

Article

3D Evaluation of Gnathion Soft-Tissue Asymmetry Across Different Angle Malocclusions in Kosovar Children and Adolescents

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Abstract

Purpose: The aim of this study was to assess gnathion soft-tissue deviation in Kosovar children and adolescents with Angle malocclusions using structured light scanning technology. **Methods:** This cross-sectional study was conducted on 90 children (aged 6–9) and 90 adolescents (aged 10–14). Facial scans were obtained using the MetiSmile facial scanner (Version 2.2.5.6), while intraoral scans were obtained using Aoralscan 3. Gnathion soft-tissue deviation from the midsagittal plane was assessed and categorised as left- or right-sided. Associations of gnathion asymmetry with sex, age group and Angle’s malocclusion classification were analysed using chi-square, Fisher’s exact, Mann–Whitney U and Kruskal–Wallis ANOVA by ranks tests. **Results:** Right-sided gnathion deviation was prevalent in both children (66.7%) and adolescents (72.2%). Right-sided gnathion deviation was more frequently observed than left-sided deviation in both age groups. No significant association was found between gnathion position and age group ($p = 0.99$), sex (children: $\chi^2 = 0.201$, $p = 0.654$; adolescents: $\chi^2 = 2.072$, $p = 0.150$), or Angle malocclusion classification (children: Fisher’s exact test, $p = 0.594$; adolescents: Fisher’s exact test, $p = 0.435$). Likewise, gnathion deviation did not differ significantly among Angle malocclusion groups (children: $H = 1.41$, $p = 0.49$; adolescents: $H = 4.77$, $p = 0.09$). **Conclusions:** Within the limitations of this cross-sectional study, mild gnathion soft-tissue asymmetry appears to be a common form of normal craniofacial variation and not a characteristic specifically associated with the type of Angle malocclusion. Three-dimensional facial scanning may provide a clinically applicable and non-invasive method for assessing facial asymmetry in paediatric orthodontic patients.

Keywords: 3D facial analysis; gnathion asymmetry; facial asymmetry; Angle malocclusion; structured light facial scanner



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1. Introduction

Malocclusion represents one of the most common developmental disturbances of the craniofacial complex and involves alterations in dental, skeletal and soft-tissue relationships. According to Angle’s classification, malocclusions are categorised into Class I, characterised by a normal molar relationship with dental malpositions; Class II, characterised by a distal relationship of the mandibular arch relative to the maxillary arch; and Class III, characterised by a mesial relationship of the mandibular arch relative to the maxillary

arch. There are various methods for treating malocclusions, including fixed, ceramic, and transparent orthodontic appliances. Their choice depends on many factors, but it is also important to consider their side effects outside the oral cavity [1–3]. However, beyond occlusal discrepancies, malocclusion may negatively influence facial aesthetics, oral function, mastication, speech, temporomandibular joint function, and psychosocial well-being. Indeed, facial appearance plays an important role in social interaction and self-perception, particularly during childhood and adolescence. This has led to the evaluation of facial morphology becoming an essential component of diagnosis and treatment planning in contemporary paediatric orthodontics [4–6], particularly in Kosovo, where oral health is closely linked to children's overall quality of life [7].

Facial symmetry is considered an important feature of beauty and craniofacial balance. However, perfect bilateral facial symmetry is rare in humans, and mild asymmetry is quite common in healthy individuals [8]. Craniofacial asymmetry is also known to emerge as a result of genetic, environmental, developmental, functional, or traumatic factors and can involve dental, skeletal, muscular, or soft-tissue structures [9–11]. Minor asymmetries are often described as physiological variations, whereas pronounced asymmetries can lead to functional disturbances and aesthetic issues that require orthodontic or surgical intervention [12]. The chin region and mandibular midline are particularly important determinants of the perception of facial symmetry, while small deviations anywhere in the lower third of the face may be clinically relevant [13–15]. In this context, the gnathion soft tissue is a particularly useful landmark. Specifically, deviation of the gnathion from the midsagittal plane is frequently used to evaluate mandibular asymmetry and transverse imbalance [16,17]. Previous studies have shown that asymmetry of the lower facial third may be associated with different malocclusion patterns, particularly skeletal discrepancies and sagittal disharmonies [18,19]. However, the relationship between gnathion soft-tissue position and Angle's malocclusion classification remains insufficiently investigated, especially in paediatric populations [20–22].

Historically, craniofacial asymmetry has been assessed using clinical examination, two-dimensional photography, posteroanterior cephalograms and cone-beam computed tomography (CBCT) techniques [23]. While these approaches have made a substantial impact on orthodontic diagnosis, they have major inherent limitations. For example, magnification errors, projection distortion, superimposition of anatomical structures and inability to accurately represent complex three-dimensional morphology also affect two-dimensional imaging techniques [24,25]. In the case of CBCT, although it provides extremely detailed skeletal information, it involves exposure to ionising radiation and is very limited in its accuracy in soft-tissue colour and texture analyses [26,27]. Structured light facial scanners and stereophotogrammetry systems enable rapid, non-invasive and radiation-free acquisition of highly accurate 3D facial data [28]. These technologies allow realistic visualisation of facial morphology and provide reproducible measurements of facial proportions, asymmetry, soft-tissue contours and treatment-related changes. 3D facial analysis has therefore become increasingly important in digital orthodontic workflows and the generation of virtual patients [29–32].

