combined orthodontic-surgical treatment. Cephalometric measurements were extracted from lateral cephalometric radiographs, and upper airway dimensions comprehensively evaluated using multi-slice spiral computed tomography scans and OsiriX software. Based on the results statistical analysis was performed.

Results. No statistically significant correlations was found between the cephalometric measurements using two-dimensional cephalometry and the upper airway dimensions using three-dimensional computed tomography in patients with skeletal Class III malocclusion.

Conclusions. No direct influence of skeletal Class III malocclusion on upper airway dimensions was observed in study participants. Incorporating additional factors, such as soft tissue characteristics and functional aspects, may provide a more comprehensive understanding of the relationship between skeletal malocclusion and upper airway dimensions.

Key words

Angle Class III, Cephalometry, malocclusion, upper airway dimensions

INTRODUCTION

A significant portion of patients requiring orthognathic treatment consists of individuals with skeletal Class III malocclusion, which occurs less frequently than Class II malocclusion but more commonly requires surgical treatment [1, 2]. The preferred treatment for these patients, especially in cases of severe malocclusion, is combined orthodontic-surgical treatment. The choice of surgical procedure depends on the required changes in the position of the jaw bones and teeth, as well as the expected changes in facial soft tissues. In cases of complex malocclusions with disturbances in multiple planes, two-jaw surgeries are necessary. Single-jaw surgeries are reserved for minor abnormalities involving a single bone [3]. They were preferred in past years but are now performed less frequently and mainly reserved for cases where the cause of the Class III malocclusion is a developmental disorder affecting only the maxilla or mandible [4]. The repositioning of the jaw bones during orthognathic surgery leads to improvements in occlusal relationships and the restoration of proper function within the stomatognathic system. Simultaneously, there are changes in the position of surrounding soft tissues, including muscles attached to the maxilla and mandible. Additionally, the repositioning of the hyoid bone and its associated muscle group is also significant. It appears that both upper airway measurements and cephalometric measurements are significant for a comprehensive assessment and treatment planning of patients with skeletal Class III malocclusion. They enable practitioners to conduct a precise analysis and understanding of the issue, allowing for appropriate therapeutic approaches that may involve both orthodontic and surgical treatments to improve breathing function and facial aesthetics.

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OBJECTIVE

The aim of the study was to evaluate the values of upper airway dimensions and cephalometric measurements in patients with skeletal Class III malocclusion. Based on the available medical documentation and imaging studies, the following assessments were planned:

1. Determination of the maxillary and mandibular positions relative to each other, and relative to the cranial base using selected cephalometric measurements.
2. Selected dimensions of the upper airway prior to the surgical procedure.
3. Relationships between preoperative cephalometric measurements and values of upper airway dimensions

MATERIALS AND METHOD

The medical documentation of patients with craniofacial abnormalities treated at the Department of Maxillofacial Surgery of the Medical University of Lublin between 2013 – 2017 was used as the research material. During this period, a total of 100 patients underwent procedures due to jaw deformities, of which 18 patients met the inclusion criteria for the present study. The inclusion criteria were:

1. Diagnosis of skeletal Class III malocclusion (maxillary hypoplasia and excessive anterior mandibular protrusion) based on clinical examination, radiological assessment, and cephalometric analysis.
2. Qualification for combined orthodontic-surgical treatment following the standard protocol, involving orthodontic decompensation of the patient in the first stage, and bimax surgery in the second stage.
3. Pre-operative imaging conducted with multi-slice spiral computed tomography in a supine position, using a soft collar in an intermediate position to stabilize the head.

All patients included in the study underwent orthodontic treatment or had their treatment consulted by the physicians from the Department of Orthodontics at the Medical University of Lublin. To diagnose skeletal Class III malocclusion, indicating the morphological nature of the deformity, cephalometric analysis was performed using standard lateral cephalometric radiographs using the OrtomedEvo software (Infomed).

The following angular measurements expressed in degrees were utilized for cephalometric analysis.

