

# Measuring mandibular asymmetry in Class I normal subjects using 3D novel coordinate system

## Access this article online

### Website:

www.amsjournal.com

### DOI:

10.4103/2231-0746.133073

### Quick Response Code:



Nadia Abou Kheir, Chung How Kau

Department of Orthodontics, University of Alabama at Birmingham,  
Birmingham, AL, USA

### Address for correspondence:

Prof. Chung How Kau, Department of Orthodontics, School of Dentistry,  
University of Alabama at Birmingham, 1919, 7<sup>th</sup> Avenue,  
South SDB 305, Birmingham, AL 35294, USA.  
E-mail: ckau@uab.edu

## ABSTRACT

**Introduction:** Orthodontic treatment plays a major role in cosmetic dentistry. A harmonious facial balance is normally the end point in comprehensive orthodontic outcomes. In order to achieve this goal, correct diagnosis of asymmetry should be done starting from the outer facial morphology forms and progressively moving to the dental occlusion. The prime importance of measuring mandibular asymmetry is its tremendous effect on the occlusion. **Objective:** The aim of this study was to measure mandibular asymmetry in a cohort Class I molar relationship comparing right and left sides using new three-dimensions (3D) imaging technique with the aid of 3D software (*in vivo* 5.2.3 [San Jose, CA]). **Materials and Methods:** 35 DICOM files were initially collected retrospectively and seven were excluded due to (1) condylar resorption, (2) history of trauma and (3) unclear DICOM file. A new coordinate system was set for the mid-sagittal plane (MSP), Frankfort horizontal plane and frontal plane (FP). Each cone beam computed tomography (CBCT) was appraised using 16 evaluation criteria bilaterally. Five mandibular landmarks were selected: Condylion\_R, Gonion\_R, Menton, Gonion\_L and Condylion\_L. Using these points, the mandible was further divided into four parts: (1) Ramus length right side, body of the mandible right side, body of the Ramus left side and Ramus length left side. The angles between each line and the three different planes were acquired in order to compare each line from a 3D aspect. Mean and standard deviation were calculated for the 28 CBCTs. **Results:** Significant bilateral differences were reported in the angle between the ramus length and MSP and the ramus length and the FP ( $P < 0.05$ ). Significant lateroanterior shift of the mandibular ramus on the left side in comparison with the right side. **Conclusion:** Viewing an object using three different angles between the four parts of the mandible and each plane is a valid method to replicate the actual object.

**Keywords:** Three-dimensions imaging, cone beam computed tomography, mandibular asymmetry

## INTRODUCTION

Asymmetry is a phenomenon present in nature, plants, animals and even humans. Asymmetry in the face gives us characteristic appearances or may jeopardize the proportionality of a face. These asymmetries are present in facial structures that may affect the skeleton, the muscles and its corresponding attached facial tissues. In the skeleton, a percentage of asymmetry is present in the cranial base, maxillary arch and mandibular arch. The mandible has one of the highest percentages of asymmetry in the human skull which could reach up to 74%.<sup>[1]</sup>

The etiology of mandibular asymmetry is multifactorial and it can be congenital, genetic, environment and functional.<sup>[2]</sup> There are several treatment approaches depending on the severity and the cause of the mandibular asymmetry. If it was a mild case of asymmetry with midline deviation, orthodontic camouflage could improve the case. This is done by using fixed orthodontics combined with other modalities e.g., asymmetric extraction or asymmetric elastics.<sup>[3]</sup> For a severe case of asymmetry, surgical treatment might be considered e.g., orthognathic surgery, or detaching a muscle if it was the cause of restricted growth on one side.<sup>[3]</sup> Therefore, the initial diagnosis is of paramount importance.

Farkas was among the first who were interested in measuring facial space dysmorphism using anthropometry.<sup>[4]</sup> Moreover, he had used 10 nasal direct anthropometric measurements to measure the cleft lip nose.<sup>[5]</sup> This draws attention to the importance of quantifying the severity of asymmetry which can be challenging sometimes. Several methods have been reported to measure magnitude of asymmetry, which involves evaluation of vertical and horizontal proportion of the face using different methods such as facial photographs, radiographic analyses, or direct clinical observations.<sup>[6]</sup> Unfortunately, these methods don't allow an examiner to view the face from all aspects and in three-dimensions (3D).