The MetiSmile facial scanner [33] is a modern structured light 3D imaging system specifically intended for use in acquiring images of facial soft tissue in digital dentistry as well as orthodontics [34]. Validation studies have demonstrated that structured-light facial scanners provide clinically acceptable accuracy and reproducibility for anthropometric measurements and facial asymmetry assessment [35–37]. Moreover, these systems permit multiple examinations without radiation exposure, making them especially beneficial for children and adolescents undergoing craniofacial growth [36,38].

The field of orthodontics has also witnessed substantial progress as a result of the incorporation of artificial intelligence (AI) for digital diagnosis and treatment planning. Systems in which AI tools are integrated for automatic landmark identification, malocclusion classification, facial analysis and prediction of treatment outcome are becoming more common [39]. Studies have suggested that AI-based procedures can enhance diagnostic efficiency, standardisation and reproducibility, as well as minimise operator-specific variability. For example, it has been shown that AI-assisted analysis, together with an intraoral scanner, can objectively identify occlusal relationships and characterise malocclusions based on Angle's classification system for modern digital orthodontic assessment [40,41].

Although three-dimensional facial imaging and artificial intelligence have become increasingly important in digital orthodontics, their applications are distinct. In the present study, structured-light three-dimensional facial scanning was used to assess soft-tissue facial asymmetry, whereas AI-assisted analysis was applied exclusively for automated Angle malocclusion classification based on intraoral scans [42]. Despite recent advances in digital orthodontics, evidence regarding the relationship between soft-tissue gnathion asymmetry and Angle malocclusion in children and adolescents remains limited. Furthermore, most previous studies have focused on skeletal asymmetry assessed using radiographic imaging rather than non-invasive three-dimensional soft-tissue evaluation [43].

Therefore, the aim of the present study is to evaluate the position and deviation of the gnathion in children and adolescents with different Angle's malocclusion classifications using the MetiSmile 3D facial scanner and automated digital intraoral analysis Aoralscan 3. This study also investigates potential associations of gnathion asymmetry with sex, age group and sagittal malocclusion patterns within a contemporary digital orthodontic workflow.

2. Materials and Methods

2.1. Subjects

A total of 180 healthy Kosovar children ($n = 90$, age 6–9) and adolescents ($n = 90$, age 10–14) from primary schools in Pristina, Kosovo, were included in this study. The study was conducted in three public schools in Pristina. The three public schools were selected in collaboration with the Municipal Directorate of Education of Pristina. Information about the study was provided to school principals, teachers, and parents. Children whose parents provided written informed consent and who met the eligibility criteria were invited to participate.

The criteria for inclusion in this study were as follows: (1) age between 6 and 14 years; (2) mixed or permanent dentition; (3) occlusion classified as dental Class I, II or III based on Angle's classification and (4) complete clinical records. Meanwhile, the exclusion criteria were: (1) previous or current orthopaedic, orthodontic or orthognathic treatment; and (2) history of facial trauma; (3) any missing teeth (except third molars); (4) any facial deformity that arose congenitally or pathologically, such as cleft lip and palate, tumour, cyst, temporomandibular joint disorder or maxillofacial syndrome.

An a priori sample size calculation was performed using G*Power software (version 3.1; Heinrich Heine University, Düsseldorf, Germany). Assuming a significance level of $\alpha = 0.05$, statistical power of 90% ($1 - \beta = 0.90$), and a moderate effect size (Cohen's $d = 0.50$), a minimum sample size of 84 participants was required for each age cohort. To compensate for possible incomplete records and unusable 3D facial scans, the sample size was increased to 90 participants per cohort, resulting in a total sample of 180 participants. Because the distribution of Angle malocclusion classes was unequal, particularly for Class III subjects, the calculation was intended to ensure an adequate overall sample size rather than statistical power for each malocclusion subgroup individually.

2.2. Ethics Statement and Informed Consent

The study was approved by the Ethics Committee for Research on Human Subjects at the Faculty of Medicine, University of Pristina, Kosovo (ref. No. 489/26 January 2026). The parents/guardians of the participants were informed in advance about the study and gave written informed consent for their children/adolescents to participate in it before the initiation of the study. All procedures involving human participants were conducted in accordance with the ethical standards of the institutional research committee and with the Declaration of Helsinki, as revised in 2024. Written informed consent for the publication of identifiable facial photographs was obtained from the participant's parent/legal guardian.

