Journal of Craniomaxillofacial Research

Vol. 8, No. 2 Spring 2021

Accuracy of CBCT measurements of posterior mandible

Izzati Nabilah Ismail [1*], Mohammad Aizuddin Abu Bakar [2], Khairul Fikri Hairul Anuar [2], Mohamad Arif Ramlee [3]

1. Department of Oral and Maxillofacial Surgery and Diagnosis, Kulliyyah of Dentistry, International Islamic University Malaysia.

2. Kulliyyah of Dentistry, International Islamic University Malaysia.

3. Dental and Maxillofacial Surgery, Sultan Ahmad Shah Medical Center, International Islamic University Malaysia.

ARTICLE INFO

Article Type:
Original Article

Received: 2 Sep. 2020
Revised: 2 Oct. 2020
Accepted: 25 Jan. 2021

**Corresponding author:*
Izzati Nabilah Ismail

Department of Oral and Maxillofacial Surgery and Diagnosis, Kulliyyah of Dentistry, International Islamic University Malaysia, Jalan Sultan Ahmad Shah, Kuantan 25200, Pahang, Malaysi.

Tel: +6095704000 ext 2942
Fax: ----
Email: izzatiismail@Iium.edu.my

ABSTRACT

Objectives: This study is aimed at analysing the accuracy and reliability of the cone beam CT (CBCT) measurements and direct physical measurements of the posterior mandible.

Materials and Methods: Eighteen cadaveric hemi-mandibles were dissected from the soft tissues and the CBCT images of the mandibles were taken. Direct physical and cone beam CT measurements of six landmarks which includes height of ramus (R), distance of lingula to sigmoid notch (LS), distance of lingula to inferior border (LI), position of lingula in relation to occlusal plane (L-OP), ramus thickness at crestal level (RT-C), and ramus thickness at midway between sigmoid notch and lingula (RT-M) were determined. Accuracy and reliability of the measurements were tested.

Results: Four landmarks showed high accuracy when measuring the posterior mandible, while two landmarks, LI and RT-M, showed statistically significant weaker accuracy ($p<0.05$). Inter-reliability were good for all landmarks when measured directly physically on mandibles (ICC>0.7 and $p>0.05$), but were low on two landmarks, LI and RT-C, on CBCT measurement (ICC<0.5 and $p<0.05$).

Conclusion: A generally strong accuracy between direct physical and CBCT measurements for most landmarks on posterior mandible were found. Reliability between two researchers were high on direct physical measurements. Meanwhile, two landmarks on CBCT which include LI and RT-C showed low inter-reliability. Hence, CBCT measurements proved to be a good tool for pre-operative assessment, since high inter-reliability and strong accuracy corresponding to direct physical were recorded.

Keywords: CBCT accuracy; CBCT measurements; CBCT reliability; Physical measurements; Posterior mandible.

Introduction

In clinical practice, there are many procedures that involve the posterior mandible. These include inferior alveolar nerve (IAN) block, removal of impacted lower wisdom tooth, temporomandibular joint surgery, and orthognathic surgery. The variations in the maxillo-mandibular development leads to an unpredictable posterior mandible anatomy containing vital structures that are crucial for oral surgeons [1]. Therefore, the importance of having a good knowledge regarding anatomy related to the posterior mandible prior to any procedure is warranted to prevent complications. In orthognathic surgery, one of the surgical procedures on the mandible that is commonly used to treat mandibular deformities are known as sagittal split ramus osteotomy (SSRO). SSRO is one of the most technique sensitive mandibular procedure as it comes with multiple complications. The major intraoperative complications of SSRO is unfavourable fracture which can lead to postoperative neurosensory disturbances, surgical instability, and temporomandibular joint disorder [2-5]. It was reported that in Class II and Class III dentofacial deformities, the ramus were thinner with minimal cancellous bone. This made SSRO fracture lines unpredictable and increases the risk to unfavourable fractures [2-5].

These anatomical variations of the posterior mandible were thought to be a huge limiting factor in predicting the osteotomy cuts for SSRO [5-7]. Making anatomical assessment intraoperatively by performing direct physical measurement of the mandible may or may not prevent or reduce the risk of unfavourable fracture and nerve injury. There is an importance for clinicians to assess the anatomy of the posterior mandible prior to the surgery to ensure a safe surgery void of permanent complications [8-10]. Hence, it was suggested that the preoperative assessment of the posterior mandible can be complemented by radiographic assessment. Radiographic imaging has been widely used for preoperative assessment of the mandibular anatomy to detect the gross anatomy of the posterior mandible. Important anatomical structures that were commonly investigated during preoperative assessment of SSRO include the height and thickness of the ramus, the location of lingula and coronoid notch, as well as the mandibular foramen [11,12]. This preoperative assessment is deemed important to prevent complications associated with SSRO.