Hallikainen reported that the Panorex panoramic radiography machine was the first panoramic manufactured machine in the USA in 1959.<sup>[7]</sup> Panoramic radiographs have been used remarkably in epidemiological studies,<sup>[8]</sup> diagnosis of mandibular fracture<sup>[9]</sup> and evaluation of bone loss in periodontal disease.<sup>[10]</sup> However, it is considered unreliable in measuring condylar height in mandibular asymmetry cases due to the confocal trough and deterioration of the image.<sup>[11]</sup> However, it poses more reliable results when the panoramic radiograph is analyzed using Levandoski panoramic analysis.<sup>[12,13]</sup>

Cephalometric radiograph was first used in Germany by Hofrath<sup>[14]</sup> and Broadbent in US.<sup>[15]</sup> Later on, several cephalometric analysis were introduced by Downs<sup>[16]</sup> and Tweed.<sup>[17]</sup> Cephalometric analysis have been used remarkably in quantifying statistical facial dimorphism, racial differences, in skeletal and soft-tissue tracing in orthodontic treatment planning. However, Devereuk has reported that cephalometric radiographs didn't affect the decision of the treatment planning unless the treatment might involve extraction. This was concluded on sample of 6 orthodontic patients only.<sup>[18]</sup> One of the drawbacks of cephalograms is accurate landmark identification and that can be due to:

1. Position of the landmark on flat or curve surface,
2. Point located in low or high contrast and
3. The superimposition of other structures.<sup>[19]</sup>

Arai was among the first who produced high quality cone beam computed tomography (CBCT) of the oral and maxillofacial region at a low radiation dose in 1999.<sup>[20]</sup> This started the era of the use of 3D imaging in dental disciplines and particularly in orthodontics, e.g., Upper airway evaluation,<sup>[21]</sup> periodontal evaluation for implant loading,<sup>[22]</sup> evaluating surgical outcome,<sup>[23,24]</sup> and assessing orthodontic treatment outcomes.<sup>[25]</sup> In a literature review done by De Vos for 86 articles in the clinical application of CBCT in the oral and maxillofacial region, it was found that 16% of these articles are related to orthodontics.<sup>[26]</sup> The wide application of 3D imaging in orthodontics can be due to the accurate 3D representation of a subject, low radiation and the possibility of conversion from 3D images to two-dimensions (2D) images when required.<sup>[26]</sup> However, artifact and limitation of accurate soft-tissue data are flows that should be overcome for a better image quality.<sup>[26]</sup> Now-a-days, researchers are trying to translate the genetic factor of facial multi-morphism with the aid of 3D imaging for a better facial recognition.

A good diagnosis of mandibular asymmetry can be achieved by maintaining two factors: Creating a network which covers the full

length of the mandible and analyzing it from the different 3D. The aim of the study was to measure mandibular asymmetry in a cohort Class I subjects by comparing right and left sides by applying a new 3D imaging analysis using 3D software (*in vivo* Dental5.2.3 [San Jose, CA]).

## MATERIALS AND METHODS

### Subjects

A total of 28 consecutive DICOM files for Class I patients were collected from the database of the Department of Orthodontics at UAB. The subjects' heads were oriented into natural head position (NHP), which is a reproducible head orientation.<sup>[27]</sup> Initial screening was done for 35 CBCTs and 7 of them were excluded due to:

1. Condylar resorption,
2. History of trauma and
3. Unclear DICOM file. The analysis was carried out on 5 male patients with the mean age of 12.4 years and 23 female patients with mean age 19.1 years.

### Imaging

The machine used for hard tissue acquisition was Kodak 9500 cone beam 3D system device (Atlanta, GA). The radiation dose of each CBCT taken was 90 kV in a pulsed mode and frequency of 140 kHz. The tube focal spot was 0.7 mm and the sensor was a flat panel detector. The voxel size was (300, 300, 300  $\mu$ m) for the full field 3D image taken. The exposure time was 24 s (pulse beam X-ray) and the image reconstruction took 2 min and 30 s.

