

Comparative analysis of cephalometric K-angle index of mixed dentition patients

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ABSTRACT

Aim: To analyse the effectiveness and reliability of $\angle K$ -angle cephalometric index usage in mixed dentition and to assess the correlation between different types of facial skeleton growth patterns.

Materials and Methods: 52 high-quality cephalograms were randomly selected from the archives of the Bogomolets National Medical University Dental Medical Centre and divided into three groups according to facial skeleton growth patterns and into subgroups according to Engle's malocclusion classes. Multifactorial analysis of variance (ANOVA) was used to identify statistical differences between the mean angular values of studied groups; a p -value ≤ 0.05 was considered statistically significant. Pearson's correlation coefficient was used to assess the correlation between angles.

Results: According to our study results, statistically significant correlation was found among patients in the first group between ANB and K angles and neutral growth type ($p=0.005$); significant correlation was found between the K and APDI angles and horizontal growth pattern ($p=0.002$); statistically significant correlation was found between the APDI parameter and both angles with vertical growth ($p=0.001$). According to the results of multifactorial ANOVA analysis of the mean values of the studied angles, there were no statistically significant differences in the $\angle K$, $\angle ANB$, and APDI parameters between all groups at the level of $p \leq 0.05$.

Conclusions: The K-angle revealed to be the most valid and reliable indicator of sagittal jaw discrepancy assessment among all cephalometric parameters. $\angle K$ index can be a full-fledged alternative to ANB angle during mixed dentition.

KEY WORDS: orthodontics, cone-beam computed tomography, 3D cephalometrics, mixed dentition, cephalometric analysis

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INTRODUCTION

Malocclusion occurs as a result of deviations in the normal growth of the craniofacial region in the sagittal, vertical or transversal planes [1]. Sagittal malocclusion is usually the most common orthodontic problem and has significant functional, psychological and aesthetic consequences [2]. The formation of skeletal sagittal malocclusion background of differences in the development of the upper or lower jaw often requires complex and expensive treatment methods in permanent occlusion; therefore, early detection of its signs is an essential step in treatment effectiveness improvement.

Planning of orthodontic treatment depends on precise diagnosis of skeletal discrepancies, the patient's facial skull growth type, and the (dentoalveolar) parameters of the dentition [1-16]. X-rays are the most effective methods to analyse skeletal discrepancies in the sagittal plane, as accurate assessment of the morphology of various skeletal components, as well

as their relationship with surrounding tissues [2, 8]. For the diagnosis of sagittal discrepancies at the level of the skeleton, teeth and soft tissues, the standardised lateral cephalogram has become the gold standard, but 3D cephalometric studies are increasingly being used for this purpose. The results of cephalometric calculations using different approaches are diagnostically significant and reliable for understanding the basic morphological characteristics of patients' skeletal and dental components. They are recommended to be used in combination with each other to obtain a more complete cephalometric diagnostic perspective and to develop an orthodontic treatment plan taking into account the characteristics of each individual. Sam et al.'s systematic review [15] evaluated the high accuracy of various 3D cephalometric landmarks in CBCT imaging. They came to the conclusion that deep learning techniques for automated 3D cephalometric landmarking produced high-accuracy results of modern orthodontic diagnostics [11-17].

Among the common indicators in the diagnosis of sagittal occlusion anomalies in orthodontics, it is customary to consider the ANB angle [4] of Steiner's cephalometric analysis, which shows changes in the position of the jaw bases relative to the skull base, as well as the presence of sagittal discrepancies in their sizes. However, to determine a complete orthodontic diagnosis, it is still necessary to perform a differential diagnosis between dental-alveolar and gnathic forms of occlusion pathology. For this purpose, orthodontists use the APDI parameter according to Kim's cephalometric analysis, which greatly facilitates the diagnostic process [5].

Although the ANB angle is widely used as a reliable indicator of the anteroposterior relationship of the jaws, to date, many famous researchers have conducted studies related to assessing the stability of the ANB angle in connection with changes in growth and instability of the N point position, which affects the size and clarity of the ANB angle during jaw growth [4, 5].

