# EVALUATION OF MANDIBULAR ANATOMY RELATED TO SAGITTAL SPLIT RAMUS OSTEOTOMY USING THREE DIMENSIONAL COMPUTED TOMOGRAPHY SCAN IMAGES

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*In partial fulfillment for the degree of*

**MASTER OF DENTAL SURGERY**

**BRANCH III**

**ORAL AND MAXILLOFACIAL SURGERY**

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# CERTIFICATE

This is to certify that this dissertation titled **"EVALUATION OF MANDIBULAR ANATOMY RELATED TO SAGITTAL SPLIT RAMUS OSTEOTOMY USING THREE DIMENSIONAL COMPUTED TOMOGRAPHY SCAN IMAGES"** is a bonafide record of work done by **DR. G. SATHEESH** under my guidance during his postgraduate study period between 2008-2011.

This dissertation is submitted to THE TAMIL NADU Dr. M.G.R. MEDICAL UNIVERSITY, in partial fulfilment for the degree of **MASTER OF ORAL AND MAXILLOFACIAL SURGERY,BRANCH III** . It has not been submitted (partial or full) for the award of any other degree or diploma.

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## Introduction

Sagittal split osteotomy has been performed routinely for correction of mandibular prognathism, retrognathia, mild open bite, and asymmetry[11]. Obwegeser (1955)-Dal Pont (1959) sagittal osteotomy of the ramus for correction of mandibular malformations has been widely accepted because it can be adapted with minor variations, to the majority of malformations. Being performed intra-orally, the procedure leaves no external scars, involves no risk to the facial nerve, permits large displacements and, a highly important point, modifies the obtuseness of the mandibular angle.[32]

One of the big objections to the sagittal split technique is the likely damage to the inferior alveolar nerve.[31] The mandibular canal is located inside the jaw and transmits the lower alveolar artery and lower alveolar nerve, a branch of the third division of the trigeminal nerve, from the mandibular foramen to the mental foramen (Berberi et al., 1994 And Madeira, 1995). This plexus emits branches that supply the lower teeth and the adjacent bone tissue, interdental papilla, periodontium, lower lip, anterior buccal mucosa and vestibular gingival of the anterior lower teeth (Heasman, 1988 and Madeira, 1995)[20].

Many authors have addressed the problem of persistent Neuro Sensory Deficit, and the reported incidence varies from 5% to 70%. The mechanism of inferior alveolar and mental nerve paresthesia after SSRO can be divided into two categories: indirect damage to the nerve by postoperative oedema or haematoma, and direct damage to the nerve which occurs during the sagittal osteotomy or as a result of exposure to air.[31, 35]

Jaaskelainen monitored the IAN during SSRO intraoperatively and noticed that the most obvious changes in sensory nerve conduction occurred during preparation of the medial side of the ramus for horizontal bone cuts when the nerve was compressed and stretched at the same time by retractors[31].

The surgical technique of BSSO may result in direct damage to the nerve, injury occurring from the reciprocating saw or chisels during splitting of the bone, stretching of the nerve on the medial side by the protecting retractors, or compressing or stretching of the nerve when the distal segment is advanced or set back. When nerve transection occurred, it was anterior to or in the third molar region in all instances. Confining the osteotomy to the retro molar region provides greater protection to the neurovascular bundle, since it is usually most lateral in this area.[25, 31]

Indirect damage can result from postoperative oedema or hematoma in the mandibular canal or the wound area. 69% of all sides were “totally normal” after 1 year, and 31% of them were “almost normal.” The patients seem to adapt to a mild neurosensory deficit and report their sensation as “normal” even if there is a slight difference compared with the preoperative situation[31].

Jaaskelainen et al evaluated the function of the inferior alveolar nerve with repeated nerve conduction tests during mandibular sagittal split osteotomy and found that the sensory nerve action potential remained stable in the IANs not exposed during surgery[31].

