Transverse Mandibular Morphology in Different Sagittal Skeletal Malocclusions: A CBCT Study

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Abstract

Objectives

The study aimed to evaluate the mandibular width in males and females in different sagittal skeletal malocclusions (SSMs) using cone-beam-computed-tomography (CBCT).

Materials and methods

The study sample consisted of 90 CBCT scans of subjects (45 males and 45 females) aged between 18 and 40 years old with a mean age of 31.91 ± 7.61, divided into six equal groups with fifteen subjects each according to their SSM: Class I males and females (CIM, CIF), Class II males and females (CIIM, CIIF) and Class III males and females (CIIIM, CIIIF). Landmarks were identified on the axial plane as well as on the three-dimensional reconstructed views, then the distances between the right and left: condylar superior (CsupR-CsupL), Antegonions (AGR-AGL) and mental foramens (MFR-MFL) were measured using Dolphin imaging-software along with the following 2 angles: CsupR-AGR/CsupL-AGL and AGR-MFR/AGL-MFL. All relevant data were then analyzed with a two-way ANOVA.

Results

Mandibular width was significantly superior in males compared to females in all SSMs at the level of Csup, AG and MF, except in CII subjects at the MF area where it was higher in females. AGR-AGL as well as MFR-MRL distances was elevated in CIIIM compared to CIIM and CIM. CsupR-AGR/CsupL-AGL angle was smaller in CIIIF compared to CIF and CIIF subjects. AGR-MFR/AGL-MFL angle was higher in CIIM than that of CIIF.

Conclusions

Although the mandibular width increases in CIII malocclusion compared to CI and CII, the intercondylar distance does not significantly change.

Clinical Relevance:

Surgically facilitated orthodontic treatment (SFOT) can be a better alternative than mandibular distraction osteogenesis in class II transversally deficient mandibles as the latter increases the intercondylar width while the former does not.

INTRODUCTION

The mandible presents an important determinant of facial morphology.[1,2] Its shape is dependent on the dynamic environment as trabecular deposition is bound to the biodynamic principles to achieve maximum strength with least amount of material.[3] Thus, in clinical orthodontics, an understanding of mandibular growth is very important. Previous studies suggested that a plethora of environmental and genetic factors is involved in a complex interplay controlling maxillofacial morphological growth. The involvement of genetic factors is illustrated by the similarity in facial growth patterns within families and the apparently race dependent variation in the frequency of specific facial types within a population. [4]

Cone beam computed tomography (CBCT) could provide sub millimeter spatial resolution in images of high diagnostic quality with markedly shorter scanning times and radiation dosages much smaller than traditional computed tomography (CT) imaging methods.[5] It is indubitable that the traditional cephalometry is still a valuable tool that can provide important information when used properly. However, during the past decade, it has been verified many times in the literature that 3D evaluation has shown to be greatly superior to the 2D approach, both in the reliability of anatomical landmark identification [6, 7] and in measurement accuracy. [8] The increased use of CT in dentistry has also spurred the development of new 3D analysis software, the use of which will help to better understand the 3D mandibular morphology of skeletal CI, CII and CIII malocclusions. [9]

Development of mandibular width in males continues beyond the spurt periods in a pattern similar to developments in sagittal facial length and frontal facial height. [10] Growth in jaw width reportedly declines to a slower rate earlier than sagittal and vertical development, except in the posterior areas where the jaws grow wider as they grow in length posteriorly. [11] The greater growth observed in the mandible relative to the maxilla at the dento-alveolar level, suggests the presence of a compensatory mechanism that allows the preservation of normal occlusion avoiding the appearance of a cross bite on the posterior teeth.[12]

Since mandibular width has been studied at the dento-alveolar level, inadequacy of data about mandibular width at the skeletal level in the transverse plane, dictates further studies to evaluate the difference of skeletal mandibular width in different SSMs.

To the best of our knowledge, past research evaluating the mandible in different SSM's using CBCT ,[9, 13–15] employed a volumetric study of mandibular morphology, considering it as one unit and studying it as such. However, these studies excluded the relationship between different components of the mandible, the ramus, and the mandibular body. This study will assess the relationship between the rami as well as mandibular width at the Condylar Superior (Csup), the AG and the MF area from the transverse plane, in the three SSMs CI, CII and CIII in males and females.

MATERIALS AND METHODS

Before commencing the study, acceptance was taken from the institutional review board of the university (2018H-0057-D-M-0257). The sample size was calculated by using the statistical software G-power. A medium sized effect size equals 0.06 and a power (β) = 0.8 and an alpha value (α) = 0.05 was used. In addition, to the one-way ANOVA test. Due to sample collection limitation, especially with the group of individuals having CIII skeletal malocclusion meeting the inclusion and exclusion criteria, the number of subjects needed was estimated to be 90, distributed equally on six groups, according to SSM. CIM, CIF, CIIM, CIIF, CIIIM and CIIIF. (Table 1).

CBCT full head scans were collected from the archive of a radiographic center, taken by the same certified radiologist and same machine (Kodak Dental Systems, Carestream Health Inc., Rochester, NY) at 10 mA, 80 KV and an exposure time of 10.8 s. with a voxel dimension of 300 µm.). The sample selection was done by choosing the DICOM files randomly referring to subject's ID number from the database of the radiographic center. Subjects chosen were Caucasians aged between 18 and 40 years old at the time the CBCT was taken, presenting either a CI, CII or CIII skeletal malocclusion with the presence of all the teeth and having an adequate full head CBCT scan. Those having any craniofacial anomalies, facial asymmetry or history of orthodontic treatment were excluded.