2.3. 3D Facial Scanning (MetiSmile System)

All facial scans were acquired using the MetiSmile 3D (SHINING 3D Tech Co., Ltd., Hangzhou, China) Face Scanner [33]. This scanner uses structured light 3D scanning technology to capture accurate 3D data of the facial surface and generate a realistic digital facial model. The system includes multiple data acquisition cameras and a high-definition texture camera, enabling the recording of morphology, colour and details of the facial surface. Its reported accuracy of up to 50 µm supports its use in digital dentistry, orthodontic diagnosis, treatment planning and the creation of virtual patient models. Although the nominal accuracy of the MetiSmile scanner is approximately 0.05 mm, the software generates continuous numerical values after three-dimensional surface reconstruction and mesh interpolation. Therefore, values below the nominal scanner accuracy should not be interpreted as indicating measurement precision beyond the manufacturer's specified accuracy. The system uses structured light technology to capture high-resolution three-dimensional images of the facial surface. All facial measurements were performed by a single calibrated examiner using the same standardized protocol. During the scan, subjects were asked to sit in a chair and remain still to prevent forward, backward and sideways head movement while maintaining their natural head position. Participants were instructed to maintain a relaxed facial expression, keep their lips gently closed and avoid any movement, including speaking or swallowing, throughout the scanning procedure [44]. Following image acquisition, 3D facial orientation and reference plane alignment were performed using the integrated facial analysis software (FScan software Version 2.2.5.6) (Figure 1).

2.4. Facial Asymmetry Assessment

The soft-tissue planes and landmarks used in this study were determined in accordance with previously reported methods [45]. Facial asymmetry was assessed using three-dimensional data obtained with the MetiSmile 3D Facial Scanner. Gnathion soft-tissue deviation from the midsagittal plane was assessed and categorised as left- or right-sided (Figure 2).

Gn-L and Gn-R refer to left- and right-sided soft-tissue gnathion deviation relative to the midsagittal plane. Participants were classified as Gn-L when the soft-tissue gnathion was located to the left of the midsagittal plane and as Gn-R when it was located to the right of the midsagittal plane.

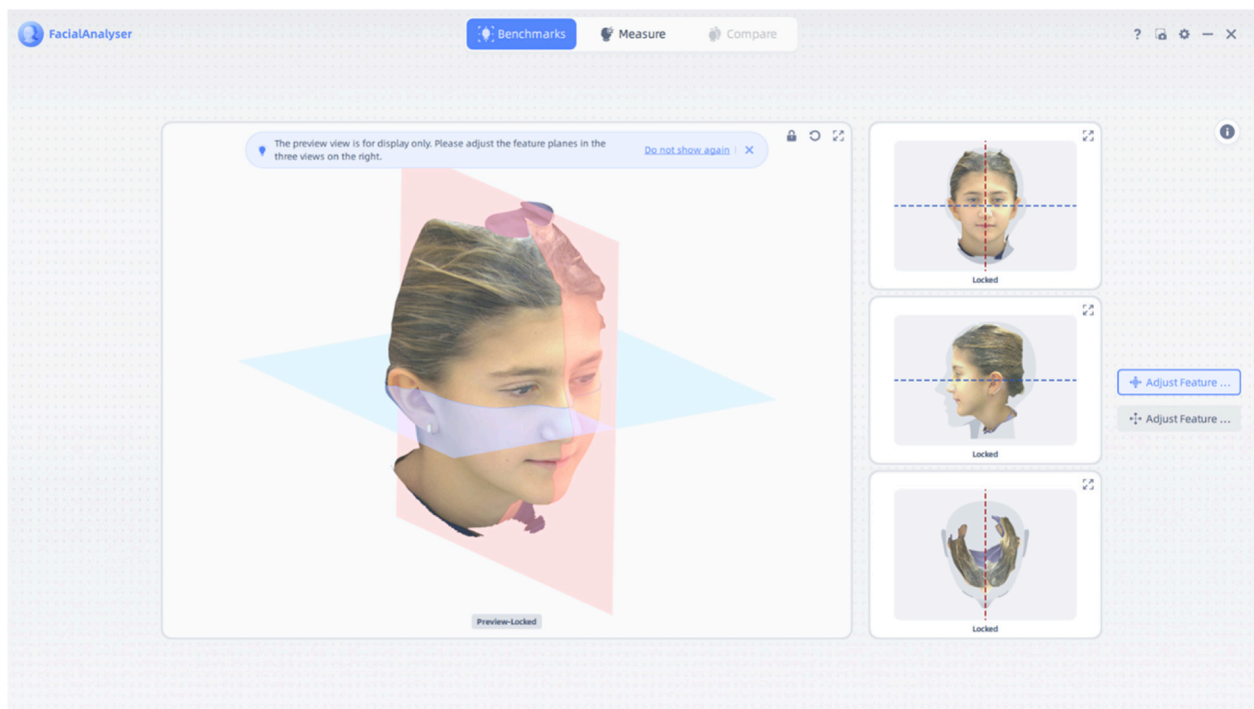


Figure 1. 3D facial orientation and reference plane alignment performed using the MetiSmile facial analysis software prior to asymmetry assessment. The colored lines indicate the reference planes and facial orientation used for the analysis.