A study with 6000 panoramic x-rays evidencing the bifurcation of the mandibular canal in 57 (0.95%) of these, had carried through. The presence anomalies in the course of the inferior alveolar nerve increases the incidence of nerve injury during BSSO.[29,39]

The mandibular sagittal ramus osteotomy must certainly be the most "cussed" and discussed single procedure in all the history of orthognathic surgery[43], because it produces an 85 % incidence of paresthesia on immediate postoperative day, and a residual 9 % incidence 1 year after surgery.[35]

Long term follow up using Clinical and radiological investigation of sagittal split technique had shown that 60% have some impairment of sensation in the lower lip.[52]

BSSRO has a very important step of a horizontal bone incision in the ascending ramus, specifically in the area located between the sigmoid notch and mandible foramen[12]. Performing an osteotomy too far superiorly above the mandibular foramen may induce a fracture line in purely cortical bilaminar zone which increases the chances of bad split. Smith et al anatomic cadaver study of the mandibular ramus found that fusion of the buccal and lingual cortex of the ramus occurs only in 2% below the lingula[25]. It is recommend that the medial horizontal cut be at or just above the tip of the lingula because a higher cut may be associated with an increased difficulty in splitting or incidence of unfavourable fracture[25]. The most obvious changes in all IAN parameters (latency, amplitude and conduction velocity) and the highest risk of nerve injury occurred during preparation on the medial side of the ramus[48].

Most importantly, surgeons are unable to operate at the osteotomy site effectively when the exact location of the mandibular foramen and the course of the IAN is not known. Therefore identification of mandibular foramen is very important. Several anatomic landmarks have been proposed in the literature to guide surgeons in locating and avoiding the IAN. The existing measurements using dry human skulls, conventional radiographic techniques or topography have severe limitations, which include shrinkage of dry skulls, fracture of subtle structures, magnification, distortion and questionable reproducibility of radiographic images.[57]

In 1954, Caldwell and Letterman first proposed to use ‘antilingula’ as the reference for the entrance of the IAN, which was defined as ‘a very slight rounded prominence on the lateral surface of the ramus that can be used to identify the mandibular foramen on the mesial side’[57]. The antilingula has since been referred to as being located near the mandibular foramen. This guideline has been used by many surgeons in performing medial horizontal osteotomy. Several reports suggested that the medial horizontal osteotomy should be ‘just above the mandibular lingula’, and should be extended as far back as possible from the tips of the mandibular lingula. The presence of antilingula and its relationship to the true lingula and the mandibular foramen is highly variable in the literature, and sometimes it is hard to recognize the true lingula due to a poor surgical field of vision, musculotendinous attachment and morphological variants.[10, 57]

Hogan and Ellis concluded that the use of this term for marking the location of ramus osteotomies was illogical and that the antilingula was the musculotendinous apparatus that attaches to the portion of the mandible rather than to the entrance of the IAN. A large amount of compression and stretching force exerted on the neurovascular bundle was found in cases where there was minimal vertical distance between antilingula and mandibular foramen[56, 57].

The panoramic radiograph is an important auxiliary resource in diagnosis and treatment plan of the dental anomalies and pathologies involving the mandibular canal, because it allows the evaluation of its anatomy and anatomical variations, reducing the failure risk in invasive and non-invasive interventions in the mandibular bone. The radiographic appearance of the mandibular canal is characterized by a radiolucent line delimited by two radiopaque lines (WORTH, 1975), usually as a single and bilaterally symmetrical structure, it can assume different positions inside the body of the mandible, both superoinferiorly and mediolaterally.[29, 39]

The major limitations of panoramic radiographs include lower resolution, higher distortion, potential of overlapping anatomical structures; image is often related to the bone density and difficult to accurately identify vital structures.[17]

The knowledge of the mandible anatomy as well the lower alveolar nerve course through the mandible canal is of great importance for the dental surgeons, especially those planning to perform Orthognathic surgeries. An accurate imaging technique might be required to give a detailed form of the mandible including the position of the mandible foramens in relation to the sigmoid notches[41].

Three-dimensional (3-D) studies in medicine began in the early 1970s presented by Ferencz and Graco.[12] MIMICS software is an image-processing package with 3D visualization functions that interfaces with common scanner formats. It is an interactive tool for the visualization and segmentation of CT images.[9] Measurement with the MIMICS program is a measurement on both

2D and 3D images by identifying landmarks points on a 3D reconstructed model or on CT-scanning images. This method is quite accurate and a comfortable method in comparison with 2D or other measurement methods in the past.[26]

Poor two dimensional view, unequal magnification of the Inferior alveolar nerve course in an OPG or Lateral Cephalogram, different anatomical variations of the IAN course in the mandible and the high incidence of postoperative neurosensory deficit of the IAN during BSSRO, has necessitated for three dimensional reconstruction of CT of Mandible and analysing the IAN course in it for patients who are planned for BSSRO surgery.