Head repositioning

DICOM files were opened with CS 3D Imaging Software v3.2.13, and head repositioning was accomplished to superimpose left and right side structures and prevent any double image on the lateral cephalogram generated from the CBCT scan.

This procedure was accomplished according to the following planes:

a. On the sagittal view: The Frankfort plane was used as the horizontal guide plane (Fig. 1).
b. On the coronal view: The infra-orbital plane was used as the horizontal guide plane (Fig. 2).
c. On the axial view: The head was positioned face forward by placing the anterior nasal spine and the posterior tubercle of the cervical vertebrae along the antero-posterior axis (Fig. 3).

Cephalometric measurements

Dolphin Imaging software version 11.9 Premium (Dolphin Imaging and management solutions, Chatsworth, CA 91311, United States) was used for the cephalometric analysis.

On the reconstructed lateral headfilm from the CBCT, sagittal skeletal morphology was classified according to ANB angle and Wits into CI ($1 \leq ANB < 5$, $-1 \leq Wits < 0$, n = 30, 15 males and 15 females), CII ($ANB \geq 5$, $Wits \geq 0$, n = 30, 15 males and 15 females) and CIII ($ANB < 1$, $Wits < -1$, n = 30, 15 males and 15 females).

After accomplishing the lateral cephalometric analysis, the DICOM file was opened in the 3D format in a multiplanar window, which allows us to view the head in all three planes: sagittal, axial, and coronal planes simultaneously, in addition to the 3D reconstructed image of the head. It was possible to visualize the three projections and the 3D rendered image together or choose one of the four images in full screen. Landmarks were added electronically by using the "landmark tool" (Table 2).

For the Csup landmark, the axial plane was used. The most superior point on the condyle is seen on the axial plane as a rounded radiopaque structure surrounded by the radiolucency of the condylar fossa.

AG landmarks were located using the 3D format view at the lateral inferior margin of the antigonial protuberance.

As for the ME, the axial view was used again, and the landmark added on the slice where the mental nerve exists the bone. It is seen as a discontinuity of the outer cortical bone.

Linear and angular measurements of 3D coordinates was obtained using the "Measurement" tool. The following linear and angular measurements were done (Table 3) and (Figs. 4, 5 and 6).

The angular measurement tool requires that we locate three points to provide us with the angle between them. Since the left and right ramus do not meet in the viewed image because the angle between them is relatively small, it was only possible to measure the CsupR-AGR-AGL angle then measure CsupL-AGL-AGR angle and subtract 180 from the sum of these two angles to get the angle between the left and right ramus. The same procedure was used to calculate the angle between AGL-MFL/AGR-MFR (Figs. 7 and 8).

Statistical analysis

The statistical analysis was performed using the Statistical Package for Social Sciences SPSS (IBM SPSS Statistics version 23, Armonk, NY).

Intra-observer reliability in measurement of the parameters were determined using the Dahlberg formula [16] by randomly selecting 18 subjects (20% of the sample size) and repeating the measuring procedures after one month (Table 4).

The descriptive statistics of each linear and angular parameter in each of the 3 sagittal craniofacial patterns in males and females were obtained.

Two-way ANOVA test were used to compare each measurement according to SSM and gender. It was followed by univariate analysis and TUKEY multiple comparison test. Shapiro-wilk test were used to assess the normality distribution of measurements. The level of significance was set at -P- value < 0.05 for all the statistical tests.

RESULTS

Table 5 reveals the p-values of the simple main effects for the 6 two-ways ANOVA tests performed along with univariate analyses and Tukey post-hoc tests.

1- CsupR-CsupL:

The mean CsupR-CsupL was not significantly different between the SSMs in males (-P- value = 0.781) and females (-P- value = 0.473).

Moreover, the mean value was significantly elevated in males compared to females for CI (-P- value = 0.016), CII (-P- value = 0.001) and CIII (-P- value < 0.001).

2- AGR-AGL:

The mean AGR-AGL was not significantly different between the SSMs in females (-P- value = 0.064).

However, it was significantly different in males (-P- value = 0.020), most significantly elevated in CIII, intermediate in CII and least in CI.

Moreover, the mean AGR-AGL was significantly superior in males compared to females for different SSMs (-P- value < 0.05).

3- MFR-MRL:

The mean MFR-MFL was not significantly different in SSMs for females (-P- value = 0.093).

However, it was significantly different in males for the different SSMs (-P- value = 0.006); It was higher in CIII, with the absence of significant difference between CI and CII (-P- value = 1.000).

Moreover, the mean MFR-MFL was significantly superior in males compared to females in CI (-P- value = 0.016) and in CIII (-P- value < 0.001). The difference was not significantly different between males and females in CII SSM (-P- value = 0.116).

4- CsupR-AGR/CsupL-AGL:

The mean CsupR-AGR/CsupL-AGL was not significantly different between the SSMs in males (-P- value = 0.069).

However, it was different significantly in females (-P- value = 0.012). It was smaller in CIII, intermediate for CII and elevated in CI.

Moreover, we did not find a significant difference between males and females for SSM (-P- value > 0.05)

5- AGR-MFR/AGL-MFL

No significant difference in different SSMs for males (-P- value = 0.109) and females (-P- value = 0.08).

However, it was significantly elevated in CII males compared to CII females (-P- value = 0.034); but we did not find a significant difference between CI (-P- value = 0.081) and CIII (-P- value = 0.054) in males and females.

DISCUSSION

The aim of this study was to evaluate mandibular width in different SSMs using CBCT full head scans, that could be useful clinically and in research. Our results showed significant difference in mandibular width according to gender and in different SSMs.