A 3D system to measure mandibular asymmetry comparing the right and left side was applied on each CBCT using *in vivo* 5.2.3 (San Jose, CA) software. Each CBCT was examined from one meter distance with a constant screen contrast by one examiner. A co-ordinate system was set for the mid-sagittal plane (MSP), Frankfort horizontal plane (FHP) and frontal plane (FP). Nasion, sella and anterior nasal spine were chosen as landmarks for the MSP, because it was found that the nasion and anterior nasal spine falls almost over the MSP.<sup>[28]</sup> FHP was connecting porion right, orbitale right and orbitale left [Table 1]. FP was perpendicular on the MSP and FHP [Figures 1 and 2].

### Parameters

Sixteen evaluation criteria were set to examine each CBCT: 4 linear and 12 angles. Five craniometric landmarks were plotted on the volumetric model: Condylion\_R, Gonion\_R, Menton, Gonion\_L and Condylion\_L. Condylion represented the most lateral point on the mandibular condyle, Gonion was the most

**Table 1: Definition of the different vectors**

| Landmark             | Definition   |
|----------------------|--|
| Sella                | Midpoint of the sella turcica                                    |
| Nasion               | Most anterior point of the frontonasal suture                    |
| Anterior nasal spine | Most anterior point of the nasal spine                           |
| Orbitale             | Most anterior inferior point of the orbital margin               |
| Porion               | Most superior part of the margin of the external auditory meatus |
| Condylion            | Most lateral point on the mandibular condyle                     |
| Gonion               | Most posterior inferior point on the mandibular angle            |
| Menton               | The lowest point on the mandibular symphysis                     |

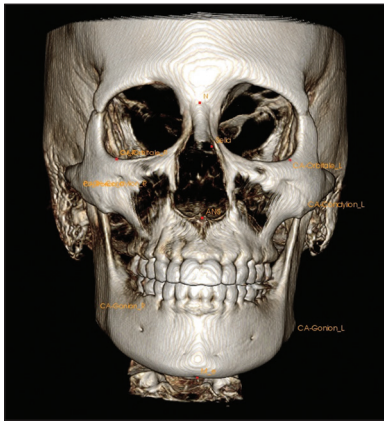
posterior inferior point on the mandibular angle and Menton was the lowest point on the mandibular symphysis [Table 1 and Figure 1]. This divided the mandible into four vectors each one was connected by two landmarks [Table 2 and Figure 3]. The magnitude of each vector was compared between right and left side.

The angles between each line and the three different planes were acquired in order to compare each line from a 3D aspect. The angles between the ramus length and the MSP, FHP and FP define the mediolateral, superoinferior and the anteroposterior position of the mandibular ramus respectively. The angles between the body of the mandible and the MSP, FHP and FP define the mediolateral, superoinferior and the anteroposterior position of the body of the mandible respectively. These angles represent the spherical coordinates of each vector in space. The angles of the right and left side were acquired and compared for any differences.

**Table 2: Landmarks of the different vectors**

| Vector | Landmark 1     | Landmark 2  |
|--------|----------------|-------------|
| RLR    | CA Condylion R | CA Gonion R |
| BMR    | CA_Gonion_R    | M_e         |
| BML    | CA_Gonion_L    | M_e         |
| RLL    | CA Condylion L | CA_Gonion_L |

RLR: Ramus length right side, BMR: Body of the mandible right side, BML: Body of the mandible left side, RLL: Ramus length left side



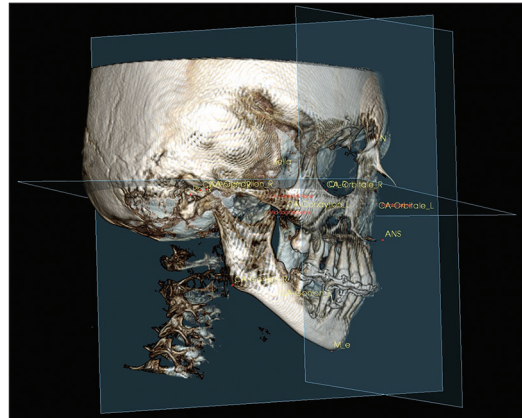
**Figure 1:** Landmarks used for the coordinate system and the mandibular asymmetry analysis

Statistical test was used to analyze the data using Excel 2010 (WA, USA). The mean and standard deviation (SD) for each criteria for the 28 DICOM files were computed. The mean and SD for the differences between right and left for the full sample were also measured.

