Original Article

Anatomical Study of the Mandibular Canal in Thai Patients with Mandibular Prognathism: Implications for BSSRO

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Abstract

This retrospective study analyzed the mandibular canal (MC) anatomy in relation to bilateral sagittal split ramus osteotomy (BSSRO) in mandibular prognathism patients, comparing measurements obtained from cone beam computed tomography (CBCT) and ortho-panoramic (OP) images. Twenty-seven pre-operative radiographs (12 males, 15 females; mean age 26.3 years) revealed significant differences in MC distances to the anterior border of the ramus and sigmoid notch between CBCT (13.80±2.20 and 15.89±2.00 mm) and OP (10.27±1.27 and 14.93±2.25 mm) at $p<0.001$ and $p=0.007$, respectively. However, measurements of MC distances to the alveolar crest and inferior border of the mandible were consistent. Side differences were observed in MC to ramus distances as well as in buccal/lingual bone thickness. There were no significant differences between males and females. However, the buccal bone at the second molar area was thicker than the first molar area. The findings emphasize the superiority of CBCT over OP in the ramus region, which is critical for avoiding inferior alveolar neurovascular injury during BSSRO, Based on this, performing vertical osteotomies in the second molar region may lead to safer surgical outcomes.

Keywords: Bilateral sagittal split ramus osteotomy, Cone beam computed tomography, Mandibular canal, Mandibular prognathism, Ortho-panoramic radiograph

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article in press

Introduction

Mandibular prognathism, as defined by John Hunter[1] in 'The Natural History of the Human Teeth' (1778), refers to the protrusion of the lower jaw resulting in anterior positioning of the lower teeth relative to the upper teeth, leading to facial disfigurement and malocclusion. Additional defining characteristics include Class III malocclusion, incomplete lip closure, midline deviation, and reduced labiomental fold.[1] Class III malocclusion is notably more prevalent among Asians than Caucasians. Etiological factors contributing to mandibular prognathism encompass hereditary predisposition, congenital conditions (e.g. cleft lip and palate), endocrine disorders (e.g., acromegaly, gigantism, pituitary adenomas), upper airway obstruction (e.g., enlarged tonsils), habitual mandibular protrusion posture, birth trauma (e.g., instrumental deliveries), tongue position, and tonsillar hypertrophy.2 Treatment strategies vary by age group: facial growth modification using dentofacial orthopedic appliances is employed for growing patients, while orthognathic surgery combined with orthodontic treatment is indicated for adults. Treatment goals include correcting jaw relationship, reducing negative incisal overlap, achieving intermaxillary skeletal stability, and optimizing dental occlusion to enhance both functional and aesthetic outcomes.[2]

Bilateral Sagittal Split Osteotomy (BSSRO) is a widely utilized surgical technique for correcting mandibular deformities, particularly retrognathism (retracted mandible) and prognathism (protruding mandible). This procedure enables the repositioning of the mandible to improve both functional occlusion and aesthetic outcomes.[3] The osteotomy begins with a horizontal incision on the medial aspect of the ramus, just above and behind the mandibular foramen (MF), extending to the anterior border of the ramus. The sagittal cut is then carried anteriorly along the external oblique ridge to the body of the mandible, near the first or second molar. A downward vertical cut toward the inferior border of the mandible is made .[4] After completing the osteotomy, the ramus is split into medial and lateral segments (Fig. 1).[5] Once both rami are separated, the medial segment can be repositioned either forward or backward to achieve the desired occlusion and aesthetic alignment. The nerve bundle typically remains in the medial segment.