# Introduction

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# REVIEW OF LITERATURE

**Dal Pont (1961)**[41] Changed the lower horizontal cut to a vertical cut on the buccal cortex between the first and second molars, thereby obtaining broader contact surfaces and requiring minimal muscle displacement in bilateral sagittal split osteotomy.

**Hunsuck (1968)**[41] Modified Dal Pont's technique of BSSO, advocating a shorter horizontal medial cut, just past the lingula, and to minimize softtissue dissection on the medial aspect of the ramus. This modification reduced haemorrhage, manipulation of the neurovascular bundle and postoperative swelling.

**Simpson W(1974)**[44] In his study, showed that the ascending ramus was so thin that the lingual cut could only be extended as far as the post-lingular depression. However, by use of the fine chisel and a careful technique, the split in most of these cases extended backwards to the posterior aspect of the ascending ramus. In none of the cases did the ascending ramus shatter.

**Hans Peter M et al (1975)**[19] In their study, showed that the most frequent pathological postoperative findings are Par- and Hypo- aesthesia of the mental nerve and clicking in the TMJ. However, neither are usually disturbing to the patient. The clicking is not associated with other disorders in the joint area, such as pain or limited excursion of the condyle.

**Reitzik et al (1976)**[42] They found that the greatest distance that the lingula may lie above and behind the midpoint of the waist of the ascending ramus is 6 and 5 mm respectively; therefore the intersection of the horizontal and vertical bone cuts should be placed at a point 8 mm above and 11 mm behind the midpoint of the waist of the ascending ramus. This has proved to be the most useful method of avoiding the inferior dental bundle in practice, as this point is the easiest to determine at operation.

**Yates C et al (1976)**[56] Described antilingula as a highly variable anatomic landmark and in most instances is situated considerably anteriorly and superiorly to the inferior dental foramen. However, a cut made between 5 and 10 mm. distal to the antilingula is within a statistically safe area, in over 72 per cent of cases, to avoid encroaching upon the inferior alveolar foramen.

**Hayward et al (1977)**[20] A Boley gauge which allows one to read to the nearest 0.1 mm was used in their study to measure 107 mandibles to find the A-P position of mandibular foramen. The points of the callipers were filed to a point to facilitate greater accuracy. The measurements were taken from the anterior border of the ramus to the anterior portion of the mandibular foramen and then from the anterior portion of the mandibular foramen to the posterior border of the ramus. Their findings agree with the observations on the location of the mandibular foramen published by miller, who stated that the location of the mandibular foramen is just posterior to the middle of the ramus. This study indicates that the mandibular foramen is located in the third quadrant. Our findings indicate that the mandibular foramen, and thus the inferior alveolar nerve’s entry into the ramus of the mandible, is located at or near the axis of rotation, as indicated by Moss.

**Nortje et al (1977)**[39] Classified mandibular canal into 4 types:

Type 1: Bilateral single high mandibular canals - single canals either touching or within 2 mm of the apices first and second permanent molars.

Type 2: Bilateral single intermediate mandibular canals – single canals not fulfilling the criteria for either high or low canals.

Type 3: Bilateral single low mandibular canals, single canals either touching or within 2 mm of the cortical plate of the lower border of the mandible.

Type 4: Variations including: asymmetry, duplications and absence of mandibular canal.

**Walter J. PEPEI SACK (1978)**[52] In his long-term postoperative follow-up of BSSO patients, showed that 95 % of the patients are satisfied, 60% have some impairment of sensation in the lower lip. This however goes unnoticed in 40 % of these cases. The temporo-mandibular joint does not appear to be affected. 73 % of the patients have excellent or good occlusion, while 18% have an unsatisfactory anterior occlusion due to some degree of relapse. The remaining 9% have poor occlusion without sign of relapse.