1. SNA – the angle formed between the SN and NA lines, determining the anteroposterior position of the maxilla relative to the cranial base.
2. SNB – the angle formed between the SN and NB lines, determining the anteroposterior position of the mandible relative to the cranial base.
3. NL/NSL – the angle formed between the NL and NSL lines, indicating the inclination of the maxilla in relation to the cranial base.
4. ML/NSL – the angle formed between the ML and NSL lines, indicating the inclination of the mandible in relation to the cranial base.
5. ArGoGn – the angle formed between a tangent to the posterior border of the mandibular ramus and a tangent to the mandibular body, determining the so-called mandibular angle.

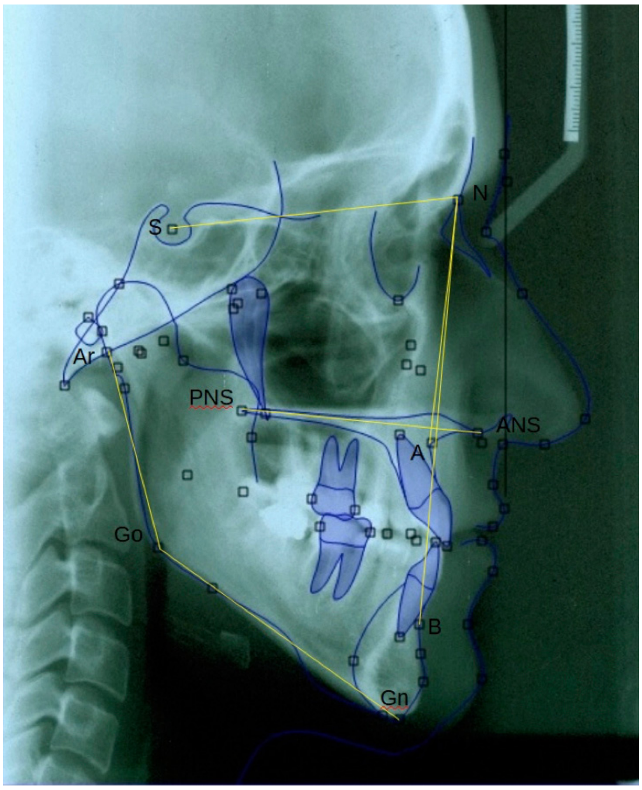

Figure 1. Angels used in cephalometric analysis (original work)

The computer tomography scans were performed at the Second Department of Medical Radiology of the Medical University of Lublin, and subsequently archived in the hospital's Picture Archiving and Communication System (PACS). The scans were conducted using a 64-row CT scanner, General Electric Light Speed VCT (GE Medical Systems, USA), with a spiral technique and slice thickness of 1.25 mm, using a pitch factor of 1. Quantitative evaluation of specific dimensions of the upper airway (UA) was performed on these images. The measurements were taken on a diagnostic console Mac Pro using OsiriX software (Pixmeo SARL). The measurements were made on scans in the soft tissue window in both the horizontal (Frankfurt) and sagittal planes. The most commonly reported reference points in the international literature on upper airway dimension assessment were selected [5, 6].

The upper boundary of the examined area was defined as the horizontal plane called the posterior nasal spine plane. Simultaneously, the surface of the airway cross-section at this level in the horizontal plane was identified as characteristic of the nasal portion of the upper airway.

To determine the surface of the cross-sections of the oral part of the upper airway, a horizontal plane passing through the lowest point of the soft palate (called soft palate plane or uvula plane) was used.

The lower boundary of the examined area and the surface of the upper airway cross-section in the laryngeal part of the throat were determined by the plane passing through the base of the epiglottis (epiglottis plane). As a result of this, a two-dimensional surface of the airway cross-section was obtained at the level of the nasal part (referred to as S1) (Fig. 2), oral part (referred to as S2) (Fig. 3), and laryngeal part (referred to as S3)(Fig. 4) of the upper airway. This was measured in square centimeters.