Conventional two-dimension (2D) radiographs such as orthopantomogram (OPG), lateral and frontal cephalogram are commonly used for diagnostic and preoperative assessment. However, due to the limitation of being two dimensional, they are insufficient to detect the gross anatomical structures. The usage of three-dimensional (3D) imaging such as computed tomography (CT) and cone-beam CT (CBCT) has been reported to be a useful preoperative tool in preventing complications of mandibular surgery. Multiple studies found that 3D-CBCT data and measurements increases the precision of surgical procedure, be it for implant procedure, endodontic procedure, or third molar removal [13-16]. Although inherently superior to a 2D radiographic imaging, multiple reports still found moderate discrepancies between CBCT measurement and direct physical measurement [17-19]. With improved technology of CBCT, many studies found improved accuracy in measurements of dental structures such tooth length, pulpal length and dentin thickness for endodontic procedures [16], as well as overjet, overbite and arch width for orthodontic purposes [15]. Some also studied the alveolar bone thickness at the alveolar ridge for implant planning [13,20]. These studies made their measurements on CBCT and compared them with physical measurement made directly during clinical procedure and on study models using high precision digital callipers. However, in relation to SSRO procedure and assessment of the posterior mandible, no studies had been done to assess the accuracy and reliability of the CBCT measurements in comparing with the direct physical measurement of the posterior mandible.

The focus of this research is in identifying whether CBCT provides an accurate and reliable measurement tool for the anthropometric measurement of the posterior mandible. It is hypothesized that there is no difference between direct physical measurement and CBCT measurement when two assessors are involved in the linear measurement analysis of the posterior mandible. Therefore, this study is aimed primarily at investigating the accuracy of CBCT measurements of the posterior mandible relative to direct physical measurements on cadaveric mandible to establish a safe surgical procedure. In addition to that, this study will also investigate the reliability of CBCT and direct physical measurements of the posterior mandible.

Materials and Methods

Study sample

A cross-sectional study on dried mandibles and their corresponding CBCT was conducted upon ethical approval by the IIUM Research Ethical Committee (IREC 2018-078). Fresh frozen heads were obtained from the Department of Otolaryngology-Head and Neck Surgery, Kulliyyah of Medicine, International Islamic University Malaysia. The head specimens obtained for educational and research purposes had been approved and consented by corresponding regulatory bodies. The mandibles were dissected from the soft tissues and stored in formalin 10%. The mandibles were then divided into hemi-mandibles. All the cadaveric mandibles included in the study were adult mandibles above the age of 18 with no history of mandibular surgery or bony pathology and did not have any craniofacial syndromes. Since the researchers wished to detect the difference of measurements between two different methods of measurement at 1.5mm difference in the mean mandibular height in a two-sided 5% significance level test with 80% power, with the standard deviation of mandibular height according to a similar study done by Apinhasmit et al. at 0.7mm using the formula based on the power of the test, the total sample size required is 17 [19].

Data Collection

Upon dissection of mandibles from the soft tissues of the head, the mandibles were stored in a 10% formalin solution. CBCT images of the hemi-mandibles were taken using Planmeca Promax 3D imaging device (Planmeca, Helsinki, Finland) at 90 kV, with a voxel size of 0.2mm and a field of view of 18-20cm, being the scan time of 18 seconds. The CBCT imaging of the hemi-mandibles were done within 3 months of the mandibular dissection to minimize gross distortion of the mandibles. Direct gross measurements were also made within 3 months of the CBCT image date using a high precision electronic digital sliding callipers (Aerospace Digital Calliper) (see Figure 1), whereas the digital measurements on the CBCT images were done using Planmeca Romexis Version 2.0 software (see Figure 2-5).