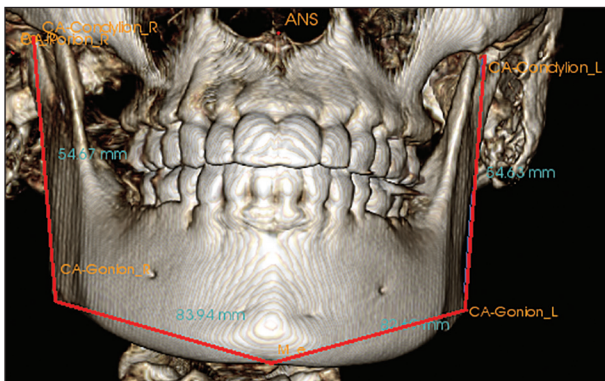
In order to measure the repeatability of the analysis each 5<sup>th</sup> DICOM file was selected from 28 DICOM files. The analysis was repeated by the same operator under the same conditions: (1) 1 m distance from the screen and (2) Fixed screen contrast for five CBCTs. The interclass correlation was measured for the first and the repeated attempt using Stata SE version 12.1 software (Texas, USA).

**RESULTS**

The ramus length on the right side had the higher mean  $52.04 \pm 5.73$  mm than the left side ( $P > 0.05$ ). The angle between the mandibular ramus on the left side and the MSP had a mean  $9.47 \pm 4.09^\circ$  which was  $4.87 \pm 3.48^\circ$  more than the right side [Figure 4]. The angle between the mandibular ramus on the right side and the FP had a mean  $9.79 \pm 4.9^\circ$  which was  $3.77 \pm 2.75^\circ$  higher than the left side [Figure 5]. There was no significant bilateral angular difference between the ramus length and the FHP and the mandibular ramus. On In contrast, significant differences were reported in the angle between the ramus length and MSP



**Figure 2:** Three planes used as a reference in the coordinate system



**Figure 3:** Mandible divided into four parts bilaterally

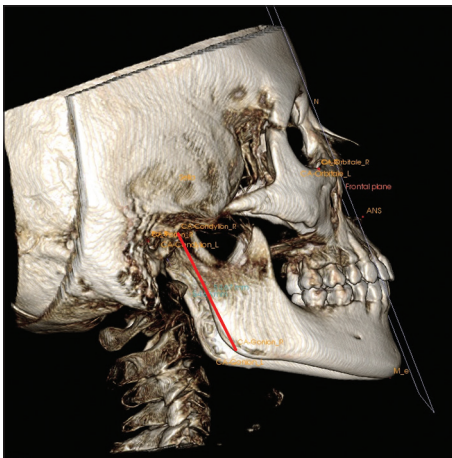


**Figure 4:** A significant difference presented in the angle between the ramus length on the left side and the mid-sagittal plane ( $P < 0.05$ )

( $P < 0.05$ ) [Figure 4]. Moreover, there was a significant difference in the angle between the ramus length and the FP when comparing right and left side ( $P < 0.05$ ) [Figure 5]. As a result, there was a significant deviation of the right mandibular ramus to the medial and posterior side in comparison with the left side [Table 2].

The body of the mandible on the right side (BMR) had a higher mean  $82.2 \pm 5.48$  mm than the left side ( $P > 0.05$ ). The angular measurement between the BMR and the mid-sagittal had a higher mean  $32.71 \pm 3.74^\circ$  in comparison with the left side. The angular measurement between body of the mandible on the left side and the FP had a higher mean  $48.88 \pm 3.89^\circ$  in comparison with the left side. There was no significant bilateral difference between the length of the mandible and the angular measurement of the three different planes ( $P > 0.05$ ) [Table 3]. In conclusion, the mandible was significantly symmetrical in the mandibular body, but the ramus of the mandible posed some asymmetry.

The correlation between the two sets of data was 0.99, which represents a high level of agreement. The confidence level was 0.99. These values showed that the analysis has good test-retest reliability.