New linear and angular measurements for assessing sagittal discrepancy of both upper and lower jaw bases are proposed in many recent studies: YEN angle, BETA angle, W angle, K angle, etc. [6-9]. Among them, the K-angle illustrates a new strategy in this direction of 3D cephalometry development, which requires more comprehensive research. A K-angle value of 40° to 46° indicates a Class I skeletal occlusion, a value above 46° indicates a Class III skeletal occlusion, and a value below 40° indicates a Class II skeletal occlusion [3].

It has been proven that angle K is a reliable indicator in the permanent occlusion period [3], but the question of the reliability of using this angular indicator in mixed occlusion, depending on the types of facial skull growth, remains poorly understood and requires more detailed and in-depth study.

AIM

This study aimed To analyse the effectiveness and reliability of $\angle$ K-angle cephalometric index usage in mixed dentition and to assess the correlation between different types of facial skeleton growth patterns.

MATERIALS AND METHODS

52 case histories of patients with mixed dentition aged 7 to 11 years (29 females and 23 males; mean age = 8.9 ± 1.2) with high-quality 3D cephalograms, were randomly selected from the archives (of the Dental Medical Centre of the Bogomolets National Medical University for the period from 2021 to 2024. The study was approved by the Bioethics Committee of Bogomolets National Medical University.

The distribution into research groups was based on the available types of facial skull growth (neutral, horizontal, vertical) according to the results of Björk-Jarabak cephalometric analysis. Each of the research groups was divided into two subgroups depending on the class of malocclusion (classes I and II according to Angle).

The criteria for inclusion in the study were: the presence of gnathic or combined Class 1 and 2 malocclusion form according to Angle, and the presence of the first permanent molars before the start of treatment. Exclusion criteria included patients outside the age range, with severe general somatic diseases, psychoemotional disorders, and a group of individuals with Class III sagittal malocclusion according to Angle, due to an insufficient statistically significant sample size for the study.

For accurate determination of anthropometric points and precise measurement of ANB, APDI, and K angles, high-quality 3D cephalograms generated using cone beam computed tomography (CBCT) were selected. The 3D images were obtained using a 64-slice multi-detector tomograph "NewTom Giano HR PROFESSIONAL" manufactured by NewTom (Italy). Technical characteristics of the device (according to the device passport): voltage 60–90 kV, current 1–10 mA (pulse), exposure time 1.6–10 s, voxel size 0.68–300 μ m, radiation exposure during the acquisition of 3D images of the facial skull reaches only 30 microSieverts, which is the lowest among modern tomograph models, since this tomograph has a special SafeBeam mode with radiation dose coNGPol.

Multifactorial analysis of variance (ANOVA) was used to determine statistically significant differences in the angles studied in the three groups. Pearson's correlation coefficient was used to correlate the ANB angle with the K-angle. The results of measuring angular parameters on 3D cephalograms were statistically processed to determine the arithmetic mean (X) and standard deviation (SD) of the angular indicator and its standard error (m). A 95% confidence interval (95% CI) was calculated for the assessment. The collected data were analysed using EZR v. 1.66 (a graphical user interface for R statistical software version 4.3.1 developed by the R Foundation for Statistical Computing in Vienna, Austria) [10].

RESULTS

The first study group included 25 individuals (14 female and 11 male) with a neutral facial skeleton growth pattern (NGP), which was assessed by the total Björk angle and the ratio of posterior facial height to anterior facial

Table 1. Patients’ randomisation with different facial skeleton growth patterns by gender, malocclusion, age and mixed dentition stage (N,%)

Gender	Group 1 (neutral pattern)		Group 2 (horizontal pattern)		Group 3 (vertical pattern)	
	N abs	(%)	N abs	(%)	N abs	(%)
Female	14	53,8	12	70,6	3	70
Male	11	42,3	5	29,4	7	30
Malocclusion Class	N abs	(%)	N abs	(%)	N abs	(%)
Class I	12	23,07	2	3,89	4	7,7
Class II	13	25	15	28,8	6	11,54
Mixed Dentition	N abs	(%)	N abs	(%)	N abs	(%)
Early Stage	20	57,1	10	28,6	5	14,3
Late Stage	5	29,4	7	41,2	5	29,4
Age (years)	X	SD	X	SD	X	SD
	8,46	± 1,58	8,9	± 1,21	9,07	± 1,97

Source: compiled by the authors of this study

Table 2. Results of K-angle multifactorial ANOVA statistical analysis in different facial skeleton growth patterns (N, SD)