Skull Measurement

The measurement of the anatomical landmarks on CBCT and cadaveric mandible include height of ramus (R), distance of lingula to sigmoid notch (LS), distance of lingula to inferior border (LI), position of lingula in relation to occlusal plane (L-OP), ramus thickness at crestal level (RT-C), ramus thickness at midway between sigmoid notch and lingula (RT-M). Table 1 summarised the definition and the detailed description of the method of measurements made for each landmarks. Two researchers underwent a pilot assessment by observing 3 hemi-mandible specimens. Each researcher performed the pilot assessment twice at 3 days interval for intra-observer reliability testing to ensure reproducibility of the determination of the landmarks. The intra-observer assessment for both researchers were non-significant (p>0.05).

CBCT Measurements

The digital measurements on the CBCT images were done using Planmeca Romexis Version 2.0 software by two researchers who underwent prior training on Romexis software use. The six variable of anatomical landmarks were determined on the panoramic implant tab to view the reconstructed panoramic image and its corresponding view on the coronal plane. Figure 2-5 showed the anatomic location determination and the detailed description of the measurement of landmarks identified on CBCT images.

Outcome Measures

The primary outcome of this study was the accuracy of the measurements of the posterior mandibles between CBCT measurements and direct physical measurements on cadavers. Secondarily, this study also investigated on the inter-reliability of CBCT and direct physical measurement on cadaveric mandibles.

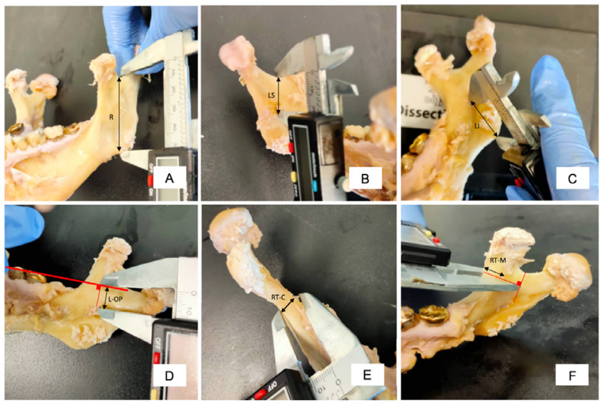

Figure 1. Direct physical measurements made on cadaveric mandibles using Aerospace Digital Caliper. (A) Height of ramus, R. (B) Distance of lingula to sigmoid notch, LS. (C) Distance of lingula to inferior border, LI. (D) Position of lingula in relation to occlusal plane, L-OP. (E) Ramus thickness at crestal level, RT-C. (F) Ramus thickness at midway between sigmoid notch and lingula, RT-M.

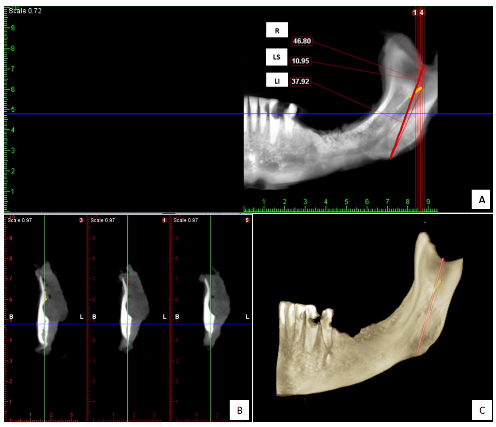

Figure 2. A panoramic implant view of the software was used to detect the anatomical landmarks. When

measuring the height of ramus, the panoramic view (A) was used to detect the sigmoid notch and the inferior border of mandible. The plane was placed at the lateral cortex of the mandible. Both landmarks were traced using red marker. The 2 points were used to measure the length of the ramus, R. When measuring the LS and LI, lingula was traced using a yellow marker on the coronal view of the mandible (B). The distance between the 2 points from lingula to sigmoid notch and inferior border were then measured on the panoramic view, respectively. The 3D reconstructed image of the mandible was used to confirm the location of landmarks (C).

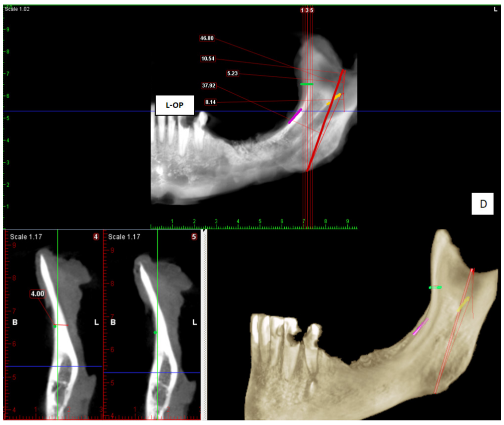

Figure 3. The location of Lingula was marked with a yellow marker and the occlusal plane was indicated by the blue line of the axial plane (D). The two points were then measured for the L-OP.