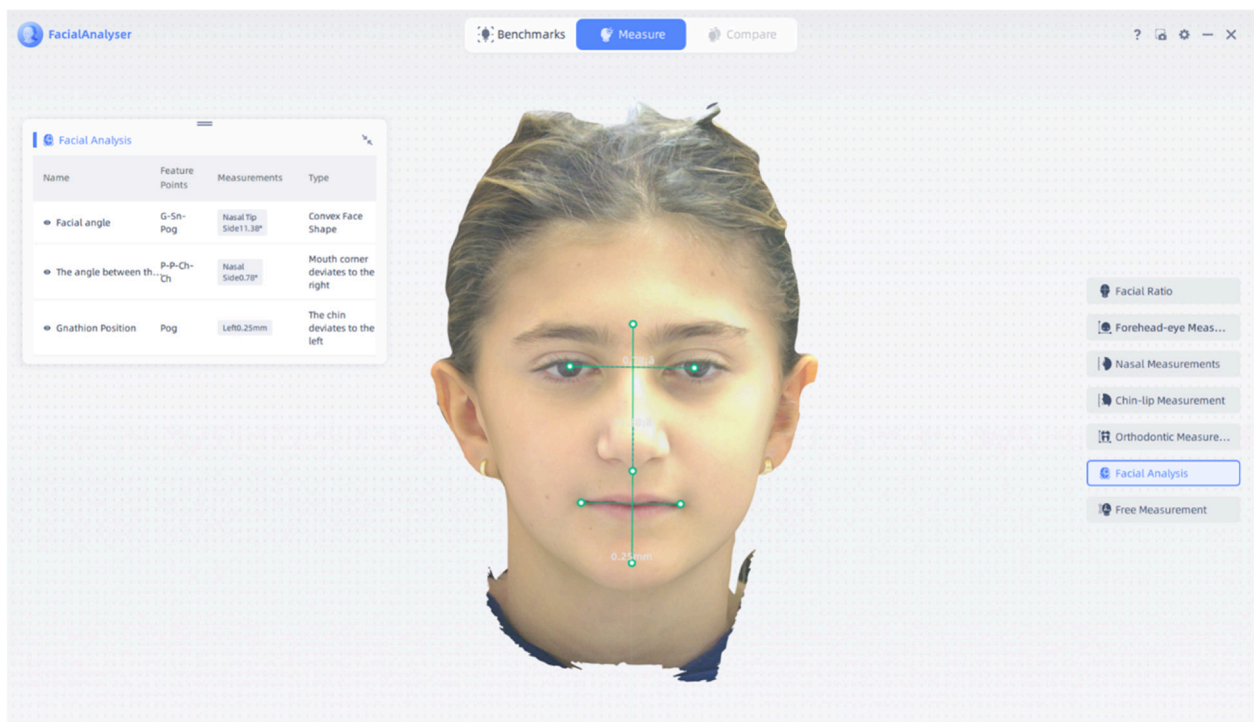


Figure 2. 3D facial analysis with the MetiSmile facial scanner demonstrates right-sided deviation of the gnathion soft tissue relative to the midsagittal plane, indicating mild facial asymmetry. The integrated facial analysis software automatically identifies facial landmarks and generates measurements for assessing asymmetry.

Since facial scanning only captures soft-tissue structures, the midsagittal plane (MSP) was constructed using facial landmarks instead of skull-based ones. Specifically, the

MSP was determined from soft-tissue landmarks at the midline, such as the glabella (G), subnasale (Sn) and soft-tissue pogonion (Pog), ensuring alignment with the facial midline. The midsagittal plane was automatically generated by the software using predefined midline soft-tissue landmarks (glabella, subnasale, and soft-tissue pogonion). All facial scans were acquired according to a standardized scanning protocol with participants in a natural head position, maintaining a neutral facial expression and maximum intercuspation. These standardized acquisition conditions minimized inter-subject variation in midsagittal plane construction and improved the consistency of gnathion asymmetry measurements. All soft-tissue landmarks used in this study are shown in Figure 3. The midsagittal plane was established according to a standardized scanning protocol using midline soft-tissue landmarks, consistent with previously published 3D facial anthropometric methodologies. Because the present study evaluated facial soft tissues only, skeletal reference landmarks were not available for defining the reference plane.