The accuracy and reliability of CBCT compared to 2D radiographs has been verified earlier by Hilgers *et al.*[5] To ensure superior accuracy of mandibular width assessment, the landmarks should be reliable, reproducible, and easy to locate on the different slices of the CBCT image. Pittayapat *et al.* [17] noticed, in an investigation on the accuracy of linear measurements using 3D imaging, that the inter-observer agreement is lower than the intra-observer agreement. In this study, measurements were taken by single examiner to ensure superior accuracy.

Naji, *et al.* [18] and Lemieux *et al.* [19] in two similar studies to identify the reliability of anatomical landmarks using CBCT, concluded that one of the most reliable and reproducible landmarks tested for CBCT, is the MF. Noticeably in the current study, MF had the least Dahlberg error number of 0.78 mm, which confirms the reliability and reproducibility of MF landmark.

Measuring the degree of divergence of the opposing rami has never been done before in the literature; To measure the angle between left and right ramus, the first landmarks should be located at the condyle while the other at the mandibular angle. The Csup landmark is the most superior point of the condyle as described by Hilgers *et al.* [5] Landmark AG, has been used when assessing mandibular width using PA cephalograms and CBCT. [20–23] Its importance resides by being at the intersection of the ramus and the mandibular body.

In the present study, the same operator measured all the variables by using a validated tool, the Dolphin imaging software version 11.9 premium. The software simultaneously provides sagittal, axial, coronal and 3D reconstructed views of every landmark; measurement errors caused by inaccurate determination of key anatomic points are therefore minimized. [24]

During the 2D era of radiography, the mandible was extensively analyzed from the sagittal aspect by cephalometric analysis. In the past years, with the introduction of CBCT imaging, examination of the mandibular morphology in different SSMs has been bound to volumetric analysis of the jaw, where the transverse aspect of the mandible overlooked. Four studies compared the mandibular volume in different SSMs. Deguchi *et al.* [9] aimed to determine whether there are any differences in the volumes of the maxilla and the mandible in subjects with skeletal CI, CII and CIII malocclusions. Similar consequent studies increased the sample size dramatically, Katayama *et al.*[13] used CBCT scans of 118 Japanese adults, while Nakawaki *et al.*[14] almost doubled that number, ending up with the same results. In conclusion, there was no statistically significant difference between the volumes of mandibles for subjects with different SSMs. In our study, results showed that CIII males have larger mandibular width than CI and CII at the level of the mandibular body, while the width at the condyle level did not significantly change. This means that a compensation is taking place that allows the mandibular volume to remain the same even though its width is larger at the level of the AG and MF.

Previous studies concerning the mandibular width were focused on the dental and alveolar aspect of the mandible, with the basal bone ignored. [25–29] Slaj M *et al.*[29] in a study on dental mandibular width using study models in different SSMs. Results showed that the mandible in males is larger I n width in CIII compared to CII and CI at the level of the molar. This agrees with the results from our current study, where the mandibular width in males is greater in CIII than CII and CI at the level of the AG and MF. Braun *et al* [28] related the increase in mandibular alveolar width and buccal molar tipping to the adaptation of the tongue to the decrease of arch depth, which led to increased lateral tongue dimension. From our study we can hypothesize that the increased alveolar and dental width in CIII malocclusion in Braun's study, can be related to the significant increase in basal bone width at the level of the MF and AG spatially in males.

Malkoc et al. showed that mandibular distraction osteogenesis considerably increased the inter-condylar width,[30] while this study showed that there were no significant differences in inter-condylar width (CsupR-CsupL) among class I, II and III malocclusions in both males and females. Accordingly, distraction osteogenesis will not transform a transversally deficient class II mandible into a normal class I mandible due to the accompanying increase in intercondylar width. The complications accompanying distraction osteogenesis are well documented in the literature,[31] an alternative procedure such as surgically facilitated orthodontic treatment (SFOT)[32] could help in increasing the width of transversally deficient class II mandibles width without altering the inter-condylar width. Consequently, as SFOT does not change intercondylar width while mandibular distraction does, SFOT may be more suitable in class II transversally deficient mandibles.

CONCLUSION

Although the mandibular width increases in CIII malocclusion compared to CI and CII, the intercondylar distance does not significantly change.

The mandibular width increases in CIII malocclusion at the level of MF and AG in males compared to CI and CII malocclusion while the angle between opposite rami does not significantly change.

DECLARATIONS

Author Contribution: MC designed the study, performed the CBCT measuring procedures on the mandibles, evaluated the statistical results and wrote the manuscript. JB, EO, AHK, RK and TEW designed the study, evaluated the statistical results, and proofread the manuscript. All authors read and approved the final manuscript.

Ethics Approval and Consent to Participate: Before commencing the study, acceptance was taken from the institutional review board of the university (2018H-0057-D-M-0257), which informed the investigators that informed consent from the individuals was not necessary according to national regulations.

Funding: No funding was obtained for this study.

Competing interest: None.

Conflicts of Interest: None.

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Tables

Tables 1 to 5 are available in the Supplementary Files section.