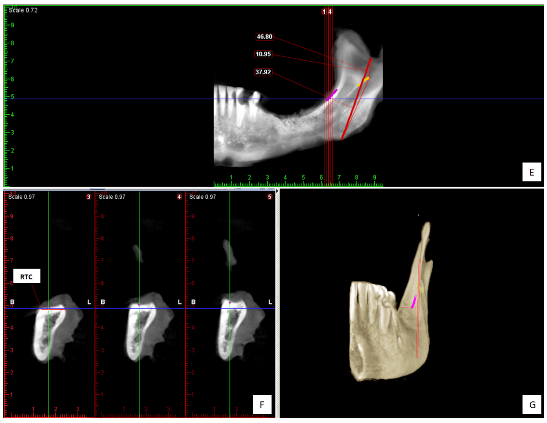

Figure 4. On the panoramic view, the blue line of the axial plane was used to indicate the crestal level at the anterior ramus. The region was marked with a purple marker (E). The measurement of the RT-C was made on the sagittal view of the ascending ramus (F). The 3D reconstructed image was used to confirm the location of landmarks (G).

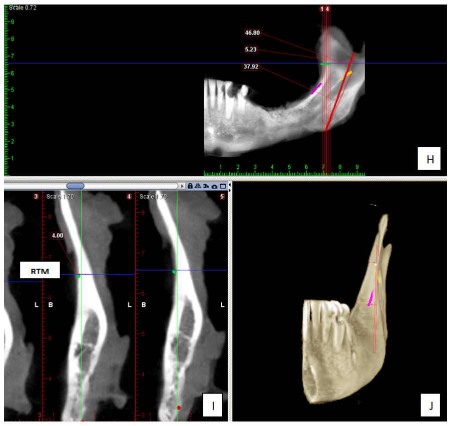

Figure 5. The midway between lingula and sigmoid notch was made by dividing the distance of LS on the panoramic view (H). The blue line of the axial plane was then moved to the desired midway. The region of the anterior ramus at the midway level was then marked with green marker. The RT-M measurement was made on the sagittal view of the ascending ramus (I). The 3D reconstructed image was used to confirm the location of landmarks.

Statistical Analysis

All the data collected were gathered and analysed using IBM SPSS Statistics Version 25. The accuracy of CBCT measurements relative to direct physical measurements were analysed using paired t-test. Meanwhile, method reliability for both direct physical and CBCT measurements were analysed by calculating two inter-observer error using paired t-test and Intra-Class Coefficient (ICC) for every landmarks. The significance level was set at $p<0.05$.

Results

There were 18 samples of cadaveric hemi-mandibles that fit the inclusion and exclusion criteria. However, the CBCT images of a pair of hemi-mandible were missing making the total sample for CBCT measurement, n=16. One mandible were completely edentulous, therefore, the landmark L-OP were unable to be obtained due to missing occlusal plane (n=14). Table 2 showed the descriptive statistics of the samples using direct physical measurements and CBCT measurements. Table 3 showed the accuracy of the measurements when comparing between two methods. Most mandibular landmarks showed no statistically significant difference with p-value>0.05, except for the landmarks LI and RT-M. For the landmark LI, the mean physical measurement was 35.93mm, whereas for CBCT measurement was 33.74mm, with a statistically significant mean difference between the two methods of 2.573 (p-value<0.05). For the mandibular landmark RT-M, the mean physical measurement and CBCT measurement were 5.71mm and 5.33mm, respectively, with a statistically significant mean difference of 0.488mm (p-value<0.05). Table 4 shows the inter-reliability agreement between two researchers. The inter-reliability analysis was assessed between using a two-way mixed, absolute agreement, average measures ICC for both physical and CBCT measurement methods on every landmarks of the cadaveric hemi-mandibles. For direct physical measurements, there was no statistical significance between two researchers when measuring directly on physical mandibles (p value>0.05) indicating high agreement between two researchers. The ICC value was also high in all mandibular landmarks with ICC>0.7, indicating a high inter-reliability. Meanwhile for CBCT measurements, all landmarks showed high inter-reliability agreement with no statistical significance between two researchers for most of the mandibular landmarks, except for measurement of the landmark LI with statistically significant mean difference of -2.68 (p<0.05). In addition to that, there were good ICC values with ICC>0.6 for all mandibular landmarks, except for the landmark RT-C, in which the ICC value was recorded to be below 0.5.