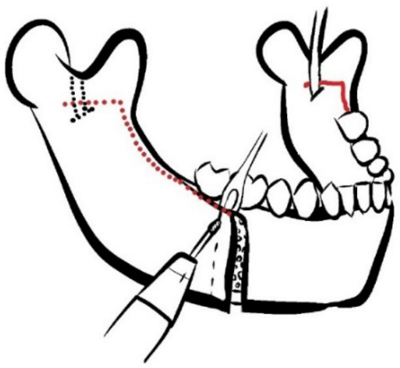

Figure 1 *The BSSRO osteotomy line. A horizontal cut is made on the lingual cortex just superior to the mandibular foramen, followed by a sagittal cut extending along the anterior border of the ramus. A vertical cut is performed anteriorly on the buccal side, ensuring proper segmentation for surgical manipulation.*

Complications associated with BSSRO include bleeding from the inferior alveolar artery, injury to the inferior alveolar nerve (IAN), unfavorable fractures, infection, limited mouth opening, condylar resorption leading to skeletal relapse, loss of masticatory force, discomfort from screws, screw loosening, postoperative swelling, malocclusion, and worsening temporomandibular joint disease (TMD).[6-8] Although the complications are documented, they may not necessarily occur in every case or during the actual procedure. Among these, injury to the IAN is of particular concern due to the potential for neurosensory dysfunction, which can range from numbness in the lower lip and chin to more severe issues such as drooling and speech difficulties. Postoperative sensory function data indicates that 28% of sites maintained normal function after two months, with further improvements observed at follow-up, suggesting a reparative potential of nerve injury. However, many patients experience prolonged sensory deficits, which can impact decisions regarding surgical approaches and the need for rehabilitation.[9]

The IAN, a key branch of the mandibular nerve in the trigeminal complex, enters the MF on the medial surface of the mandibular ramus, marking the start of the mandibular canal (MC). Within the MC, it provides innervation to the lower teeth via its terminal branches. The mental nerve exits the canal at the mental foramen, usually located between the first and second premolars, and innervates the chin and lower lip. The incisive nerve continues anteriorly, supplying sensory innervation to the mandibular incisors and canines. Direct visualization of the IAN on conventional radiographs is not possible; however, the MC is often visible, allowing clinicians to infer the IAN's location. To minimize the risk of IAN injury, careful identification of the MC position is essential.

The position of the MC is influenced by two main factors: the thickness of the surrounding bone (buccal, lingual, inferior, and superior borders) and the diameter of the canal.[10] The greatest distance between the MC and the buccal border occurs at the lower first and second molars, while the shortest distance is found at the third molar.[11] The mean distance from the MC to the buccal cortex is 3.5 mm (ranging from 1.8 to 6.5 mm) around the lower first and second molars, and 2.5 mm (ranging from 0.4 to 5.9 mm) distal to the lower third molar.[12] The mean distance to the lingual cortex is 0.6 mm (ranging from 0.0 to 3.2 mm) around the lower first and second molars, and 0.6 mm (ranging from 0.0 to 3.0 mm) distal to the third molar. The mean MC's diameter is 2.1 mm (ranging from 1.2 to 3.0 mm).[13] Additionally, the IAN may be near the buccal cortex in cases of thick rami.[12] Yamamoto *et al.*[14] found that 25% of MC were in contact with the external cortical bone. Correlations between age, race, and the position of the MC have been noted, with older and white patients showing a thinner bone between the buccal cortex and the MC.[16] Moreover, the MC in Class III molar relationship is located closer to the inferior border of the mandible compared to other Classes.[17] However, no reports exist regarding these anatomical relationship in Thai patients with mandibular prognathism.

Cone Beam Computed Tomography (CBCT) provides three-dimensional images that can be viewed in any plane, offering more detailed visualization of the mandibular canal (MC) compared to conventional two-dimensional orthopantomograms (OP).[18] da Fontoura[19] reported that distortion in the ramus from OP images is 0.9%. CBCT, developed specifically for high-quality maxillofacial hard tissue imaging, offers minimal distortion, shorter scanning times, and lower radiation doses compared to traditional computed tomography (CT).[20] The high contrast in CBCT images is particularly useful for evaluating bone structures, making it a more advantageous tool for craniofacial bone evaluation, especially before surgery.[21] CBCT has been shown to accurately determine the three-dimensional position of the MC.[23] It can measure the gap width between the MC and the external cortical bone (marrow space), which is critical for surgical planning in BSSRO. When the marrow space width is 0.8 mm or less, there is a higher likelihood of neurosensory complications.[14] However, there has been no study comparing the MC position between OP and CBCT images.