Growth pattern	N	Mean value	Standard deviation	Dispersive analysis of variance (ANOVA)	P value
Neutral	15	40,28	± 1,24	1.325	0.184
Horizontal	7	39,5	± 1,19		
Vertical	10	37,7	± 1,33		
Gender	N	Mean value	Standard deviation	Dispersive analysis of variance (ANOVA)	P value
Female	14	40,1	± 1,25	1.336	0.129
Male	11	39,6	± 1,27	1.338	0.129
Malocclusion class	N	Mean value	Standard deviation	Dispersive analysis of variance (ANOVA)	P value
Class 1	12	41,5	± 1,4	1.327	0.147
Class 2	13	38,6	± 1,2	1.329	0.147
Mixed Dent. Stage	N	Mean value	Standard deviation	Dispersive analysis of variance (ANOVA)	P value
Early	20	41,2	± 2,8	1.330	0.165
Late	5	40,9	± 2,3	1.330	0.165

Source: compiled by the authors of this study

height (PFH/AFH) according to Jarabak’s analysis. The second group included 17 children (5 female, 12 male) with a horizontal facial skeleton growth pattern (HGP) ($\angle\text{Sum} \leq 391^\circ$, PFH/AFH ≥ 0.66), while the third group included 10 patients with a vertical (VGP) facial skeleton growth pattern ($\angle\text{Sum} \geq 401^\circ$ and PFH/AFH ≤ 0.61). For NGP, HGP and VGP, the corresponding mean age and standard deviation were 8.46 ± 1.58 , 8.9 ± 1.21 and 9.07 ± 1.97 , respectively, and did not differ significantly according to ANOVA multivariate analysis of variance ($p > 0.05$). In the initial subgroups of the study groups, patients with class 1 malocclusion according to Angle were identified, while in the subsequent subgroups, patients with class 2 malocclusion were observed.

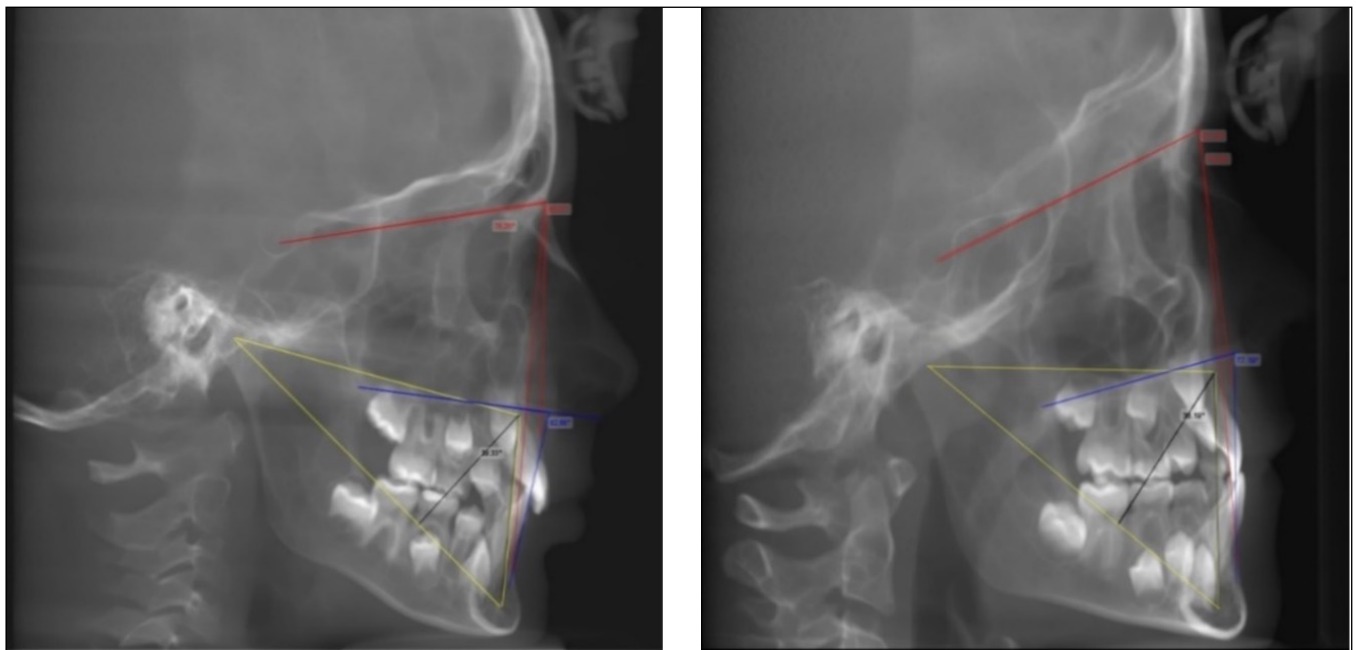
According to the results of the sample composition analysis (Table 1), it should be noted that girls prevailed in the study group 1, 14 persons (53.8%), compared to the number of boys, 11 persons (42.8%), Group 2 was also dominated by girls, 12 persons (70.6%), compared to 5 boys (29.4%). At the same time, in study group 3, on the contrary, the number of boys was 2.3 times greater: 7 (70%) against 3 (30%). It was found that 34 patients had Class II malocclusion according to Angle, which accounted for 65.4% of the total number of subjects, while only 18 children had Class I malocclusion according to Angle (34.6%). In early mixed dentition, NGP was found in 20 individuals (57.1%), HGP in 10 children (28.6%), and VGP was observed in only 5 patients (14.3%).