Table 1. Summary of the definition of landmarks.

	Definition	Description of measurement
Height of ramus (R)	*Distance from sigmoid notch to the inferior border of the mandible.*	*The deepest concavity of the sigmoid notch was identified as the superior point and the inferior point was identified at the most posterior part of the inferior border of mandible.*
Distance of lingula to sigmoid notch (LS)	*Distance measured from the tip of the lingula to sigmoid notch deepest concavity of the sigmoid notch.*	*The deepest concavity of the sigmoid notch was identified as the superior point and the tip of lingula as the inferior point.*
Distance of lingula to inferior border (LI)	*Distance from the tip of the lingula to the inferior border at the mandibular angle.*	*The tip of the lingula was identified as the superior point and the most posterior part of the inferior border of mandible as the inferior point.*
Vertical position of lingula in relation to occlusal plane (L-OP)	*Vertical distance measured from a parallel line made along the tip of the lingula with the occlusal plane.*	*The occlusal plane level was extended posteriorly towards the ramus and the vertical distance between them was recorded in tangent of those lines.*
Ramus thickness at crestal level	*The thickness measured from the medial cortex to the lateral cortex of the mandible at the crestal level.*	*The crestal level was extended posteriorly towards the ascending ramus and the width of the ramus was made at the most anterior part.*
Ramus thickness at midway between sigmoid notch and lingula (RT-M)	*The thickness measured from the medial cortex to the lateral cortex of the mandible at the level midway between sigmoid notch and tip of the lingula.*	*The midway was identified vertically by dividing the distance between them into half. The plane at where the midway was located was extended anteriorly towards the anterior ramus and the width of the ramus measured.*

Table 2. Descriptive statistics of the samples using direct physical and CBCT measurements.

Landmarks in cadaveric hemi-mandibles	*Physical measurement*			*CBCT measurement*		
	n	*Mean (mm)*	*SD*	*n*	*Mean (mm)*	*SD*
Height of ramus (R)	*18*	*50.96*	*5.94*	*16*	*50.47*	*6.04*
Distance of lingula to sigmoid notch (LS)	*18*	*18.94*	*2.69*	*16*	*18.16*	*2.96*
Distance of lingula to inferior border (LI)	*18*	*35.93*	*6.13*	*16*	*33.74*	*5.41*
Vertical position of lingula in relation to occlusal plane (L-OP)	*16*	*5.82*	*5.15*	*14*	*4.96*	*3.42*
Ramus thickness at crestal level (RT-C)	*18*	*10.18*	*1.45*	*16*	*9.83*	*2.76*
Ramus thickness at midway between sigmoid notch and lingula (RT-M)	*18*	*5.71*	*1.41*	*16*	*5.33*	*1.65*

Table 3. Accuracy of measurements between physical and CBCT measurement.

Landmarks in cadaveric hemi-mandibles	*Physical measurement*		*CBCT measurement*		Mean difference	p-value
	Mean (mm)	*SD*	*Mean (mm)*	*SD*		
Height of ramus (R)	*50.96*	*5.94*	*50.47*	*6.04*	*0.115*	*0.691*
Distance of lingula to sigmoid notch (LS)	*18.94*	*2.69*	*18.16*	*2.96*	*0.779*	*0.135*
Distance of lingula to inferior border (LI)	*35.93*	*6.13*	*33.74*	*5.41*	*2.573*	**0.001*
Vertical position of lingula in relation to occlusal plane (L-OP)	*5.82*	*5.15*	*4.96*	*3.42*	*0.265*	*0.634*
Ramus thickness at crestal level (RT-C)	*10.18*	*1.45*	*9.83*	*2.76*	*0.673*	*0.116*
Ramus thickness at midway between sigmoid notch and lingula (RT-M)	*5.71*	*1.41*	*5.33*	*1.65*	*0.488*	**0.020*

*Paired t-test with p-value<0.05.

Table 4. Inter-reliability agreement between two researchers.