At the Faculty of Dentistry, Chulalongkorn University, the i-Dixel 2.0 3D Imaging Software (J Morita) is used to produce high-quality CBCT images with low radiation doses, utilizing a high-sensitivity, high-resolution flat panel detector for multi-purpose diagnostic scanning in the maxillofacial region.[24]

This study aimed to investigate the MC anatomy in mandibular prognathism patients undergoing BSSRO and to compare the measurements obtained from OP and CBCT images.

Materials and methods

This retrospective study was conducted on a cohort of Thai patients diagnosed with mandibular prognathism who underwent BSSRO at the Dental Hospital, Faculty of Dentistry, Chulalongkorn University. The selected patients had both pre-operative OP and CBCT images of the mandible. All CBCT images were performed using 3D Accuitomo170® (Morita, Osaka, Japan) with a resolution of 0.25 mm, 90 kVp, 5mA, standard mode, field of view (FOV) 10x10 cm^2, and CB MercuRay® (Hitachi Medico Technology Corporation, Chiba-ken, Japan) with a resolution of 0.2 mm, 90 kVp, 5mA standard mode, FOV 150 mm.

Data collection

<u>Data from CBCT images</u>

CBCT data were exported as digital and communication in medicine (DICOM) format and imported into a computer DELL OptiPlex745 using INFINITT PACS® software (Seoul, Korea) for image analysis. All measurements were performed by a single examiner, with an intra-Class correlation coefficient (ICC) greater than 0.75, indicating good reliability.

First, prior to the measurement of the location of the MC, the three planes were oriented. Cross-sectional images were generated perpendicular to the arch form of the mandible. In the axial view, the sagittal plane was adjusted parallel to the left or right side of the buccal cortex of the mandibular first and second molar region. The coronal plane was oriented to bisect the crown at the furcation area of the first molars and second molars in the sagittal view. Second, to locate the tip of the lingula, the sagittal plane was generated parallel to the buccal cortex of the mandible, and the coronal plane was generated to lingula area in the axial view. The sagittal plane in the coronal view was adjusted along to medial surface of the left or right ramus.

Five measurements were done from cross-sectional view of mandibular first molar and of second molar including: (A) outer diameter of MC, (B) distance of outer surface of buccal cortex to the buccal surface of MC, (C) distance of outer surface of lingual cortex to the lingual surface of MC, (D) distance of superior border of alveolar bone to superior surface of MC, (E) distance of outer surface of inferior cortex to inferior surface of MC (Fig. 2).[4] Moreover, the distances between the lingula tip and the ascending ramus's anterior border and to the sigmoid notch were measured from the sagittal view (Fig. 3).

Data from two-dimensional OP radiograph

The distances from the MF, the most anterior and superior border of the canal, to the anterior border of ascending ramus and to the sigmoid notch were recorded. The distances from MC to the superior border of alveolar bone and to the inferior border of mandible at the first and second molars were measured (Fig. 4).

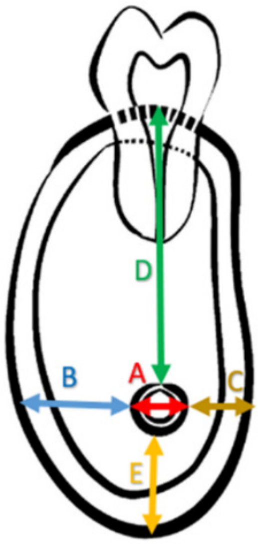

Figure 2 *The distances measured from a cross-sectional view at the mandibular first molar and second molar, A: outer diameter of the mandibular canal (MC), B: distance of the outer surface of buccal cortex to the buccal surface of MC, C: distance of the outer surface of lingual cortex to the lingual surface of MC, D: distance of superior border of alveolar bone to superior surface of MC, E: distance of outer surface of inferior cortex to inferior surface of MC.*