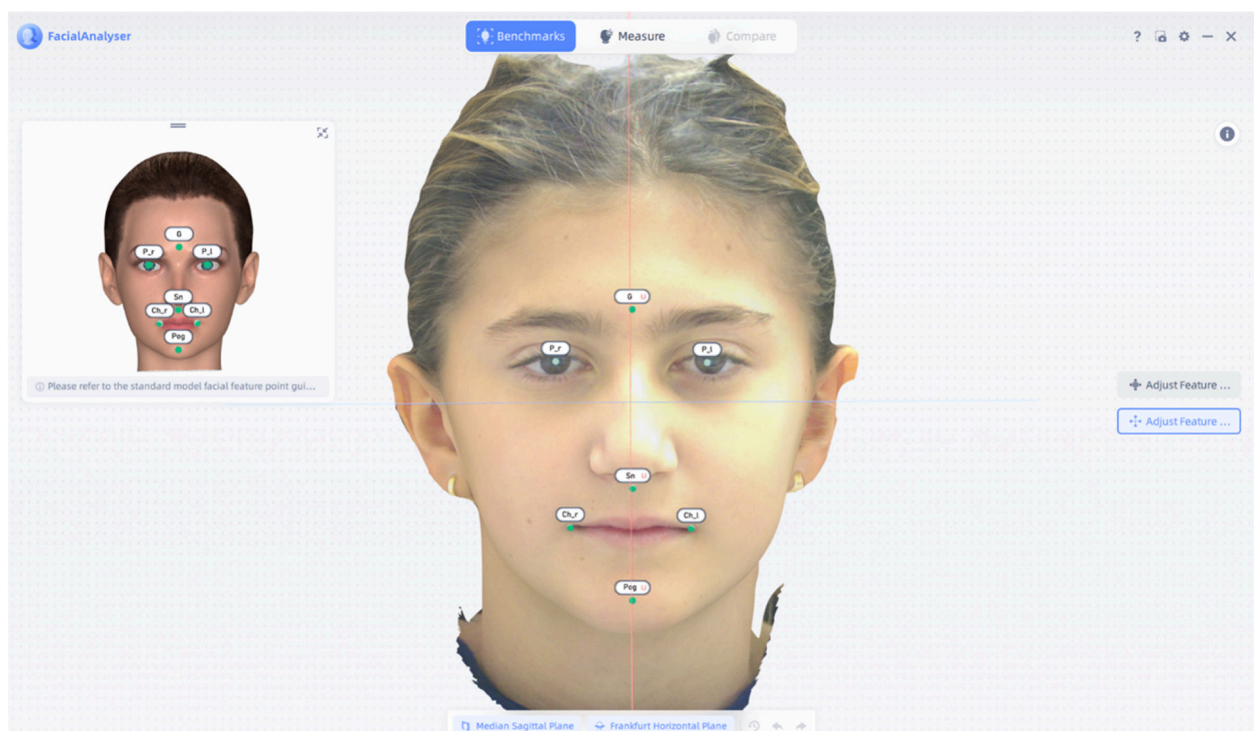


Figure 3. Midsagittal plane orientation and identification of key midline soft-tissue landmarks used for facial asymmetry analysis.

2.5. Malocclusion Classification Using Digital Analysis

Malocclusions were classified using automated digital analysis of intraoral scans obtained with the Aoralscan 3 scanner (SHINING 3D Tech Co., Ltd., Hangzhou, China) [46]. This scanner uses structured light technology to capture high-resolution three-dimensional digital models of the dental arches. All scans were performed in accordance with the manufacturer's protocol, ensuring accuracy in the malocclusion classification.

The obtained digital models were analysed using integrated software (Version 3.6.0.7) that automatically identifies occlusal relationships and facilitates classification according to Angle's classification system. The AI algorithm identified anatomical landmarks reflecting the molar relationships, enabling objective and reproducible classification into Class I, Class II and Class III malocclusions (Figure 4).