Figures

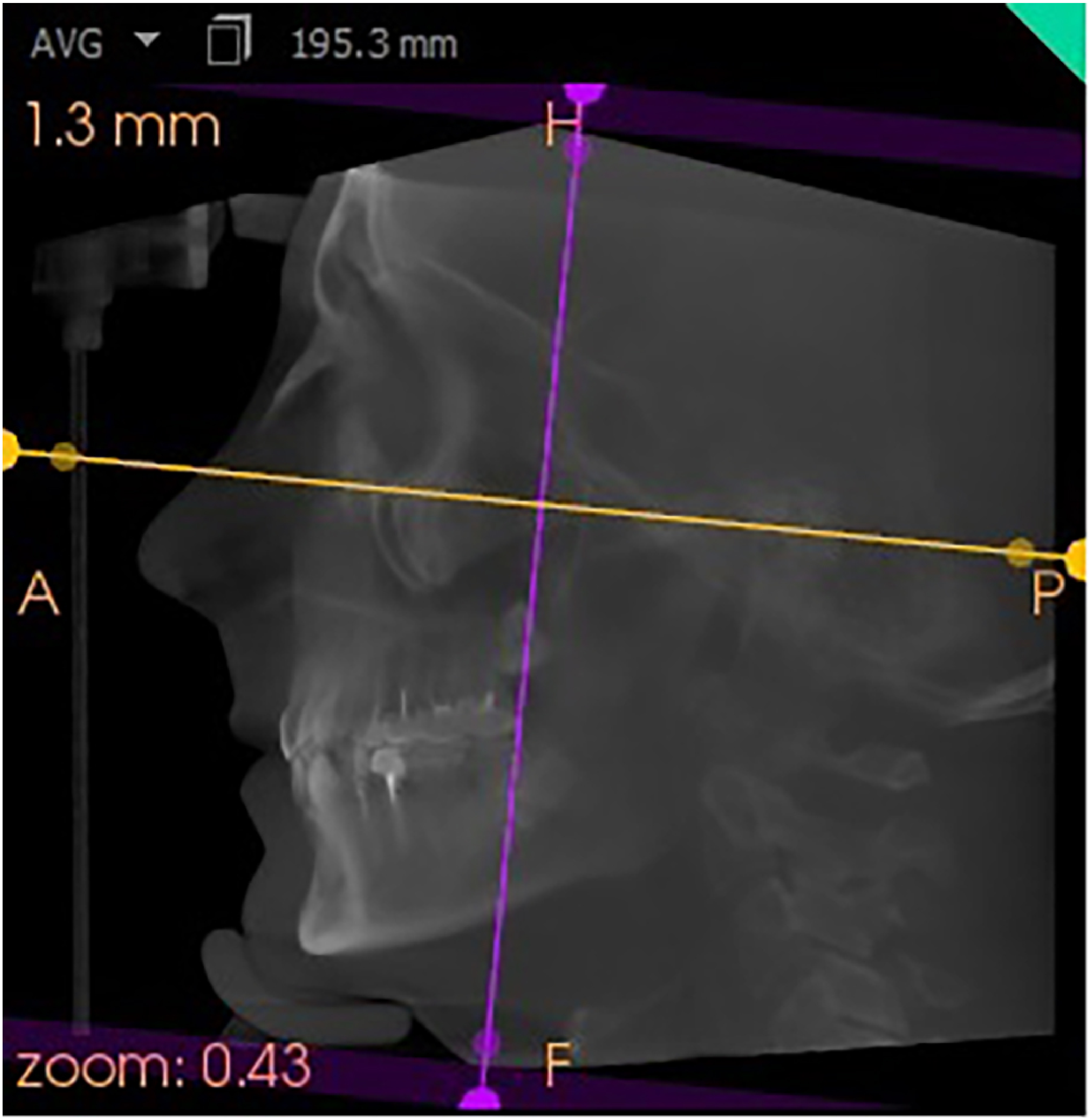

Figure 1

Head orientation in the sagittal view according to Frankfurt plane.