Landmarks in cadaveric hemi-mandibles (mm)	*Physical measurement*			*CBCT measurement*		
	Mean diff	*p-value*	*ICC*	*Mean diff*	*p-value*	*ICC*
Height of ramus (R)	*0.17*	*0.687*	*0.980*	*-0.53*	*0.288*	*0.978*
Distance of lingula to sigmoid notch (LS)	*0.89*	*0.088*	*0.803*	*-1.23*	*0.103*	*0.673*
Distance of lingula to inferior border (LI)	*-0.17*	*0.795*	*0.954*	*-2.68*	**0.005*	*0.871*
Vertical position of lingula in relation to occlusal plane (L-OP)	*0.33*	*0.402*	*0.975*	*0.97*	*0.339*	*0.685*
Ramus thickness at crestal level (RT-C)	*0.50*	*0.235*	*0.980*	*-0.11*	*0.878*	*†0.499*
Ramus thickness at midway between sigmoid notch and lingula (RT-M)	*0.56*	*0.066*	*0.743*	*-0.19*	*0.359*	*0.934*

*Paired t-test with p-value<0.05; †ICC<0.5.

Discussion

The key findings of this study evaluating the accuracy and reliability of direct physical measurements using high precision digital calliper corresponding to CBCT measurements of posterior mandible showed 1) generally strong accuracy between direct physical measurement and CBCT measurements for all landmarks, but 2) weaker accuracy for the landmarks LI and RT-M. On top of that, this study also found a 3) high reliability between two researchers in direct physical measurement method in all the mandibular landmarks, and 4) a generally high reliability in measurements made on CBCT, although low reliability in two landmarks were found, which include the distance between lingula and inferior border (LI), and ramus thickness at crestal level (RT-C). The primary outcome of this study is to assess the accuracy of measuring the posterior mandible directly on the cadavers to measuring on the CBCT images. Accuracy refers to the closeness of the measurements to a specific "gold standard" value. In this study, the "gold standard" measurement is referred to the direct physical measurement of the posterior mandibles, as it provides direct access and visualization in measuring the landmarks of the posterior mandible. This present study found a strong accuracy of CBCT measurements corresponding to the "gold standard" when the height of ramus, distance of lingula to sigmoid notch, distance of lingula to occlusal plane, ramus thickness at crestal level were measured. There were only a few studies reporting the accuracy of CBCT measurements to direct physical measurement of the posterior mandible. These studies were all made in vitro on cadaveric mandibles [14,17,19,21,22].

The lack of reports on the assessment of the posterior mandible measured on CBCT comparing to measurements made directly during clinical procedure on patient, or in vivo, is because of the poor access to the posterior mandible during surgery and the presence of soft tissue that requires unnecessary dissection during surgery. This had decreased the accuracy of measurement made directly during the surgical procedure. However, the measurements made on cadaveric mandibles had improved the evidence that measurements made on CBCT can be precise and accurate. A study done by Ganguly et al. measuring the accuracy of CBCT on bone measurements while having soft tissues around the mandibles intact had reported high accuracy [23]. This present study portrayed no statistically significant difference in majority of the posterior mandibular landmarks except for the distance between lingula to inferior border of mandible (LI) and ramus thickness at midway level between lingula and sigmoid notch (RT-M). The authors of this study suggested that the differences exist between direct physical measurement and CBCT measurement in LI and RT-M is due to the challenge in deciding the accurate position of the lingula and the level of crestal bone. As in this study, there is few samples of posterior mandible are edentulous, thus level of crestal bone in CBCT imaging is not precise, making process of measurements more difficult. Reliability is defined as the measure of consistency of an observed finding taken repeatedly. Inter-reliability indicates measurements taken repeatedly between two or more different assessors. Reliability among two researchers is very crucial to ensure that the researchers well understood all the landmarks involved to minimize error. Multiple studies stated that CBCT data and measurements provides a relatively high inter-reliability of measurements especially for implant surgery, orthodontics, and endodontics [13,16,24]. However, our study found high inter-reliability in direct physical measurements of all the landmarks, but weak reliability in two landmarks in the CBCT measurements. These include the distance between lingula and inferior border of the mandible, as well as the ramus thickness at crestal level.