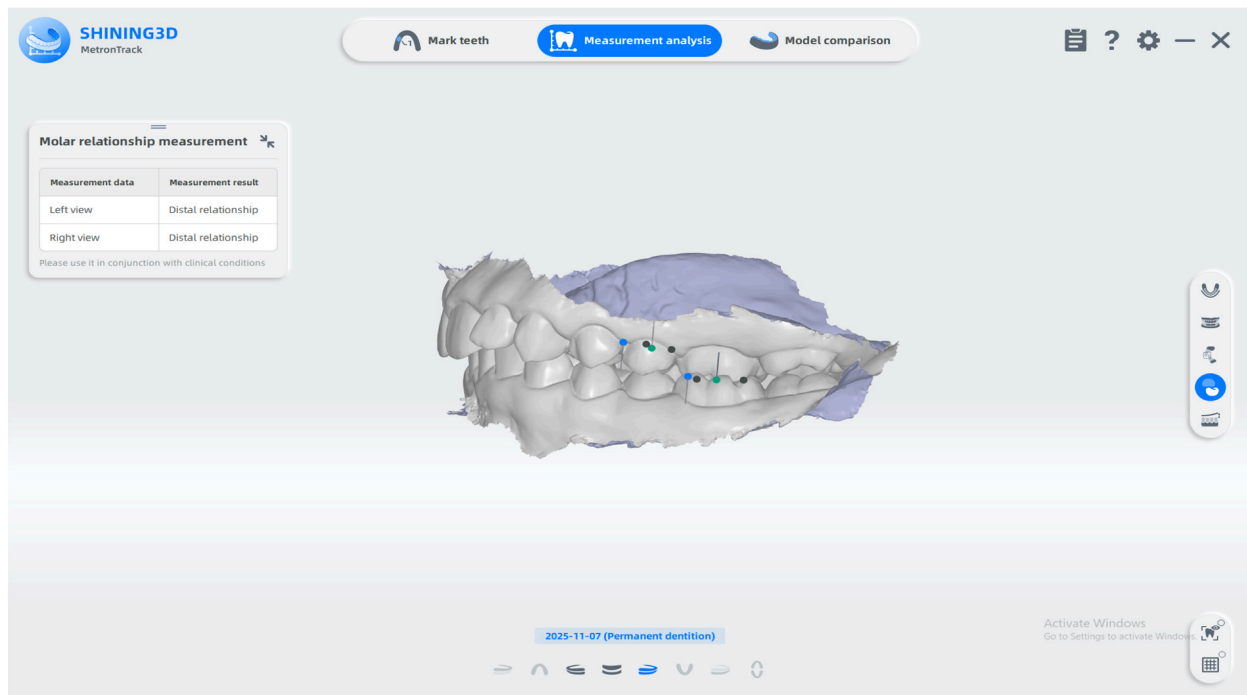


Figure 4. Three-dimensional intraoral digital model used for Angle’s malocclusion classification and analysis of molar positional relationships with the SHINING 3D intraoral scanning system.

2.6. Statistical Analysis

Data analysis was performed using Statistica version 7.1 for Windows (StatSoft Inc., Tulsa, OK, USA) and IBM SPSS Statistics version 23.0 (IBM Corp., Armonk, NY, USA). Statistica 7.1 was used for descriptive statistics, assessment of data distribution, and graphical presentation of the data. IBM SPSS Statistics 23.0 was used for the inferential statistical analyses reported in this study, including independent-samples *t*-tests, Mann–Whitney U tests, one-way ANOVA with Tukey HSD post hoc comparisons, Kruskal–Wallis tests, Pearson Chi-square and Fisher’s exact tests. The position of the gnathion soft tissue was assessed using its transverse components (Gn-L and Gn-R). Descriptive statistics, including mean, standard deviation, 95% confidence interval, median and range, were calculated for both of these variables. Normality of data distribution was assessed using the Kolmogorov–Smirnov, Lilliefors and Shapiro–Wilk tests. The results were used to determine whether parametric or non-parametric statistical tests should be applied. Parametric analyses (independent-samples *t*-tests and one-way ANOVA followed by Tukey HSD post hoc tests) were performed only for variables that satisfied the assumptions of normality. When these assumptions were not met, the corresponding non-parametric tests (Mann–Whitney U test or Kruskal–Wallis test) were applied. Differences in gnathion position between sexes were analysed using the independent-samples *t*-test for normally distributed variables and the Mann–Whitney U test for non-normally distributed variables. Differences among Angle malocclusion classes were evaluated using one-way ANOVA with Tukey HSD post hoc testing for normally distributed variables or the Kruskal–Wallis test for non-normally distributed variables. Statistical significance was set at $p < 0.05$.

2.7. Intra-Examiner Reliability

Twenty randomly selected facial scans were re-evaluated by the same examiner after a 2-week interval. Intra-class correlation coefficients (ICC) for gnathion position demonstrated excellent intra-examiner reliability, with values ranging from 0.91 to 0.96.

3. Results

3.1. Gnathion Position by Age Group

Among the children (6–9 years), the mean age $\pm$ SD was 8.01 ± 0.84 years (95% CI: 7.83–8.19). Overall, 42 (46.7%) were male and 48 (53.3%) were female. Among adolescents (10–14 years), the mean age $\pm$ SD was 11.73 ± 1.04 years (95% CI: 11.52–11.95). In this group, 47 (52.2%) were male and 43 (47.8%) were female.

The gnathion predominantly deviated to the right (Gn-R) in both children and adolescents (Two-thirds of children had right-sided deviation while the other third had left-sided deviation (Gn-L). A similar pattern was found in adolescents (72.2% and 27.8%, respectively). There was no significant difference in gnathion deviation between children and adolescents ($Z = 0.02$; $p = 0.99$). These results suggest that the pattern of mild soft-tissue asymmetry is the similar between these two developmental stages.

3.2. Descriptive Analysis of Gnathion Deviation

Table 1 provides descriptive statistics of gnathion deviation. Slightly greater deviation values were observed on the right side than on the left side in both age groups. For children, the mean Gn-L deviation was 1.01 ± 0.85 mm, and the mean Gn-R deviation was 1.27 ± 0.78 mm. Similar results were noted in adolescents.

Table 1. Descriptive statistics of Gnathion deviation in children and adolescents.