**Figure 5:** A significant difference presented in the angle between the ramus length on the right side and the frontal plane ( $P < 0.05$ )

## DISCUSSION

There are several causes for mandibular asymmetry, which can be classified into: Developmental, pathological, traumatic and functional.<sup>[3]</sup> Extraoral photos, intraoral photos, study casts, imaging procedure and biopsies are different diagnostic modalities to achieve the best treatment outcome. Imaging procedures can vary from radiographs, photographs, spiral CT scans and CBCT scan.<sup>[3]</sup>

Panoramic radiographs are one of the most widely used radiographs by the dentist to diagnose asymmetry. However, they have the disadvantage of unreliable horizontal measurements due to nonlinear magnification in different depths.<sup>[29]</sup>

Cephalograms have been used to measure mandibular asymmetry. In a study done by Damstra to detect mandibular asymmetry using posterior anterior cephalograms and CBCT, it was found that CBCT was more reliable (intraclass correlation coefficient  $> 0.957$ ) than posterior-anterior cephalograms.<sup>[30]</sup> In addition, plotting landmarks in the posterior part of the skull (e.g., sella) to a set a reference plane is hard due to superimposition of the right and left parts of the cranium. This could affect the correct position of the reference plane and as a result the asymmetry measurements done in relation to it.<sup>[31]</sup>

There is an increasing demand to improve diagnostic methods to evaluate facial asymmetry. There is a vast tendency for a scientist to improve a diagnostic tool to evaluate facial asymmetry with respect to 3D imaging. Researchers have tried to use 2D cephalometric radiographs to evaluate the facial structures from 3D relationship. Grayson has applied a multiplane cephalometry approach on a hemicraniofacial micrsomia case.<sup>[32]</sup> Several midlines were evaluated in different depth of the craniofacial complex. Later on, these midlines were transformed into a warped MSP, which gives the advantage of measuring asymmetry from 3D point of view. 3D imaging has been used tremendously to evaluate different surgical approaches to treat craniofacial anomalies. Computer-aided surgical simulation (CASS) is a new system to diagnose and plan cranio-maxillofacial surgery.

**Table 3a: Statistical analysis of the level of asymmetry present in the ramus of the mandible for the 28 DICOM files**

| Statistical measurement | Length |       |            |         |         |            | Angles  |         |            |        |        |            |
|-------------------------|--------|-------|------------|---------|---------|------------|---------|---------|------------|--------|--------|------------|
|                         | RLR    | RLL   | Difference | RLR-MSP | RLL-MSP | Difference | RLR-FHP | RLL-FHP | Difference | RLR-FP | RLL-FP | Difference |
| Mean                    | 52.04  | 51.76 | 2.88       | 5.33    | 9.47    | 4.87       | 77.26   | 77.18   | 2.87       | 9.79   | 6.77   | 3.77       |
| SD                      | 5.79   | 3.55  | 3.23       | 3.11    | 4.09    | 3.48       | 5.41    | 4.7     | 2.6        | 4.91   | 4.02   | 2.75       |
| P                       |        | 0.45  |            |         | 0.001   |            |         | 0.49    |            |        | 0.02   |            |

$P < 0.05$  represents a comparison in the bilateral difference between mandibular ramus length and angular measurement with the three planes of space. SD: Standard deviation, RLR: Ramus length right side, RLL: Ramus length left side, MSP: Mid-sagittal plane, FHP: Frankfort horizontal plane, FP: Frontal plane

**Table 3b: Statistical analysis of the level of asymmetry present in the body of the mandible for the 28 DICOM files**

| Statistical measurement | Length |      |            |         |         |            | Angles  |         |            |          |        |            |
|-------------------------|--------|------|------------|---------|---------|------------|---------|---------|------------|----------|--------|------------|
|                         | BMR    | BML  | Difference | BMR-MSP | BML-MSP | Difference | BMR-FHP | BML-FHP | Difference | BMR-FP   | BML-FP | Difference |
| Mean                    | 82.2   | 81.5 | 2.76       | 32.71   | 32.26   | 3.73       | 23.24   | 23.21   | 2.94       | 47.8075  | 48.88  | 4.11       |
| SD                      | 5.48   | 4.8  | 5.1        | 3.74    | 2.51    | 2.44       | 4.54    | 6.63    | 3.56       | 4.038356 | 3.89   | 5.05       |
| P                       |        | 0.44 |            |         | 0.38    |            |         | 0.49    |            |          | 0.34   |            |

$P < 0.05$  represents a comparison in the bilateral difference between mandibular body length and angular measurement with the three planes of space. SD: Standard deviation, BMR: Body of the mandible right side, BML: Body of the mandible left side, MSP: Mid-sagittal plane, FHP: Frankfort horizontal plane, FP: Frontal plane

Creating a computerized skull model and orienting it to match the NHP is an example of a CASS approach done by Gateno.<sup>[33]</sup> After deciding the best method to treat the asymmetry, splint is created to implement the computerized outcomes to the patient.