**Robert Bruce Macintosh (1981)**[43] In his study showed that an immediate postoperative Paraesthesia incidence of almost 85 % was observed after BSSO, which diminished to 9 % 1 year postoperatively. The prolonged paresthesias were most common in patients over 40 years of age; similarly, healing was prolonged in patients over 40, prompting the author's recommendation that 8 weeks intermaxillary fixation rather than 6 be employed in these patients. The overall relapse rate was approximately 30 %.

**William Simpson (1981)**[55] Discussed the importance in preoperatively assessing the antero-posterior width of the mandible for BSSO surgery. In some of his cases it is found that the A-P width of the mandible is inadequate to achieve the planned position because of lack of bony contact. He also discussed the neurological involvement following sagittal split osteotomy shows 20% mental nerve involvement and 2% facial nerve involvement.

**Christos S. Martis (1984)**[11] States that, Sagittal split osteotomy has been performed routinely for correction of mandibular prognathism, retrognathia, mild open bite, and asymmetry. With meticulous performance of the operation and long-term maxillomandibular fixation, complications can be negligible, and relapse, the most problematic postoperative issue, can be significantly reduced.

**Epker (1984)**[15] Surgical procedures involving mandibular osteotomies, the surgery becomes more complex with the addition of a second neuro-vascular bundle. He emphasized the necessity of the protection of the blood supply during those procedures. The interpretation of the panoramic radiographic is of great importance in its location and on surgical planning. The clinician should recognize the anatomical variations and modify the surgical technique if necessary.

**Paul H. Bailey (1984)**[40] States that, mandibular augmentation procedures requiring repositioning of the inferior alveolar neurovascular bundle may lead to both subjective and objective neurosensory alterations that may persist at long term follow up, and that the degree of subjective complaint may correlate poorly with, and may be of much greater magnitude than, the objectively tested level of neurosensory alteration.

**Irene Karabouta et al (1985)**[23] In his study, 280 patients with different types of mandibular deformities (prognathism, retrognathia, open bite, asymmetry) had been operated on by sagittal split osteotomy of the ramus. The patients, routinely checked preoperatively, were found to present subjective or objective TMJ dysfunction symptoms with an incidence of 40.8 %. After surgery the incidence of such symptoms in the same patients was 11.1%. The patients with no TMJ dysfunction symptoms preoperatively, presented such symptoms with an incidence of 3.7 % postoperatively, a percentage very low in comparison with other statistics.

**Langlais et al (1985)**[29] Classified bifurcated mandibular canal based on the panoramic findings:

Type1 : Unilateral or Bilateral bifurcated mandibular canal, extending towards retro-molar region

Type2 : Unilateral or Bilateral bifid mandibular canal limited to ramus

Unilateral or Bilateral bifid mandibular canal extending into body

Type3 : Combination of types 1 and 2

Type4 : Originating from two mandibular canals

**Henry S. Zaytoun et al (1986)**[21] In his study twenty-six patients who had been treated for mandibular prognathism by either bilateral sagittal split osteotomy or transoral vertical ramus osteotomy were evaluated by neurosensory examination. Neuropathy was demonstrable in 28.8% of the 52 mental nerves examined. The incidence of neuropathy was significantly higher in the bilateral sagittal split osteotomy group than in the transoral vertical osteotomy group.

**Ghali G.E et al (1989)**[16] In their study, patients experiencing neurosensory alteration after orthognathic surgery are tested every other week. This is continued for 2 months or until symptoms improve. At the 2-month period there are three major indications for microneurosurgical intervention: 1) persistent anesthesia 2) hyperesthesia or 3) troublesome hypoesthesia. The sensation of static light touch and brush directional stroke are also believed to selectively discriminate for large, myelinated, quickly adapting, A alpha sensory nerve fibres. Pin prick selects for small, myelinated, A delta sensory nerve fibres; on the other hand, temperature discrimination selects for small, myelinated and unmyelinated, A delta and C sensory nerve fibres.