	Variable	N	Mean	Minimum	Maximum	SD
Children	Gn-L	30	1.01	0.07	3.79	0.85
Children	Gn-R	60	1.27	0.01	2.88	0.78
Adolescents	Gn-L	25	0.96	0.06	2.28	0.70
Adolescents	Gn-R	65	1.27	0.03	3.85	0.86

3.3. Gnathion Position by Sex

The distribution of gnathion position by sex is presented in Table 2. In both children and adolescents, right-sided gnathion deviation predominated in male and female subjects. Among children, no statistically significant association was identified between gnathion position and sex ($\chi^2 = 0.201$, $p = 0.654$). Similarly, among adolescents, the association between gnathion position and sex was not statistically significant ($\chi^2 = 2.072$, $p = 0.150$).

Table 2. Distribution of gnathion position according to sex.

Children			Side	
			Gn-L	Gn-R
Sex	Female	Count	15	33
		%	31.3%	68.8%
	Male	Count	15	27
		%	35.7%	64.3%
	Total	Count	30	60
		%	33.3%	66.7%

Adolescents			Side	
			Gn-L	Gn-R
Sex	Female	Count	15	28
		%	34.9%	65.1%
	Male	Count	10	37
		%	21.3%	78.7%
	Total	Count	25	65
		%	27.8%	72.2%

Analysis of the size of deviation additionally demonstrated no statistically significant differences between males and females in either age group (children: $Z = 0.87$, $p = 0.38$; adolescents: $Z = -1.31$, $p = 0.19$), although slight differences in mean deviation values were observed between the sexes.

3.4. Gnathion Position According to Angle's Malocclusion Classification

The association between gnathion position and Angle's malocclusion classification is presented in Table 3. Right-sided gnathion deviation predominated across all Angle's malocclusion classes in both children and adolescents. In children, no statistically significant association was identified between gnathion position and malocclusion classification (Fisher's exact test = 1.251, $p = 0.594$). Similarly, in adolescents, gnathion position did not differ significantly among Class I, Class II and Class III malocclusions (Fisher's exact test = 1.892, $p = 0.435$).

Table 3. Angle class and gnathion position in the two groups.

Children			Side		Total
			Gn-L	Gn-R	
Angle class	Class I	Count	7	14	21
		%	33.3%	66.7%	100%
	Class II	Count	19	42	61
		%	31.1%	68.9%	100%
	Class III	Count	4	4	8
		%	50.0%	50.0%	100%
	Total	Count	30	60	90
		%	33.3%	66.7%	100%
Adolescents			Side		Total
			Gn-L	Gn-R	
Angle class	Class I	Count	11	19	30
		%	36.7%	63.3%	100%
	Class II	Count	13	40	53
		%	24.5%	75.5%	100%
	Class III	Count	1	6	7
		%	14.3%	85.7%	100%
	Total	Count	25	65	90
		%	27.8%	72.2%	100%

3.5. Gnathion Deviation According to Malocclusion

Kruskal–Wallis ANOVA by ranks analysis demonstrated no statistically significant differences in gnathion deviation among malocclusion classes in children ($H = 1.41$, $p = 0.49$). There was a tendency toward differences among malocclusion classes in adolescents ($H = 4.77$, $p = 0.09$).

4. Discussion

The present study on an orthodontic Kosovar cohort with malocclusion has revealed a predominance of right-sided deviation of gnathion soft tissue in children as well as in adolescents. These findings indicate that mild transverse asymmetry of the lower facial third may be a common characteristic of craniofacial morphology during growth, rather than a distinctly pathological condition. Directional asymmetry of facial regions has been reported in the literature to develop in a similar pattern, but the identified dominant side has not been consistent among studies [32,47–49].

Despite the observed predominance of right-sided deviation, no statistically significant differences were identified according to sex, age group or Angle's malocclusion classification. These findings may indicate that minor gnathion asymmetry occurs as a part of normal biological craniofacial variation and is not necessarily associated with the type of sagittal malocclusion. From a clinical perspective, this observation is important because slight deviations of the chin region should not automatically be interpreted as pathological findings requiring orthodontic or surgical intervention. Instead, evaluation of the gnathion position should be integrated with comprehensive facial, skeletal, occlusal and functional analyses. The current findings are consistent with previous reports demonstrating that mild facial asymmetry is highly prevalent in healthy populations. Previous studies suggested that a certain degree of facial asymmetry should be considered physiological, particularly when the magnitude of deviation is not clinically relevant. Furthermore, directional facial asymmetry may be influenced by functional and developmental factors, including chewing-side preference and adaptation to craniofacial growth; however, these factors were not evaluated in the present study and therefore should be considered as potential hypotheses to be investigated in future research rather than explanations supported by the current findings. Another important aspect of the present investigation is the use of 3D facial scanning technology to assess soft-tissue asymmetry. Compared with conventional two-dimensional photography and cephalometric imaging, 3D facial analysis provides more realistic and reproducible visualisation of facial morphology. Previous studies have emphasised that 3D imaging systems improve the accuracy of facial soft-tissue evaluation and allow more reliable assessment of craniofacial asymmetry [50].