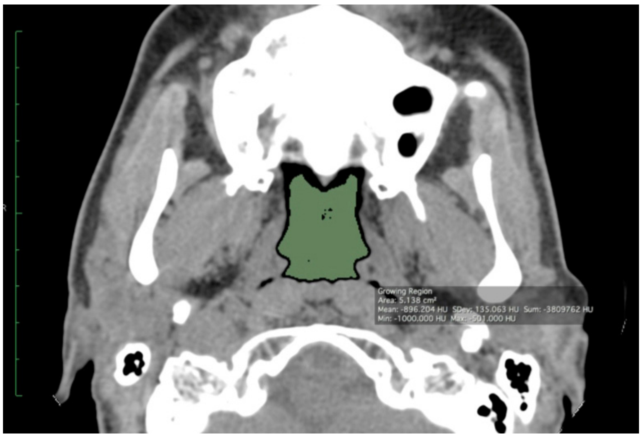

Figure 2. Airway cross-section of the nasal part (S1) (courtesy of Second Department of Medical Radiology of the Medical University of Lublin)

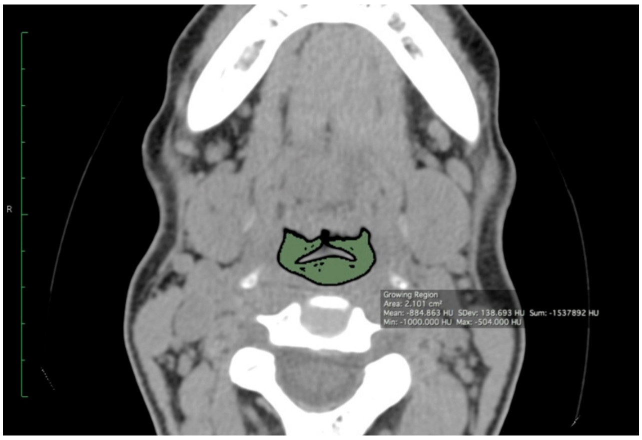

Figure 3. Airway cross-section of the oral part (S2) (courtesy of Second Departmrnt of Medical Radiology of the Medical University of Lublin)

Figure 4. Airway cross-section of the laryngeal part (S3) (courtesy of Second Departmrnt of Medical Radiology of the Medical University of Lublin)

Measurements were also taken of the distance between the planes passing through the posterior nasal spine and the base of the epiglottis, determining this dimension as the length of the upper airway, denoted as L (expressed in centimeters) (Fig. 5). Subsequently, using the capabilities of OsiriX software, the three-dimensional volume of the examined upper airway area was calculated in cubic centimeters (referred to as V) (Fig. 6).

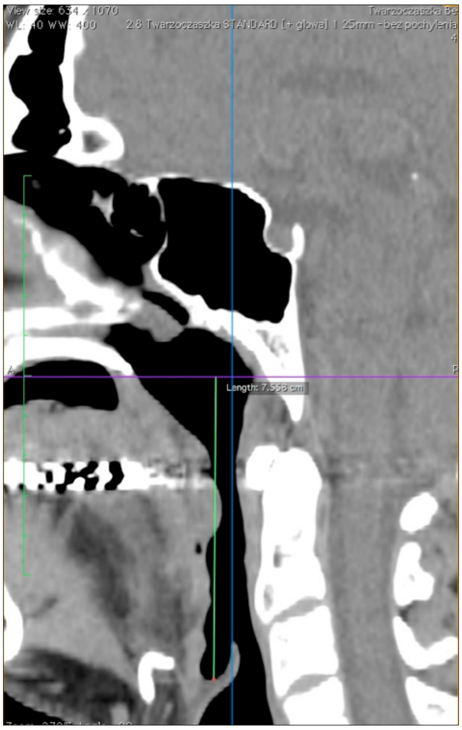

Figure 5. Length of the examined upper airway segment (L) (courtesy of Second Departmrnt of Medical Radiology of the Medical University of Lublin)