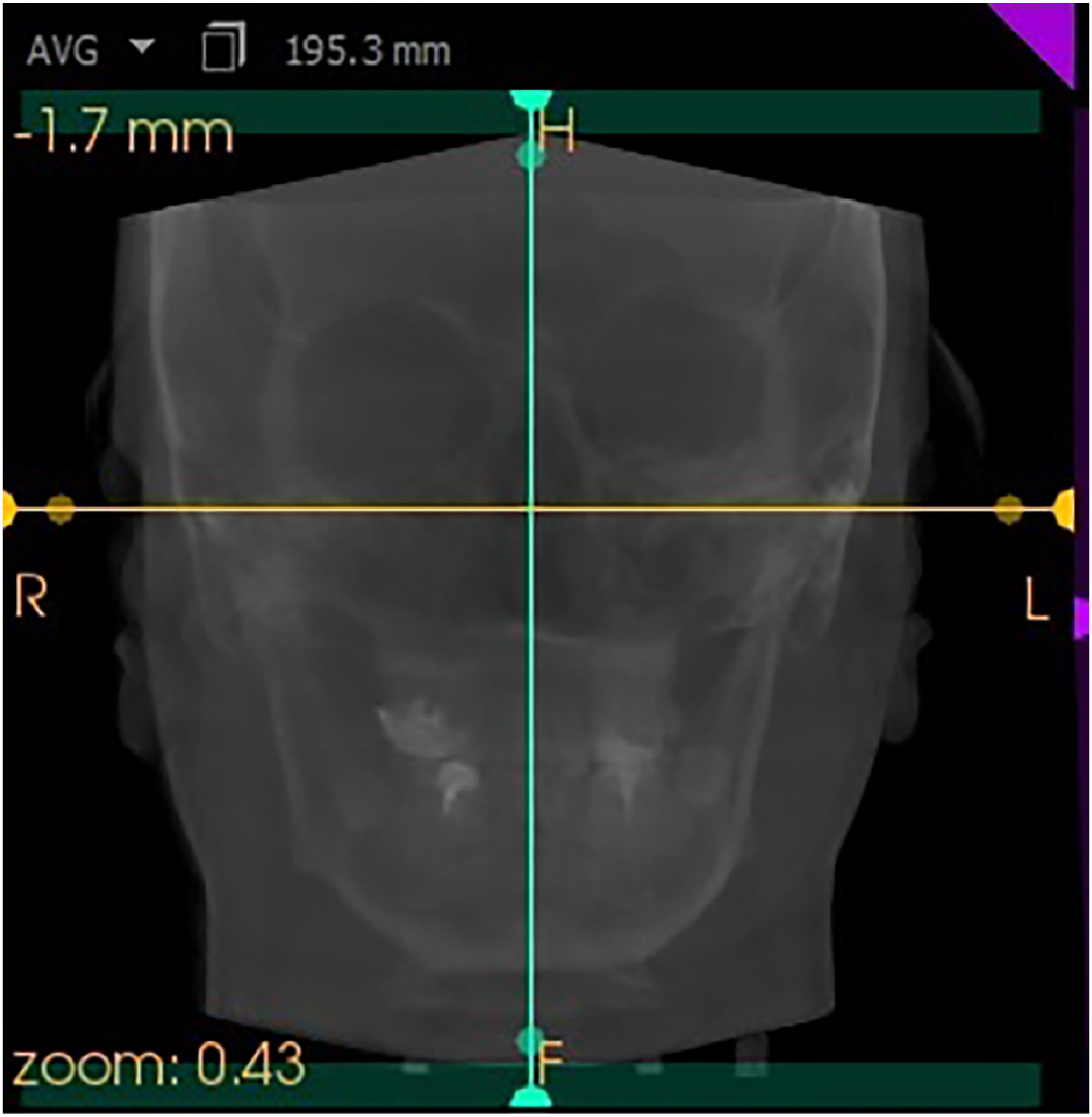

Figure 2

Head orientation in the coronal view adjusted by placing the infraorbital rim along the horizontal axis.

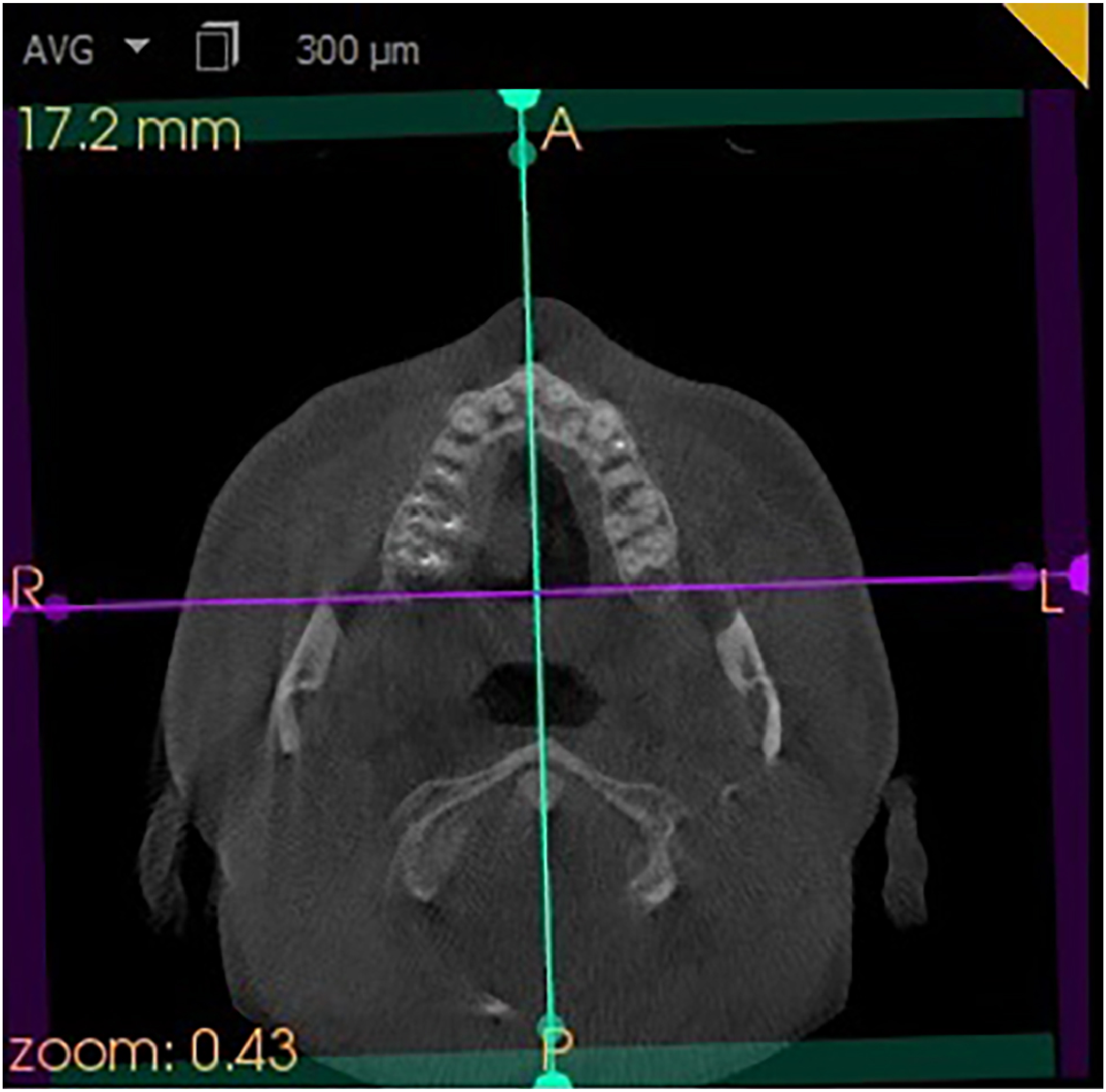

Figure 3

Head orientation in the axial view adjusted by placing the middle of the maxilla and the cervical vertebrae along the anteroposterior axis.