In the present study, the MetiSmile facial scanner enabled standardised evaluation of soft-tissue landmarks and midsagittal relationships without exposing the subjects to ionising radiation, representing a clinically applicable and non-invasive diagnostic approach [27,37,42]. Furthermore, the non-invasive and rapid workflow of 3D facial scanning is highly advantageous in pediatric dentistry, particularly for patients with sensory sensitivities or developmental challenges who significantly benefit from adapted clinical approaches. Given that traditional, invasive dental examinations are often poorly tolerated by pediatric patients with sensory and neurodevelopmental challenges, non-invasive digital tools like 3D facial scanners offer a crucial alternative to reduce anxiety and facilitate diagnostic procedures [51]. The integration of automated digital malocclusion analysis with 3D facial scanning is a recent development in orthodontic workflows [47]. Because the present study evaluated only soft-tissue morphology, the relationship between skeletal asymmetry and soft-tissue compensation could not be assessed. Therefore, the findings should be interpreted as reflecting soft-tissue characteristics only and should not be considered representative of the underlying skeletal morphology. Future studies combining 3D facial scanning with CBCT are warranted to further investigate the relationship between skeletal and soft-tissue asymmetry.

The absence of significant differences in soft-tissue gnathion deviation patterns between children and adolescents may also indicate that mild gnathion asymmetry remains relatively stable during the period of craniofacial growth. Nevertheless, there is a need for longitudinal investigations to determine whether these asymmetry patterns change throughout development and skeletal maturation.

Future multicentre studies with larger and more diverse populations are recommended to further validate these observations.

5. Conclusions

In this cross-sectional study of Kosovar children and adolescents with Angle malocclusions, right-sided gnathion soft-tissue deviation predominated in both age groups.

No statistically significant associations were identified between gnathion asymmetry and sex, age group, or Angle malocclusion classification. These findings should be considered preliminary and hypothesis-generating, suggesting that mild gnathion asymmetry may represent a common feature of normal craniofacial variation rather than a feature specifically associated with a particular Angle malocclusion. Three-dimensional facial scanning provided a standardized, non-invasive, and radiation-free method for assessing facial soft-tissue asymmetry, supporting its clinical applicability as an adjunctive tool in orthodontic assessment. AI-assisted intraoral analysis was used exclusively for digital Angle malocclusion classification and was not involved in the assessment of facial asymmetry. Further longitudinal, multicentre studies involving larger and more diverse populations, combined skeletal and soft-tissue analyses, and the inclusion of a clinically symmetrical reference group are warranted to confirm and extend these preliminary findings.

6. Limitations

This study has several limitations that should be acknowledged. First, its cross-sectional design precluded assessment of longitudinal changes in craniofacial growth and the progression of facial asymmetry over time. Second, the study population consisted exclusively of Kosovar children and adolescents, which may limit the generalizability of the findings to other populations. Third, although the MetiSmile structured-light facial scanner provided a non-invasive, radiation-free method for soft-tissue assessment, only soft-tissue asymmetry was evaluated without direct skeletal assessment using CBCT or other imaging modalities. Furthermore, the relatively small number of participants with Class III malocclusion may have reduced statistical power and increased the risk of Type II error. Functional factors potentially associated with facial asymmetry, such as chewing-side preference, temporomandibular joint status, muscular imbalance, and postural adaptation, were not evaluated. In addition, all measurements were performed by a single examiner; therefore, inter-examiner reliability could not be assessed. Participants were classified simply as having left- or right-sided gnathion deviation without defining a threshold for clinically meaningful asymmetry, and automated Angle malocclusion classification was not validated against an independent clinician-based reference standard. Another limitation is the absence of a reference group with clinically symmetrical facial morphology; therefore, the present findings should be interpreted as describing the distribution of gnathion asymmetry among different Angle malocclusion classes rather than establishing whether these patterns differ from individuals without detectable facial asymmetry. Despite these limitations, the present study provides clinically relevant information on 3D soft-tissue gnathion asymmetry in growing patients and supports the use of non-invasive digital facial imaging in orthodontic assessment. Consequently, the present findings should be interpreted as describing the distribution of gnathion asymmetry among different Angle malocclusion classes rather than establishing whether these patterns differ from individuals without detectable facial asymmetry. A further methodological limitation is that the midsagittal plane was constructed using soft-tissue pogonion, while gnathion deviation was subsequently measured relative to this plane. As these landmarks are anatomically adjacent, this approach may introduce a degree of dependency and slightly attenuate the measured magnitude of gnathion deviation, particularly in cases of more pronounced lower facial asymmetry. Future studies could compare alternative midsagittal plane definitions that do not incorporate lower facial landmarks.

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Data Availability Statement: The original contributions presented in this study are included in the article. Further inquiries can be directed to the corresponding author.

Conflicts of Interest: The authors declare no conflicts of interest.

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