Table 3. Results of multifactorial ANOVA statistical analysis of patients' studied angles in different facial skeleton growth patterns

Cephalometric index	Growth pattern	Angle value	Normal value	Dispersive analysis of variance (ANOVA)	P value
$\angle K$	NGP	39,3°	43±3°	75.461	0.005
$\angle ANB$	NGP	4,6°	2±2°	74.885	0.005
APDI	NGP	82,1°	81.4± 3,8°	75.261	0.125*
$\angle K$	HGP	40,6°	43±3°	73.565	0.002
$\angle ANB$	HGP	2,5°	2±2°	73.785	0.08*
APDI	HGP	77,2°	81.4± 3,8°	74.273	0.002
$\angle K$	VGP	35,7°	43±3°	74.653	0.001
$\angle ANB$	VGP	2,5°	2±2°	74.658	0.001
APDI	VGP	77,2°	81.4± 3,8°	74.624	0.001

*- non-significant value

Source: compiled by the authors of this study

**Fig. 1.** A-lateral cephalogram of a patient with NGP; B-patient's lateral cephalogram with HGP

Picture taken by the authors

A strong correlation was found between the K angle, ANB angle, and Kim's APDI analysis parameter, although no direct statistical correlation was found between the ANB angle under study and the horizontal type of facial skull growth, which was predominantly due to shortening of the premaxilla, the basis of the upper and/or lower jaw, as well as shortening of the lower jaw branch in patients with different types of facial skull growth.

For groups with neutral growth, horizontal growth and vertical growth, the mean value of angle K and standard deviation were 40.28 ± 1.24 , 39.5 ± 1.19 and 37.7 ± 1.33 , respectively (Table 2). In addition, the K angle values in the groups were not affected by the

age of the children ($p = 0.184$), gender ($p = 0.129$), malocclusion class according to Engle ($p = 0.184$) and periods of mixed dentition ($p = 0.165$).

According to the results (Table 3) of the comparative analysis conducted in patients with NGP (Fig. 1 A) of the facial skull, a direct statistically significant correlation was found between the ANB and K angles and this type of growth ($p=0.005$), but no statistically significant correlation was found between the neutral growth type and the APDI parameter; in patients with HGP (Fig. 1 B), a direct statistically significant correlation was found between the K and APDI angles and this growth type ($p=0.002$), however, no statistically significant correlation ($p=0.08$) was found between the horizontal