Figure 4

Distance between the right and left Csup (CsupR-CsupL).

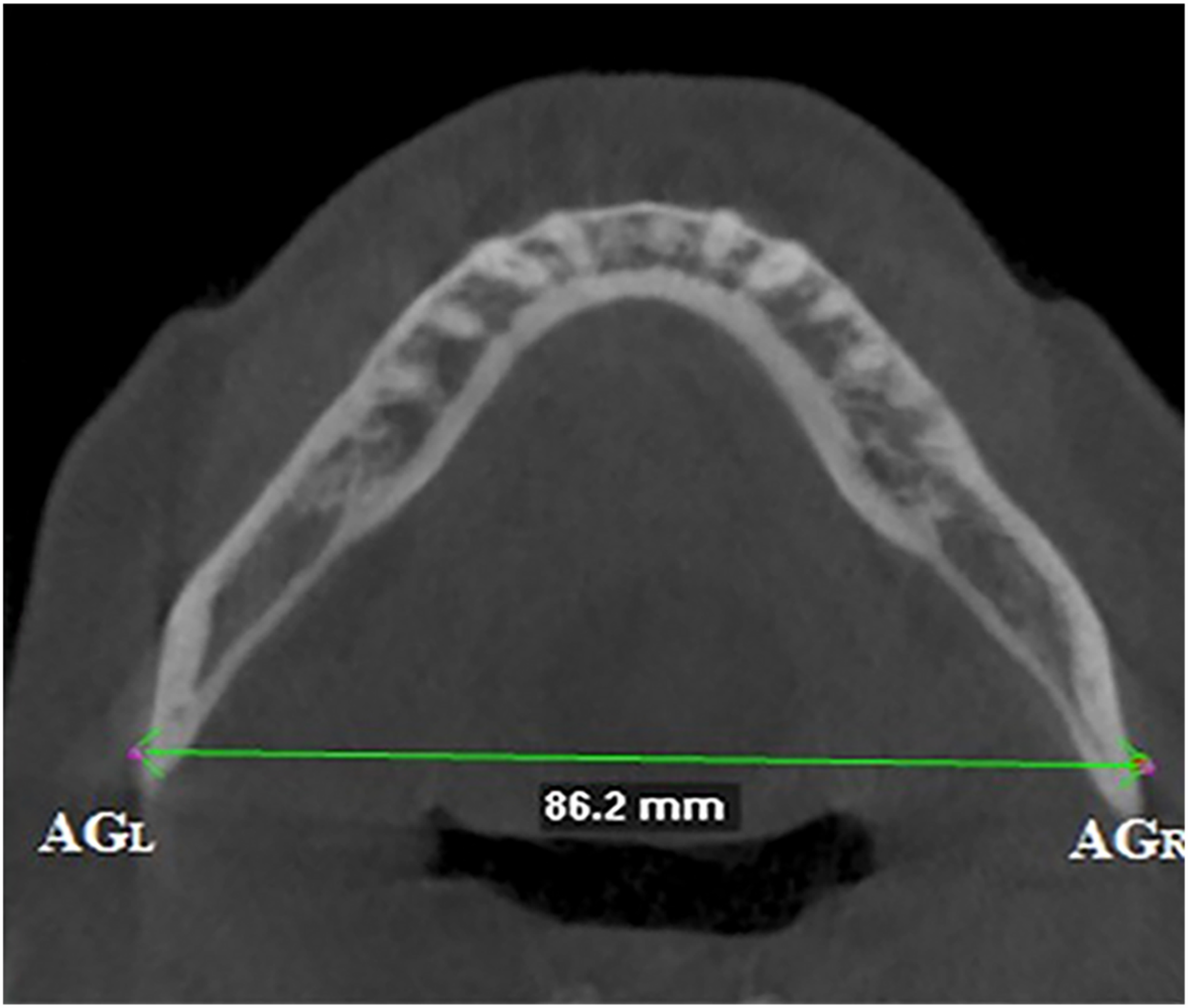

Figure 5

Distance between the right and left AG (AGR-AGL).