The authors suggested that the significant difference between two examiners in these landmarks is caused by the difficulty in determining the precise reference point of lingula in the CBCT images of the cadaveric hemi-mandibular samples. The difficulty in locating the lingula in CBCT may be explained by the variations in the morphology of the lingula in which the lingula may present as an assimilated type [19,21,25]. This discrepancy of locating vital anatomical landmark can be improved by having well-trained and experienced clinician to undergo repetitive training and calibration in the interpretation of CBCT images. The importance of preoperative assessment in mandibular surgery should be further emphasized. The authors believed that if the CBCT measurements were as reliable and as accurate as the measurements made on cadavers, the preoperative assessment using CBCT will enhance and improve the clinical procedure. Thus, this provides an in-depth information for the surgical plan and the complications that may occur intraoperatively during SSRO can be prevented. Nonetheless, CBCT is a complex radiographic imaging that requires comprehension of the spatial relations of anatomic elements and extended pathologic knowledge of numerous maxillofacial structures. Thus, it is important for clinician to improve their knowledge and skills in interpreting

CBCT imaging, so that it can assist clinical procedure effectively.

Conclusion

In conclusion, the high inter-reliability and strong accuracy of direct physical and CBCT measurements of the posterior mandible made it possible for the assessment of CBCT to be used as a pre-operative assessment tool prior to surgical procedure involving posterior mandible. Nevertheless, precaution needs to be taken when determining the exact landmarks in CBCT images as it still leads to minor measurement error. The authors suggested that calibration and training prior to making any pre-operative CBCT assessment is necessary. Ethics approval: This study was conducted upon ethical approval by the IIUM Research Ethical Committee (IREC 2018-078).

Acknowledgement

The authors acknowledge and thank the members of the editors of this journal for their careful review. This work was supported by the Research Initiative Grant Scheme IIUM (RIGS17-021-0596; 2017).

Conflict of Interest

There is no conflict of interest to declare.

References

[1] Aarabi M, Tabrizi R, Hekmat M, Shahidi S, Puzesh A. Relationship between mandibular anatomy and the occurrence of a bad split upon sagittal split osteotomy. Journal of oral and maxillofacial surgery: official journal of the American Association of Oral and Maxillofacial Surgeons. 2014; 72(12):2508-13.

[2] Leung MY, Leung YY. Three-dimensional evaluation of mandibular asymmetry: a new classification and three-dimensional cephalometric analysis. International journal of oral and maxillofacial surgery. 2018; 47(8):1043-51.

[3] Huang CY, Liao YF. Anatomical position of the mandibular canal in relation to the buccal cortical bone in Chinese patients with different dentofacial relationships. J Formos Med Assoc. 2016; 115(11):981-90.

[4] Chrcanovic BR, Freire-Maia B. Risk factors and prevention of bad splits during sagittal split osteotomy. Oral and maxillofacial surgery. 2012; 16(1):19-27.

[5] Park K-R, Kim S-Y, Kim G-J, Park H-S, Jung Y-S. Anatomic study to determine a safe surgical reference point for mandibular ramus osteotomy. . Journal of Cranio-Maxillofacial Surgery. 2014; 42(1):22–7.

[6] Yu IH, Wong YK. Evaluation of mandibular anatomy related to sagittal split ramus osteotomy using 3-dimensional computed tomography scan images. International journal of oral and maxillofacial surgery. 2008; 37(6):521-8.

[7] Westermark A, Englesson L, Bongenhielm U. Neurosensory function after sagittal split osteotomy of the mandible: a comparison between subjective evaluation and objective assessment. The International journal of adult orthodontics and orthognathic surgery. 1999; 14(4):268-75.

[8] Reyneke JP, Ferretti C. Anterior open bite correction by Le Fort I or bilateral sagittal split osteotomy. Oral and maxillofacial surgery clinics of North America. 2007; 19(3):321-38.

[9] Verweij JP, Mensink G, Houppermans PNWJ, van Merkesteyn JPR. Angled Osteotomy Design Aimed to Influence the Lingual Fracture Line in Bilateral Sagittal Split Osteotomy: A Human Cadaveric Study. J Craniomaxillofac Surg. 2014; 42(7):e359-63.

[10] Mensink G, et al. Bad split during bilateral sagittal split osteotomy of the mandible with separators: a retrospective study of 427 patients. The British journal of oral & maxillofacial surgery. 2013; 51(6):525-9.

[11] Jaaskelainen SK, Teerijoki-Oksa T, Forssell K, Vahatalo K, Peltola JK, Forssell H. Intraoperative monitoring of the inferior alveolar nerve during mandibular sagittal-split osteotomy. Muscle & nerve. 2000; 23(3):368-75.