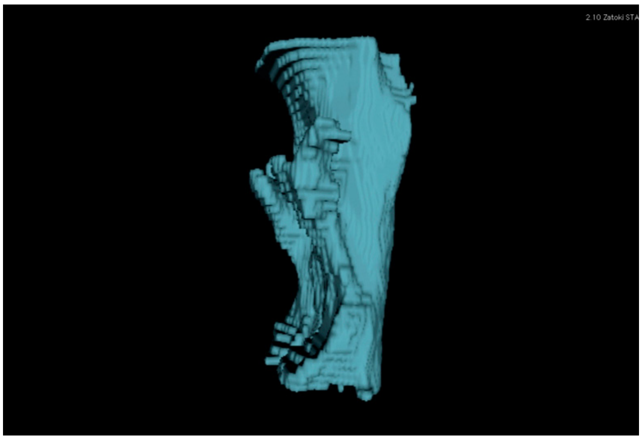

Figure 6. Three-dimensional volume of the examined upper airway area (V) (courtesy of Second Departmrnt of Medical Radiology of the Medical University of Lublin)

The decision to exclude a control group of patients with skeletal Class I and CT multi-row data from our study was necessitated by practical limitations within the available dataset. The inclusion of a control group would have entailed access to data that, regrettably, was unavailable in context due to the absence of CT multi-row scans for patients with skeletal Class I.

While a comparative analysis of both Class I and Class III groups would undoubtedly provide a more comprehensive understanding of upper airway dimensions, the current scope of the study was restricted to Class III malocclusion due to the afore-mentioned practical constraints.

Sstatistical analysis was performed based on the obtained results. The values of the analyzed measurable parameters were presented using the mean values and standard deviations;

the normality of variable distribution in the studied groups was assessed using the Shapiro-Wilk test. A significance level of $p < 0.05$ was adopted, indicating the presence of statistically significant differences or dependencies. Based on Statistica 9.1 software (StatSoft, Poland), a database was created, and statistical analyses performed.

RESULTS

Based on the available medical documentation, measurements of selected cephalometric parameters characteristic of skeletal Class III malocclusion were performed. The results obtained, with accuracy to one decimal place, are presented in the Table 1.

Table 1. Presents the values of cephalometric measurements (SNA, SNB, ML/NSL, NL/NSL, ArGoGn angles) for patients numbered from 1 to 18 (P1-P18). Abbreviations and acronyms in text

	SNA	SNB	NL/NSL	ML/NSL	ArGoGn
P1	80.4	88	4.8	32.1	125
P2	80.4	82.4	14.7	31.5	129.7
P3	76.6	76.8	14.9	40.1	128.8
P4	84.4	86.4	6.6	30.2	133
P5	83.6	87.9	25.4	32	136.4
P6	82.6	88.4	28	26.3	137.2
P7	79.5	81	20.4	32.2	131
P8	80.1	80.9	30.3	43	122.2
P9	76.8	82.1	12.7	36.5	136.1
P10	78.3	79.9	25	37.8	122.7
P11	80.3	82.4	12.4	46.8	138.7
P12	85.9	90	3.2	23.2	130.8
P13	77	78.5	29.6	31.7	133.3
P14	75.3	78	9	44	147.7
P15	82.8	92.78	6.4	27.8	129.9
P16	74.8	79.7	10.5	38.3	124.2
P17	80.7	87.9	14.9	31	130.8
P18	88.9	90.7	7.6	34	124.7

Using the method described above, based on measurements taken from consecutive computer tomography images, specific dimensions of the upper airway were obtained and recorded with an accuracy of two decimal places (Tab. 2).

Based on the conducted statistical analysis, no statistically significant correlations were observed between the investigated variables of upper airway dimensions and cephalometric parameters.

DISCUSSION

The present study aimed to investigate the cephalometric parameters characteristic of skeletal Class III malocclusion and the dimensions of the upper airway using medical documentation and computed tomography images. The results obtained provide valuable insights into the relationship between these variables.

Firstly, the measurements of selected cephalometric parameters revealed specific characteristics associated with skeletal Class III malocclusion, such as the values of the SNA and SNB angles. Although Ahmed at al. (2018) and Alassiry et al.(2020) consider the ANB to be the most authoritative angle for analysing sagittal plane defects, in present study, this angle was not used because it is an angle that only determines the mutual position of the maxilla and mandible, without reference to the base of the skull, while its value is directly derived from the values of the SNA and SNB angles that were included in the current analysis [7, 8].