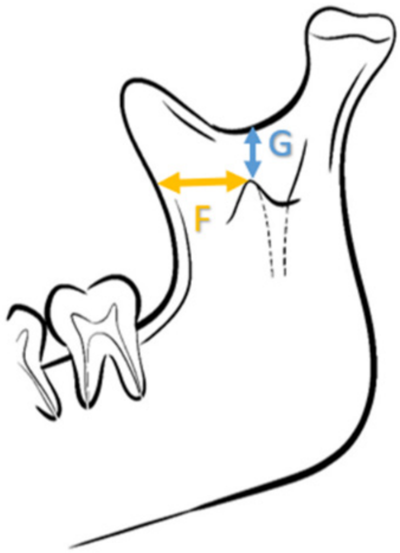

Figure 3 *The distances relating to the lingula measured in the sagittal plane, F: distance of the tip of lingula to the anterior border of ascending ramus, G: distance of the tip of lingula to sigmoid notch.*

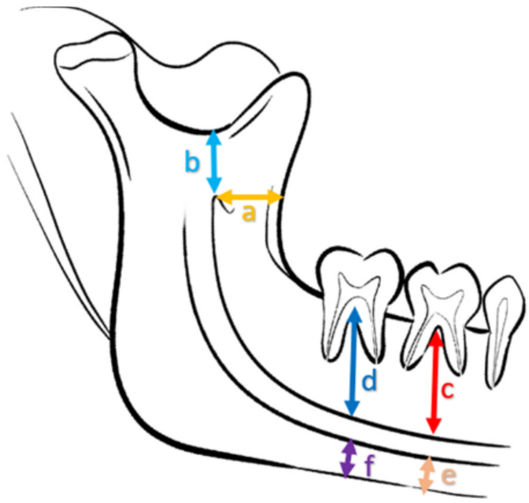

Figure 4 *Measurements performed in orthopanoramic image, a: distance from anterior border of mandibular foramen (MF) to anterior border of ascending ramus, b: distance from MF to sigmoid notch, c: distance from MC to superior border of alveolar bone at the first molar, d: distance from MC to superior border of alveolar bone at the second molar, e: distance from MC to inferior border of mandible at the first molar, f: distance from MC to inferior border of mandible at the second molar.*

Figure 5 *Examples of measurement of images by image software, A: CBCT from a cross-sectional view, B: CBCT from a sagittal view, C: Measurements performed in orthopanoramic image.*

Data analysis

All statistical analyses were performed using SPSS software version 24 (IBM Corp., Chicago, IL, USA). As the data followed a normal distribution, an independent Student's *t*-test was applied. Paired Sample *t*-test was used to analyze differences between the left and right sides and between OP and CBCT radiographs. Pearson's correlation was used to analyze the corresponding distance between CBCT and OP images. The *p*-value less than .05 was considered a significant difference.

Results

The study subjects consisted of CBCT and OP images from 27 patients (12 males and 15 females), whose ages ranged from 20 to 40 (average 26.3 years).

Comparison of distances measured from CBCT and OP images

The measurements between CBCT and OP radiographs revealed statistically significant difference in distances of MF to the anterior border and to the sigmoid notch ($p < 0.001$ and $p = 0.007$, respectively) (Table 1).

Comparison of the measured distances between the first and second molars

The distance of the outer surface of the buccal cortex to the buccal surface of MC (buccal thickness) of the mandibular second molar (left = 7.37 ± 1.72 mm, right = 7.31 ± 1.60 mm) was greater than that of the mandibular first molar (left = 5.98 ± 1.30 mm, right = 5.63 ± 1.20 mm). (Table 2 and Table 3).

Comparison of the measured distances between sides

The distances of the lingula to the anterior border of ramus and from the buccal cortex to the MC at the mandibular first molar differed significantly between the left and right sides ($p = 0.028$ and $p = 0.025$, respectively), while other distances showed no significant differences ($p > 0.05$) (Table 2 and Table 3).

Comparison of the measured distances between sexes

There were no significant differences in all measurements between males and females ($p > 0.05$) (Table 3).