[12] Shaeran TAT, Shaari R, Rahman SA, Alam MK, Husin. AM. Morphometric analysis of prognathic and non-prognathic mandibles in relation to BSSO sites using CBCT. Journal of Oral Biology and Craniofacial Research. 2017; 7:7-12.

[13] Behnia H, Motamedian SR, Kiani MT, Morad

G, Khojasteh A. Accuracy and reliability of cone beam computed tomographic measurements of the bone labial and palatal to the maxillary anterior teeth. The International journal of oral & maxillofacial implants. 2015; 30(6):1249-55.

[14] Garcia-Sanz V, Bellot-Arcis C, Hernandez V, Serrano-Sanchez P, Guarinos J, Paredes-Gallardo V. Accuracy and Reliability of Cone-Beam Computed Tomography for Linear and Volumetric Mandibular Condyle Measurements. A Human Cadaver Study. Scientific reports. 2017; 7(1):11993.

[15] Baumgaertel S, Palomo JM, Palomo L, Hans MG. Reliability and accuracy of cone-beam computed tomography dental measurements. American journal of orthodontics and dentofacial orthopedics: official publication of the American Association of Orthodontists, its constituent societies, and the American Board of Orthodontics. 2009; 136(1):19-25; discussion-8.

[16] Xu J, He J, Yang Q, Huang D, Zhou X, Peters OA, et al. Accuracy of Cone-beam Computed Tomography in Measuring Dentin Thickness and Its Potential of Predicting the Remaining Dentin Thickness after Removing Fractured Instruments. Journal of endodontics. 2017; 43(9):1522-7.

[17] Berco M, Rigali PH, Miner RM, DeLuca S, Anderson NK, Will LA. Accuracy and reliability of linear cephalometric measurements from cone-beam computed tomography scans of a dry human skull. American Journal of Orthodontics and Dentofacial Orthopedics. 2009; 136(1):17.e1–.e9.

[18] Sekerci AE, Cantekin K, Aydinbelge M. Cone beam computed tomographic analysis of the shape, height, and location of the mandibular lingula in a population of children. Biomed Res Int. 2013; 2013:825453.

[19] Apinhasmit W, Chompoopong S, Jansisyanont P, Supachutikul K, Rattanathamsakul N, Ruangves S, et al. The study of position of antilingula, midwaist of mandibular ramus and midpoint between coronoid process and gonion in relation to lingula of 92 Thai dried mandibles as potential surgical landmarks for vertical ramus osteotomy. Surgical and radiologic anatomy: SRA. 2011; 33(4):337-43.

[20] Shahidi S, Zamiri B, Abolvardi M, Akhlaghian M, Paknahad M. Comparison of Dental Panoramic Radiography and CBCT for Measuring Vertical Bone Height in Different Horizontal Locations of Posterior Mandibular Alveolar Process. Journal of dentistry (Shiraz, Iran). 2018; 19(2):83-91.

[21] Sekerci AE, Cantekin K, Aydinbelge M. Cone Beam Computed Tomographic Analysis of the Shape, Height, and Location of the Mandibular Lingula in a Population of Children. BioMed Research International. 2013; vol. 2013:8 pages.

[22] Uchida Y, Ihara K, Shikimori M, Goto M, Akiyoshi T. Measurement of Labio-lingual Bone Thickness in the Mandibular Interforaminal Region: a Pilot Cadaveric Study. Asian J Oral Maxillofac Surg. 2003; 15:194-8.

[23] Ganguly. R, Ruprecht. A, Vincent. S, Hellstein. J, Timmons. S, Qian. F. Accuracy of linear measurement in the Galileos cone beam computed tomography under simulated clinical conditions. Dentomaxillofac Radiol 2011 Jul; 40(5):299–305.

[24] Baumgaertel S, Palomo JM, Palomo L, Hans MG. Reliability and accuracy of cone-beam computed tomography dental measurements.

[25] Hsu K-J, Tseng Y-C, Liang S-W, Hsiao S-Y, Chen C-M. Dimension and Location of the Mandibular Lingula: Comparisons of Gender and Skeletal Patterns Using Cone-Beam Computed Tomography. BioMed Research International. 2020;vol. 2020,:6 pages.

Please cite this paper as:
Ismail I.N., Abu Bakar M.A., Hairul Anuar K.F., Ramlee M.A.; Accuracy of CBCT measurements of posterior mandible. J Craniomaxillofac Res 2021; 8(2): 51-59