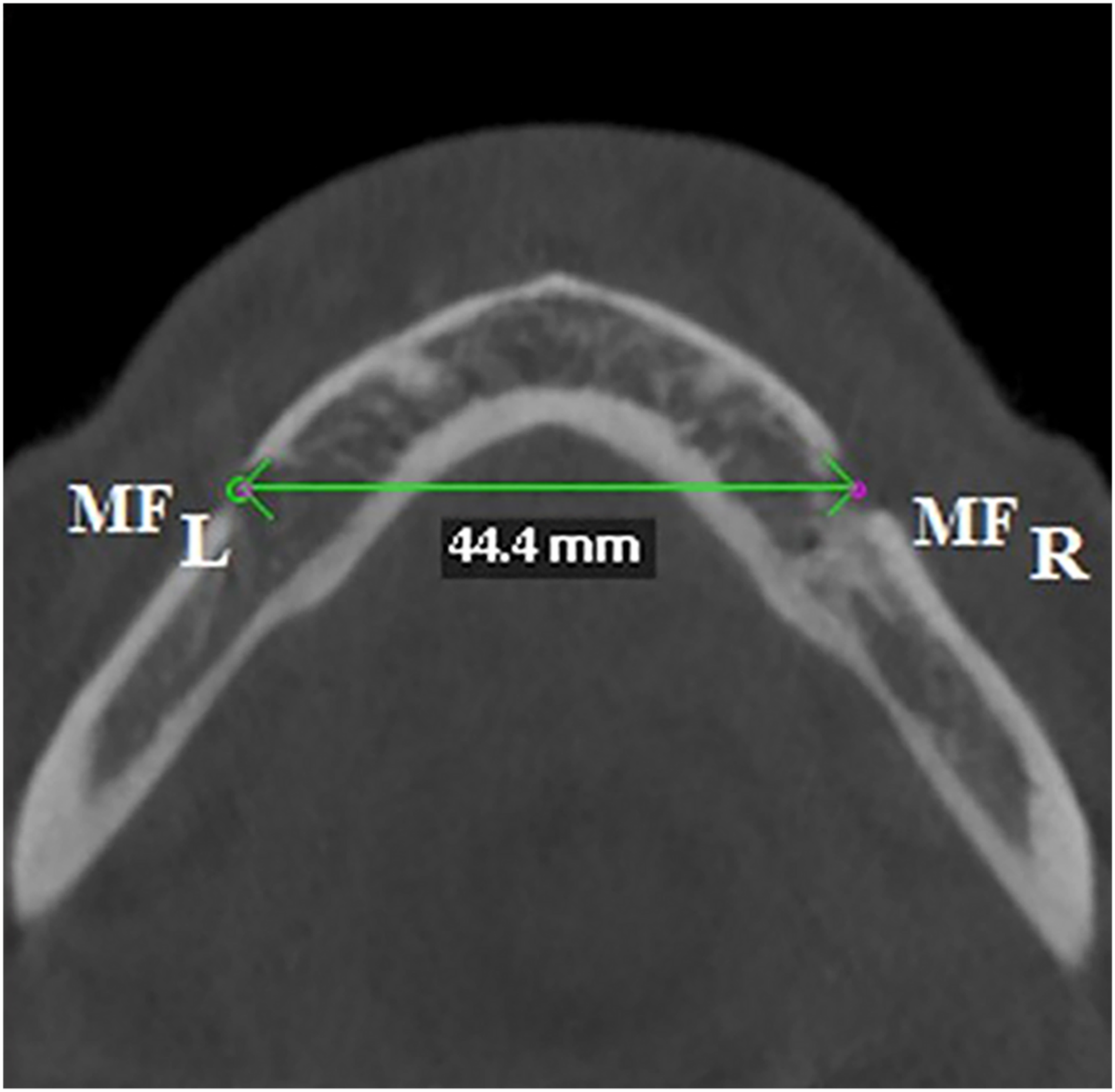

Figure 6

Distance between the right and left MF (MFR-MFL).