Table 1 *Comparison of Average Distances (± SD) Between CBCT and Panoramic Radiography (OP)*

Measurement	CBCT (mm)	OP (mm)	*p*-value (*t*-test)
Mandibular foramen to anterior border	13.80 ± 2.20	10.27 ± 1.27	< 0.001*
Mandibular foramen to sigmoid notch	15.89 ± 2.00	14.93 ± 2.25	0.007*
Superior cortex at the first molar	16.40 ± 2.26	16.47 ± 2.38	0.767
Superior cortex at the second molar	12.38 ± 2.25	12.56 ± 2.01	0.500
Inferior cortex at the first molar	7.69 ± 2.07	7.47 ± 1.67	0.323
Inferior cortex at the second molar	7.94 ± 2.02	7.75 ± 1.88	0.070

Table 2 Comparison of Average Distances (± SD) Between Left and Right Sides Measured by CBCT

	Tooth	Left (mm)	Right (mm)	*p*-value (*t*-test)
Diameter	6	2.96 ± 0.52	2.94 ± 0.55	0.879
	7	3.17 ± 0.53	3.27 ± 0.49	0.382
Buccal cortex distance	6	5.98 ± 1.30	5.63 ± 1.20	0.025*
	7	7.37 ± 1.72	7.31 ± 1.60	0.103
Lingual cortex distance	6	2.28 ± 0.98	2.57 ± 0.99	< 0.001*
	7	2.44 ± 1.19	2.52 ± 0.99	0.713
Superior cortex distance	6	16.59 ± 2.42	16.24 ± 2.72	0.464
	7	12.16 ± 2.76	12.66 ± 2.34	0.290
Inferior cortex distance	6	7.36 ± 1.84	7.96 ± 2.57	0.073
	7	7.87 ± 2.17	7.94 ± 1.99	0.711
Mandibular foramen to anterior border		13.24 ± 2.24	14.33 ± 2.76	0.028*
Mandibular foramen to sigmoid notch		15.88 ± 2.50	15.83 ± 2.23	0.928

Table 3 Comparison of Average Distances (± SD) Between Males and Females Measured by CBCT

	Tooth	Left (mm)	Right (mm)	*p*-value (*t*-test)
Diameter	6	2.92 ± 0.56	2.97 ± 0.34	0.800
	7	3.20 ± 0.49	3.23 ± 0.35	0.853
Buccal cortex distance	6	6.06 ± 0.94	5.60 ± 1.35	0.325
	7	7.85 ± 1.68	6.69 ± 1.33	0.056
Lingual cortex distance	6	2.12 ± 0.70	2.67 ± 0.97	0.108
	7	2.27 ± 1.04	2.65 ± 0.88	0.317
Superior cortex distance	6	16.16 ± 2.20	16.62 ± 2.36	0.609
	7	11.82 ± 2.09	12.88 ± 2.34	0.235
Inferior cortex distance	6	8.24 ± 1.79	7.19 ± 2.22	0.196
	7	8.57 ± 1.83	7.37 ± 2.06	0.125
Mandibular foramen to anterior border		14.17 ± 2.04	13.47 ± 2.34	0.422
Mandibular foramen to sigmoid notch		16.60 ± 1.57	15.26 ± 2.16	0.083

Discussion

The MF is the opening on the internal surface of the mandibular ramusthrough which the MC passes. The lingula of the mandible is a bone projection on the medial aspect of the ramus and lies close to the MF. Therefore, the lingula is an important anatomical landmark for locating the IAN before it enters the mandible. The position of lingula and MF varies from person to person. From the Taiwanese study, the distances from the sigmoid notch to MF measured by CBCT were 22.7 mm in males and 20.59 mm in females.[18] The distances measured by CBCT in Korean patients were 21.59 mm in skeletal Class I, 20.49 mm in skeletal Class II, and 18.77 mm in skeletal Class III.[25] The distances from anterior border of ramus to MF in Taiwanese patients measured by CBCT were 18.00 mm and 19.30 mm in women and men, respectively.[18] In Korean patients, CBCT measurements showed distances of 19.41 mm in skeletal Class I, 19.01 mm in the skeletal Class II, and 19.85 mm in the skeletal Class III.[25] From our study, the distances from the sigmoid notch to MF and from the anterior border of the ramus to MF were shorter compared to those of other studies. Some possible explanations for this discrepancy may be 1) the varied craniofacial morphology across ethnicities and populations, 2) the use of different imaging technologies and software platforms, or 3) the measurement method (e.g., manual vs software-assisted measurements).