Facial asymmetry is least found in Class I patient in comparison with Class II or even Class III,<sup>[34]</sup> due to that Class I patients were selected to measure the least amount of asymmetry that can be detected using the mandibular asymmetry analysis. The use of 3D software gives more accurate data, due to better landmark plotting. Using the standard way of measuring the mandibular longitude is not enough to judge the presence of asymmetry. Any bony landmark has x, y, z coordinates which make it look more or less elevated, protruded and shifted to a certain side. Incorporating angular measurements gives a virtual representation of the actual level of asymmetry present with respect to these angles. However, patient position can still affect the accuracy of the data acquired from the 3D image. The mandible should be fully closed while acquiring the image to decrease any operator error due to incorrect landmark plotting. This could happen especially when the subject has a functional shift and was not instructed to fully close the mandible.

In this study, there was no significance bilateral difference between the longitudes of the mandibular ramus. Yet, there was a significant lateral and anterior shift of the left side in comparison with the right side. As a result, judging mandibular asymmetry can't be done solely on the longitude and should be done with respect to 3D.

## CONCLUSION

Mathematical analysis is a valid method to measure mandibular asymmetry with respect to the third dimension which is usually absent in clinical photos and panoramic radiographs. Incorporation of angular measurements using 3D imaging software increases diagnostic accuracy for the least amount of asymmetry present.

## ACKNOWLEDGMENTS

The author thanks Mr. Jon Banh, application specialist in Anatomage (*in vivo* Dental5.2.3 [San Jose, CA]) for his software support all the way through the project and Mr. Dennis Ma for computing and analyzing the data acquired in the research.

## REFERENCES

- Severt TR, Proffit WR. The prevalence of facial asymmetry in the dentofacial deformities population at the University of North Carolina. *Int J Adult Orthodon Orthognath Surg* 1997;12:171-6.
- Bishara SE, Burkey PS, Kharouf JG. Dental and facial asymmetries: A review. *Angle Orthod* 1994;64:89-98.
- Chia MS. The aetiology, diagnosis and management of mandibular asymmetry. *Orthod Update* 2005;1:44-52.
- Farkas LG, James JS. Anthropometry of the face in lateral facial dysplasia: The unilateral form. *Cleft Palate J* 1977;14:193-9.
- Lindsay WK, Farkas LG. The use of anthropometry in assessing the cleft-lip nose. *Plast Reconstr Surg* 1972;49:286-93.
- Kronmiller JE. Development of asymmetries. *Semin Orthod* 1998;4:134-7.
- Hallikainen D. History of panoramic radiography. *Acta Radiol* 1996;37:441-5.
- Ahlqwist M, Halling A, Hollender L. Rotational panoramic radiography in epidemiological studies of dental health. Comparison between panoramic radiographs and intraoral full mouth surveys. *Swed Dent J* 1986;10:73-84.
- Chayra GA, Meador LR, Laskin DM. Comparison of panoramic and standard radiographs for the diagnosis of mandibular fractures. *J Oral*