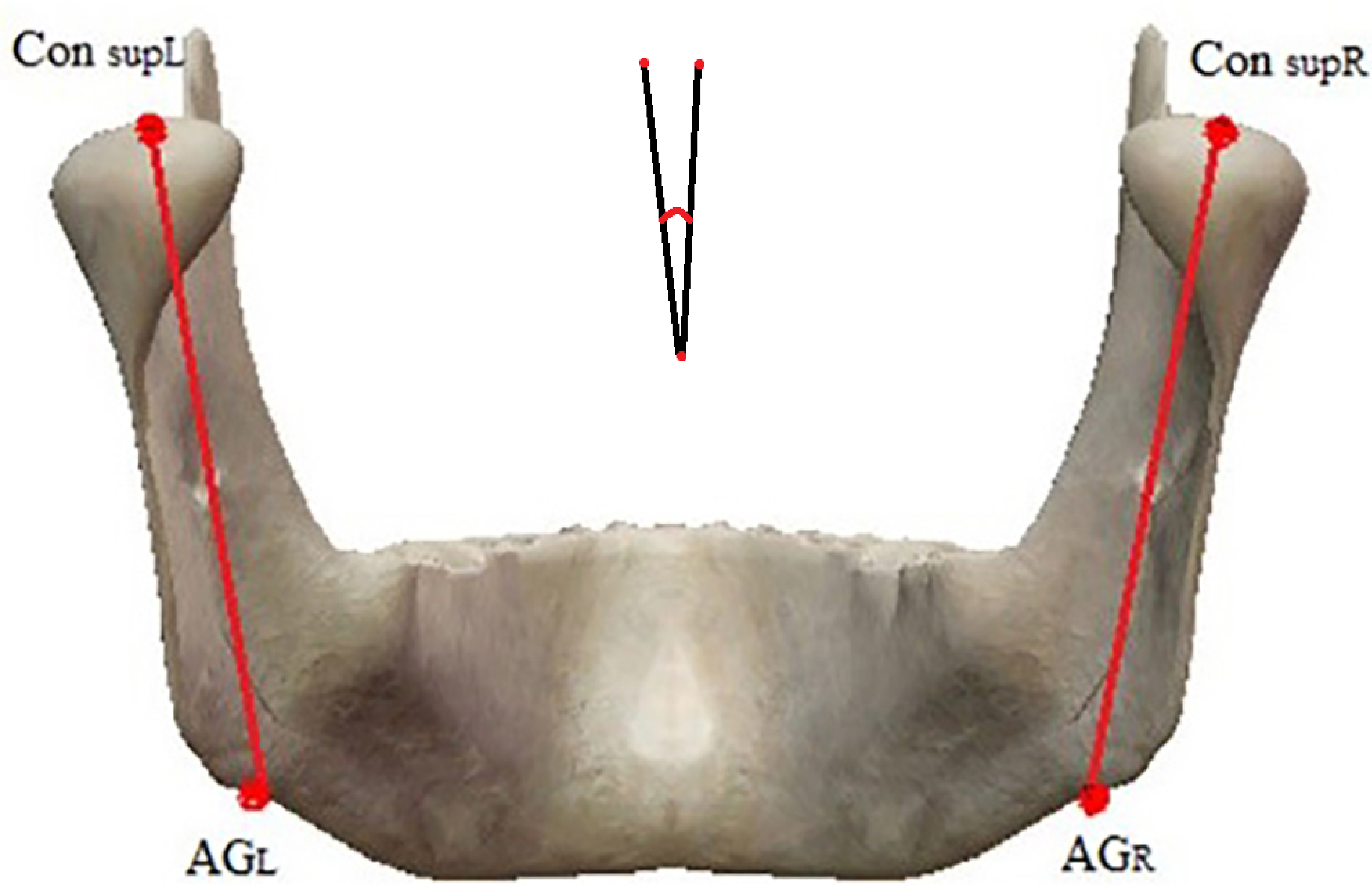

Figure 7

Angle between the right and left ramus (CsupR-AGR/CsupL-AGL).

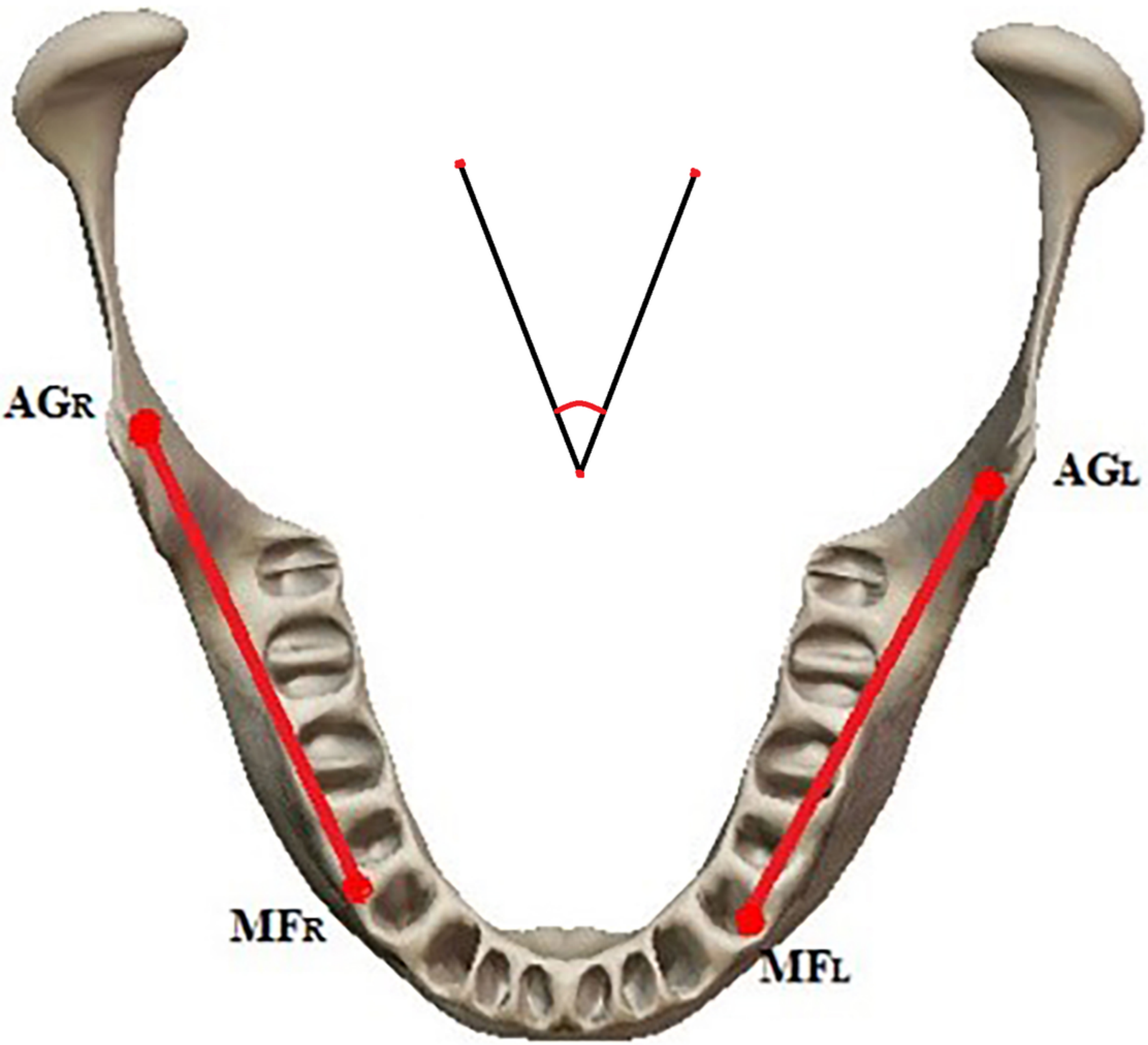

Figure 8

Angle between the right and left parts of the mandible (AGR-MFR/AGL-MFL).

Supplementary Files

This is a list of supplementary files associated with this preprint. Click to download.

- TableI.xlsx
- TableII.xlsx

- TableIII.xlsx
- TableIV.xlsx
- TableV.xlsx