Table 2. Presents the measurements of upper airways (V, S1, S2, S3, L) in patients from 1 to 18 (P1-P18). Abbreviations and acronyms in text

	V	S1	S2	S3	L
P1	26.5	5.35	4.35	5.51	5.93
P2	17.77	5.24	1.49	3.3	6.54
P3	19.74	4.91	4.57	1.49	5.32
P4	18.9	7.44	2.99	3.36	4.64
P5	27.1	9.26	5.44	4.42	5.02
P6	30.98	6.55	6.31	4.85	8
P7	19.41	4.97	1.91	4.66	5.15
P8	21.71	4.7	4.96	4.84	5.03
P9	14.55	3.3	2.29	3.3	5.09
P10	15.43	4.01	2.39	3.32	5.31
P11	24.96	5.2	4.6	3.3	5.35
P12	14.95	5.83	2.31	3.02	5.01
P13	16.51	2.23	2.28	2.63	6.28
P14	12.54	4.39	1.9	2.53	5.01
P15	17.23	3.85	2.86	2.94	5.68
P16	23.81	5.9	5.56	4.09	4.7
P17	19.73	4.22	2.42	5.35	5.67
P18	9.45	3.36	2.11	3.4	4.96

Table 3. Presents the correlations between measurements of upper airways (V, S1, S2, S3, L) and cephalometric measurements (SNA, SNB, ML/NSL, NL/NSL, ArGoGn angles). Marked correlation coefficients are significant at $p < 0.05000$. N=18 (missing data were handled by cases removal). Inclusion condition: v1=1. Abbreviations and acronyms in text

Variable	V	S1	S2	S3	L
SNA	-0.0644	0.2936	-0.0559	0.1863	-0.1701
	p=0.800	p=0.237	p=0.826	p=0.459	p=0.500
SNB	0.0963	0.2563	0.0342	0.3616	-0.0744
	p=0.704	p=0.305	p=0.893	p=0.140	p=0.769
NL/NSL	0.3306	0.0012	0.2966	0.2107	0.0755
	p=0.180	p=0.996	p=0.232	p=0.401	p=0.766
ML/NSL	-0.0479	-0.2020	0.1575	-0.2114	-0.1284
	p=0.850	p=0.421	p=0.533	p=0.400	p=0.612
AnGoGn	0.2201	0.1440	-0.0288	0.1468	-0.1190
	p=0.380	p=0.569	p=0.910	p=0.561	p=0.638

Additionally, utilizing computer tomography images allowed accurate determination of the dimensions of the upper airway. The detailed measurements obtained provided valuable quantitative data, enhancing understanding of the anatomical features of the upper airway in individuals with skeletal Class III malocclusion.

However, despite the comprehensive analysis conducted, in the current study no statistically significant correlations were found between the investigated variables of upper airway dimensions and cephalometric parameters. This suggests that the based solely on cephalometric measurements, which provided information about the extent and severity of skeletal Class III malocclusion, it was not possible to predict the dimensions of the upper airway. Other factors, such as soft tissue characteristics which can be clearly visualized on CT scans but not on cephalometric analysis, may play a more important role in determining airway dimensions.

Due to the small size of the study group, it was decided not to divide the patients by gender, although an interesting perspective on the subject is presented by Bastir at al. Their study found that sexual dimorphism exists in the soft tissue morphology of the upper airway, and that soft tissue characteristics play a significant role in determining airway dimensions. In conclusion, 3D analysis of soft tissue morphology can provide valuable insights into the relationship between soft tissue characteristics and airway dimensions [9]. In relation to the dimensions of the upper airways, the study by Alfawzan indicates that the angular orientation of the mandible can also influence these dimensions [10]. Statistically significant differences were found in airway dimensions among patients with different values of the Frankfort Mandibular Plane Angle (FMA). Specifically, the width of the airways measured at both the level of the soft palate and the lower border of the mandibular body, was smaller in patients with high FMA values, compared to those with average and low values of this angle.