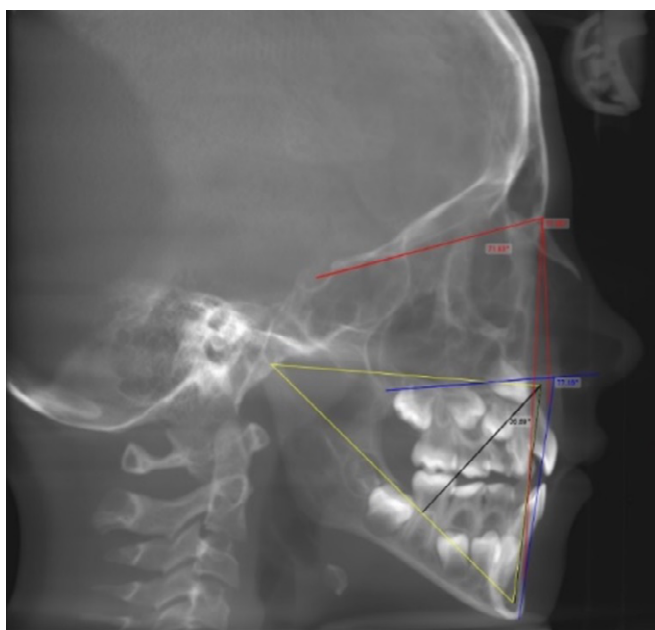


Fig. 2. 3D lateral cephalogram of a patient with VGP

Picture taken by the authors

growth type and the ANB angle, which is associated with the detection of sagittal apical base decrease of the upper jaw; in patients with VGP (Fig. 2), we found a direct statistically significant relationship between the APDI parameter and both angles studied ($p=0.001$), without detected sagittal apical base decrease of the jaws, which confirms previously published studies on the reliability of using the K angle in cephalometric analysis of orthodontic patients in the permanent occlusion period [1, 3, 6–9, 16].

Thus, no statistically significant differences in $\angle K$, $\angle ANB$, and APDI between the three study groups were found at the level of $p \leq 0.05$. We did not find strong correlations between angles K, ANB, APDI and early mixed occlusion ($r=0.231$; $p>0.05$), as well as late mixed occlusion ($r=0.224$; $p>0.05$) according to Pearson's coefficient.

DISCUSSION

In Ukraine, class 2 malocclusions are malocclusions, with a frequency of up to 79.9% during the mixed dentition period [17–19], requiring timely diagnosis and interceptive orthodontic treatment. In the late stage of mixed dentition, HGP was more common (41.2%) than others, since the type of facial skull growth tends to change during the first phase of puberty. Studies by Knigge et al [20] showed that in VGP, the prevalence of class 2 was 51.6% (46 people); in NGP – 35% (210 people); in HGP – 23.7% (68 people).

The difference between gender distribution in study group 3 (VGP) was due to the fact that men had

significantly increased posterior and anterior facial height, lower jaw length, and downward displacement of the posterior upper jaw. This is confirmed by the studies of Taner et al., which determined a statistically significant advantage of the male sex in the sample with vertical growth type in the presence of class 1 malocclusion, and also established that in class 2 malocclusion, the posterior facial height and lower facial height in men were significantly longer compared to girls [18]. Nowadays, no direct or inverse correlation has been established between facial skeleton growth patterns and sagittal occlusal anomalies [21].

Cephalometric assessment of the relationship between the jaws in the sagittal plane is considered extremely important in orthodontics. Since Broadbent introduced lateral cephalometry, many analyses have been conducted to assess the anterior-posterior relationship of the jaws [2, 4]. In many clinical cases with questionable statistical data, it is impossible to make a definitive diagnosis based on the sagittal skeletal pattern, as different skeletal analyses can produce conflicting results. Based on the results of the study of most factors, a 'final diagnosis' of the anterior-posterior skeletal malocclusion class was made. The consistency of diagnostic criteria for various cephalometric parameters was assessed by using kappa statistics, specificity and sensitivity. We compared the diagnostic accuracy of the included skeletal parameters between all study groups: K-angle, ANB-angle, APDI [3, 5].

An important step in orthodontic diagnosis and treatment planning is the assessment of the sagittal relationship between the jaws. Numerous linear and angular measurements have been proposed to assess this relationship, but they can be inaccurate because variations in facial height, jaw inclination, and overall jaw prognathism can alter angular measurements [4, 8]. The ANB angle is still widely used to assess the sagittal relationship of the jaws, but it depends on a number of various factors. Some studies have shown that the length of the anterior cranial base, vertical growth pattern and minor variations in nasion and sella turcica locations can all affect the ANB-angle measurements [6, 8]. In order to evaluate the class and form of malocclusion more accurately than ANB angle analysis, clinicians are still searching for a new reliable cephalometric index [1, 13].