- Maxillofac Surg 1986;44:677-9.
- Kaimenyi JT, Ashley FP. Assessment of bone loss in periodontitis from panoramic radiographs. *J Clin Periodontol* 1988;15:170-4.
- Kambylafkas P, Murdock E, Gilda E, Tallents RH, Kyrkanides S. Validity of panoramic radiographs for measuring mandibular asymmetry. *Angle Orthod* 2006;76:388-93.
- Kubota Y, Takenoshita Y, Takamori K, Kanamoto M, Shirasuna K. Levandoski panoramic analysis in the diagnosis of hyperplasia of the coronoid process. *Br J Oral Maxillofac Surg* 1999;37:409-11.
- Padrón CM, Portillo GG. Facial asymmetries prevalence using Levandoski panoramic analysis. *Rev Odont Mex* 2009;13:99-104.
- Hofrath, H. Bedeutung der röntgenfern und abstands aufnahme für die diagnostik der kieferanomalien. *Fortschritte der Orthodontie* 1931;1:231-58.
- Broadbent HB. A new X-ray technique and its application to orthodontia. *Angle Orthod* 1931;1:45-66.
- Downs WB. Variations in facial relationships; their significance in treatment and prognosis. *Am J Orthod* 1948;34:812-40.
- Tweed CH. Evolutionary trends in orthodontics, past, present, and future. *Am J Orthod* 1953;39:81-108.
- Devereux L, Moles D, Cunningham SJ, McKnight M. How important are lateral cephalometric radiographs in orthodontic treatment planning? *Am J Orthod Dentofacial Orthop* 2011;139:E175-81.
- Leonardi R, Annunziata A, Caltabiano M. Landmark identification error in posteroanterior cephalometric radiography. A systematic review. *Angle Orthod* 2008;78:761-5.
- Arai Y, Tammisalo E, Iwai K, Hashimoto K, Shinoda K. Development of a compact computed tomographic apparatus for dental use. *Dentomaxillofac Radiol* 1999;28:245-8.
- Aboudara CA, Hatcher D, Nielsen IL, Miller A. A three-dimensional evaluation of the upper airway in adolescents. *Orthod Craniofac Res* 2003;6 Suppl 1:173-5.
- Aranyarachkul P, Caruso J, Gantes B, Schulz E, Riggs M, Dus I, *et al*. Bone density assessments of dental implant sites: 2. Quantitative cone-beam computerized tomography. *Int J Oral Maxillofac Implants* 2005;20:416-24.
- Swennen GR, Mollemans W, Schutyser F. Three-dimensional treatment planning of orthognathic surgery in the era of virtual imaging. *J Oral Maxillofac Surg* 2009;67:2080-92.
- Christou T, Kau CH, Waite PD, Kheir NA, Mouritsen D. Modified method of analysis for surgical correction of facial asymmetry. *Ann Maxillofac Surg* 2013;3:185-91.
- Baumrind S, Carlson S, Beers A, Curry S, Norris K, Boyd RL. Using three-dimensional imaging to assess treatment outcomes in orthodontics: A progress report from the University of the Pacific. *Orthod Craniofac Res* 2003;6 Suppl 1:132-42.
- De Vos W, Casselman J, Swennen GR. Cone-beam computerized tomography (CBCT) imaging of the oral and maxillofacial region: A systematic review of the literature. *Int J Oral Maxillofac Surg* 2009;38:609-25.
- Kau CH, Richmond S, Zhurov AI, Knox J, Chestnutt I, Hartles F, *et al*. Reliability of measuring facial morphology with a 3-dimensional laser scanning system. *Am J Orthod Dentofacial Orthop* 2005;128:424-30.
- Hanvonn E. Cleft lip and palate. Morphologic studies of facial skeleton. *Am J Orthod* 1954;40:493-506.
- Gupta S, Jain S. Orthopantomographic analysis for assessment of mandibular asymmetry. *J Indian Orthod Soc* 2012;46:33-7.
- Damstra J, Fourie Z, Ren Y. Evaluation and comparison of postero-anterior cephalograms and cone-beam computed tomography images for the detection of mandibular asymmetry. *Eur J Orthod* 2013;35:45-50.
- Katsumata A, Fujishita M, Maeda M, Arijii Y, Arijii E, Langlais RP. 3D-CT evaluation of facial asymmetry. *Oral Surg Oral Med Oral Pathol Oral Radiol Endod* 2005;99:212-20.
- Grayson BH, McCarthy JG, Bookstein F. Analysis of craniofacial asymmetry by multiplane cephalometry. *Am J Orthod* 1983;84:217-24.
- Gateno J, Xia JJ, Teichgraeber JF. New methods to evaluate craniofacial deformity and to plan surgical correction. *Semin Orthod* 2011;17:225-34.
- Cheong YW, Lo LJ. Facial asymmetry: Etiology, evaluation, and management. *Chang Gung Med J* 2011;34:341-51.

**Cite this article as:** Kheir NA, Kau CH. Measuring mandibular asymmetry in Class I normal subjects using 3D novel coordinate system. *Ann Maxillofac Surg* 2014;4:34-8.

**Source of Support:** Nil, **Conflict of Interest:** None declared.