From another perspective, the thickness of the buccal cortical bone (the distance from the buccal surface of the mandible to the MC) is a critical factor in ensuring the safety of the vertical osteotomy cut in the BSSRO procedure. Consistent with the findings of Nagadia *et al.,*[4], the greatest distance from the buccal cortex to the MC was observed in the second molar region, indicating that the buccal bone is thicker there than in the first molar region. Therefore, performing osteotomy at the second molar region is considered safer. This information is particularly valuable in skeletal Class III patients, for whom BSSRO is typically performed as a setback procedure. In such cases, it is unnecessary to extend the vertical cut anteriorly to the first molar region, as is often required in BSSRO advancement for skeletal Class II patients to achieve sufficient bone contact. When comparing buccal bone thickness between the left and right sides of the mandible, a statistically significant difference was found at the first molar region. Further studies with more robust designs are needed to clarify the underlying cause of this asymmetry.

Although Hoseini Zarch *et al,*[27] reported that linear measurements on OP are generally more reliable in the posterior region than in the anterior region, our findings demonstrated significant discrepancies in measurements at the ramus region between CBCT and OP radiographs. This may be attributed to the susceptibility of panoramic radiographs to distortion, which can result from patient positioning errors and the inherent limitations of the two-dimensional imaging technique.[28,29]

CBCT imaging is particularly valuable when assessing complex anatomical structures in the mandible due to its ability to provide three-dimensional view. This imaging modality offers numerous advantages over traditional two-dimensional imaging methods, such as OP, in several key areas: (1) Enhanced Visualization: CBCT allows the detailed visualization of critical anatomical landmarks, including the lingula, borders of the mandible, and the MC. This degree of clarity aids in precise surgical planning. (2) High Contrast Resolution: The high contrast resolution provided by CBCT enables practitioners to distinguish between closely situated structures, such as root tips, which is particularly crucial when close to vital nerves and blood vessels. A systematic review by Haas *et al*[30] explains a remarkably high frequency of variation of MC detected by CT or CBCT compared with OP. (3) Pre-operative Planning: Prior to major surgical procedures, such as osteotomies, utilizing CBCT enables surgeons to assess the spatial relationship between the MC and other vital structures. This pre-operative evaluation is essential for reducing the risk of injury to these structures, thus mitigating complications during and after surgery. (4) 3D Reconstruction: CBCT imaging can produce 3D reconstruction of the mandible, providing a comprehensive view that allows for more accurate analysis of the path of the IAN and the location of the MC compared to traditional imaging methods. In summary, incorporating CBCT into the pre-operative workflow improves surgical outcomes by enhancing the surgeon's ability to visualize and plan for anatomical complexities, ultimately leading to a reduction in the risk of complications associated with nerve and vascular injuries. A Systematic review by Araujo *et al*[26] showed a significant influence of CBCT versus OP to avoid injury to vital structures during third molar surgical procedure. This technology represents a significant advancement in the field of dental surgery, aligning with modern practices aimed at enhancing patient safety and care.

Limitations of our study include a relatively small sample size and the lack of data on normal jaw relationship in the Thai population for comparison. The effect of missing first or second molars on the MC morphology cannot be underestimated, as bone resorption and bone remodeling usually follow dental extraction, which can affect the position of the MC. Further studies may evaluate the post-operative complications after follow-up and may explore other mandibular Classifications such as retrognathism.

Conclusion

The differences between preoperative measurements from CBCT and OP highlight the importance of using the appropriate imaging modality. CBCT provides three-dimensional views and more accurate spatial relationships, which are crucial for assessing the position of the inferior alveolar canal, especially in the mandibular ramus. This can help to reduce the risk of complications during osteotomies or other surgical procedures. Performing a vertical osteotomy at the second molar area, where the buccal bone is thicker and the inferior alveolar canal is more favorably positioned, may reduce the risk of nerve injury and improve healing. Overall, utilizing CBCT for preoperative evaluation in cases requiring surgical intervention in the mandible is recommended. It allows for a more thorough understanding of anatomical variations and potential risks, leading to a more refined approach to surgical planning and execution. This careful evaluation ultimately aims to enhance patient safety and surgical outcomes.

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