In our research results, the K-angle, ANB angle, APDI parameter, and all study groups showed a low degree of consistency ($k=0.321$, $p<0.01$). In turn, the K-angle, ANB angle, and APDI showed a high degree of consistency in the NGP and VGP of the facial skull ($k=0.845$, $p<0.01$), while in HGP, the kappa coefficient indicated a moderate degree of agreement ($k=0.505$, $p<0.01$) of the studied

angles, which is explained by a change in the ANB angle in these patients due to sagittal dysplasia of the upper jaw. The specificity and sensitivity of each diagnostic parameter were also determined independently for all groups. The ANB angle had the highest specificity (0.930), and the K angle had the highest sensitivity (0.978) in Class I malocclusions. The K angle had the highest sensitivity (0.948) and specificity (0.921) in Class II malocclusions. The ANB angle in group I had the highest sensitivity (0.902), compared to group III (0.813) and group II (0.485). In contrast, the K angle had the best specificity (1.00) throughout all groups under our study, with slightly different sensitivity values of 0.901 (group I), 0.876 (group III) and 0.732 (group II). In research made by Ahmed et al. [8], ANB angle sensitivity was 0.809 in the class 1 group, while in the class 2 group, its value was 0.928, which was slightly different from our findings. They also revealed that the ANB angle is only valid in patients with NGP of the facial skeleton, while in VGP and HGP, more accurate parameters have to be involved in order to precisely assess sagittal jaw discrepancy.

According to Jacobson [4, 6], the patient's age, vertical growth direction, jaw rotation, and length of the anterior skull base affect the change in the value of this angle. In addition, high-quality X-rays are required for accurate identification of point A, which sometimes complicates diagnosis, since it is not always possible to take high-quality images using digital technologies [12, 13].

Angle K has a statistically significant advantage over angle ANB in that it remains stable even when the jaws rotate or increase in the vertical direction [1, 3, 8, 9, 16]. For example, the C-G line rotates in the same direction as point G when it rotates downwards and backwards, carrying with it the perpendicular from point M. Angle K remains relatively constant because the M-G line also rotates in the same direction. Therefore, when the jaws rotate clockwise or counterclockwise, this tends to obscure the sagittal relationship of the jaws in gnathic forms of malocclusion, which angle K can assess. The quality of the cephalogram must be high [14]. However, it is not always easy to find the middle of the premaxilla and determine it correctly [4, 7]. The advantage of determining the centre of the condylar head is that there is no need to accurately trace the

contour of the condylar head; if the centre is within 2 mm of its actual location, the value of angle K will have a minimum error of about 1°, which is not statistically significant ($p=0.01$) [3]. Bajjad et al. [17] compared values of different angles (including K-angle) in class 1 and class 2 malocclusion patients in permanent occlusion with different facial skeleton growth patterns. The author discovered that in both class 1 and class 2 malocclusion patients, despite the growth pattern, with good reliability, $\angle YEN$ displays the greatest alpha value (0.849), followed by $\angle W$ (0.841) and $\angle K$ (0.816). Those results are similar to our findings, which also proved that the K-angle is a reliable cephalometric index which should be taken into consideration, especially when we use 3D cephalometrics for landmark detection. Thus, no statistically significant differences in $\angle K$, $\angle ANB$, and APDI between the three study groups were found at the level of $p \leq 0.05$, which is confirmed by the studies of Mohammadi Shayan et al. [20].

CONCLUSIONS

The K-angle showed a significant correlation with APDI in every facial skeleton growth pattern group and was revealed to be the most valid and reliable indicator of sagittal jaw discrepancy assessment amongst the three studied cephalometric indexes. That's why the K-angle can be used to accurately establish and also precisely differentiate malocclusion's class and its aetiological form during mixed dentition as well.

It is advisable to take this angle into account not only in the permanent occlusion period, but also in the mixed dentition period, regardless of the existing types of facial skeleton growth patterns, as a full-fledged alternative to using the ANB angle to assess the anteroposterior relationships of the upper and lower jaws during the diagnosis and planning of treatment tactics for orthodontic patients with occlusion anomalies, which directly depends on the specific malocclusion and its form.

Further research should focus on a more detailed study of the dependence of the K angle on changes in the position of the jaw bases, as well as sagittal dysplasia of the alveolar ridge of the upper jaw, to fully implement this cephalometric indicator in 3D cephalometric diagnostics in modern orthodontic practice.

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CONFLICT OF INTEREST

The Authors declare no conflict of interest

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