Regarding differences with the present study, the following should be noted: 1) the Alfawzan study was conducted only in patients with Class I skeletal malocclusion; 2) the study was based on lateral cephalograms, which are two-dimensional images as opposed to the three-dimensional images in the current study. This, in itself, is a limitation because it allows for linear assessment rather than surface or spatial evaluation.

It is worth mentioning studies that assessed upper airway sizes in patients with Class I and II skeletal malocclusion in relation to cephalometric measurements. Although the authors related these dimensions only to the ANB angle (not utilized in the current study), they arrived at noteworthy conclusions. According to Dr. Paul et al., the size of the upper airway in patients with Class II skeletal malocclusion is statistically smaller than in patients with Class I skeletal malocclusion [11]. Similar conclusions were reached by Aby et al., even though their results did not show statistical significance [12]. It should be emphasized that both studies were conducted based on three-dimensional diagnostic methods (CBCT).

Several studies have investigated the relationship between cephalometric measurements and upper airway measurements in patients with OSA**.** Emsaeili at al. found that patients with OSA had a narrower upper airway and a more retruded mandible compared to control subjects. However, in their study, most skeletal variables, such as the anteroposterior relationship of the jaws and jaw rotation, were not significantly different between the two groups [13].

A meta-analysis by Neelapu at al. investigated the relationship between craniofacial dimensions in lateral cephalometric images and the occurrence of obstructive sleep apnea (OSA) [14]. The authors identified correlations between the presence of reduced pharyngeal airway dimensions, inferiorly placed hyoid bone, and increased anterior facial height with the occurrence of OSA in adult patients, compared to the control group.

Additionally, it's worth mentioning the research conducted by Campos at al. [15]. According to their findings, a more effective method for assessing potential airway obstructions in patients with OSA, compared to computed tomography and lateral cephalometry, is drug-induced sleep endoscopy (DISE). DISE allows for a dynamic assessment of the airways under conditions closely resembling a patient's sleep, and may serve as a valuable tool for further investigations in this field.

With advancements in technology enabling the use of modern three-dimensional imaging and the utilization of increasingly advanced software, the efficient and straightforward assessment of upper airway dimensions is now possible for each individual patient. In the opinion of the authors of the present stusy, such an assessment should be performed as part of the treatment qualification process. It is important to note that for the detailed diagnosis of a particular patient, other methods, such as polysomnography or DISE can also be used.

CONCLUSIONS

In the presented study, no significant correlations were observed between the measured airway dimensions and measured cephalometric parameters: SNA, SNB, ML/NSL, NL/NSL and ArGoGn, which basically indicates that there is no association between 2D lateral cephalogram values and 3D volumetric values. This suggests that in some patients the anatomical characteristics of the upper airway may not be directly influenced by skeletal Class III malocclusion. Future research should consider incorporating additional factors, such as soft tissue characteristics, functional aspects, to gain a more complete understanding of the complex interplay between skeletal malocclusion and upper airway dimensions.

The findings of this study have several clinical implications for the management of patients with skeletal Class III malocclusion: 1) Treatment Planning – recognizing the complex nature of skeletal Class III malocclusion, treatment planning should be personalized, considering factors beyond cephalometric measures, including, for example, soft tissue characteristics and function.

2) Personalized Care – given the lack of clear correlations, treatment strategies should be adapted to each patient's unique craniofacial and airway characteristics. 3) Airway Assessment – advanced imaging for upper airway evaluation can assist in identifying potential issues, guiding surgical decisions for optimal outcomes.

Despite the valuable insights gained from this study, several limitations should be acknowledged: 1) Sample Size – the relatively small sample may restrict generalizability. Future studies with larger, diverse cohorts are needed. 2) Data Sources – the study used existing records which may vary in quality, therefore, future research with standardized data collection is advisable. 3) Soft Tissue Analysis – incorporating soft tissue assessment in cephalometry in future research could provide a more comprehensive view of craniofacial dynamics.

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