**Brian R. Smith et al (1991)**[5] In their study, the following measurements were made on 50 dried mandibles with a microcaliper capable of measuring to the nearest 0.1 mm (Helios Microcaliper Inoxyd, Precision Gage Co, Chicago, IL): 1) the vertical distance from the tip of the lingula to the point at which the medial and lateral cortical plates became fused without any intervening medullary bone, measured perpendicular to the occlusal plane; 2) the vertical distance from the depth of the sigmoid notch to the point at which the medial and lateral cortical plates became fused; 3) the thickness of the ramus at the level of the lingula; 4) the thickness of the ramus at a level one-half the distance between the lingula and the depth of the sigmoid notch. They suggest that, based on considerations of fusion, there is no rationale to extend the medial osteotomy to the posterior border (a mean distance of 3 1.5 mm from the coronoid notch) because the incidence of fusion of the cortices increases posterior to the lingula, increasing the potential for an unfavourable fracture. Instead, these results support the work of Dal Pant, Hunsuck, Epker, and Jonsson, who all suggested extending the medial osteotomy only as far posteriorly as the lingual fossa. This is more easily achieved, with less periosteal stripping and less chance for haemorrhage. The mean length of the medial osteotomy would, therefore, be about 18 mm.

**Tammisalo T (1992)**[47] Conducted a study on the position of mandibular canal in relation to the superimposed roots of 173 impacted lower third molars was evaluated radiographically, the mandibular canal was located buccally to the roots of impacted lower third molars in 61% cases, lingually to the roots in 33% cases, between the roots in 3% cases and in 3% the relationship between the roots and canal was not able to determine.

**Takeuchi T et al (1994)**[46] In their study examined the changes in the shape of the foramen mandibulae over a period of 6 months after BSSO surgery during which the transient mental nerve paresthesia was recovered, and studied the distance from the foramen mandibulae to the spina mentalis (F-S distance) on 3 D film. The postoperative 3-D CT scan showed bone resorption in front of the foramen mandibulae, and the F-S distance was shortened by an average of 2.94 mm. These findings suggest that possible causes of the paresthesia are due to compression of the nerve trunk resulting from posterior movement of the mandibular ramus.

**Barbara Luka (1995)** [4] States that, with spiral CT the entire midfacial skeleton can be scanned by a single 40-sec acquisition. Facial asymmetry and deformity as well as type, shape and volume of a hard tissue implant can be determined by 3D visualization

**Kirk L. Fridrich et al (1995)**[27] Discussed the long term follow up after BSSO surgery shows the chance for neurosensory recovery is good despite intraoperative nerve manipulation. Patients seem to adapt and report normal neurosensory function even though objective testing indicates continued neurosensory deficit.

**Hooman M. Zarrinkelk et al (1996)**[22] States that, Vertical maxillary excess/retrognathia patients suffer from substantial deficiencies in their oromotor function. Surgical correction of this particular type of dentofacial deformity improves both the morphologic and functional deficits. Although some changes were not statistically significant, all were toward normalization of the presurgical values.

**John A Gregg (1996)**[24] It is suggested that protocols for assessing recovery from nerve injury should incorporate and quantify three different measures as much as possible. They are

1) Functional impairments (mastication, hygiene, speech, work, sleep, social interaction)

2) patient-perceived abnormality

3) stimulus-detection deficits (discriminitive, fine and crude touch, noxious, hot, cold, taste stimuli).

**Meredith August et al (1998)**[35] In their study discussed the incidence of persistent Functional Sensory Deficit more than 2 years post-BSSO increases with increasing age in a predictable and highly significant manner. Presurgical counselling should address this issue. Functional Sensory Deficit is also significantly associated with “bad splits.”

**Marcelo G.P. Cavalcanti (1999)**[33] In his study, the results showed no statistically significant differences between the measurements made in 3D-CT and the physical measurements. The mean difference between the image and real measurements was less than 2 mm in all instances. It is concluded that measurement of the skull and facial bone landmarks by 3D reconstruction is quantitatively accurate for surgical planning and treatment evaluation of craniofacial fractures.

**Mirco Raffaini (2002)**[36] States that, bilateral sagittal split osteotomy for mandibular advancement is the surgical procedure of choice for the treatment of Class II malocclusion with mandibular deficiency. The major advantage of sagittal mandibular osteotomy under local anesthesia and intravenous sedation are the chance to control functionally the TMJ in actual conditions and without the distortions caused by gravity and muscular relaxation commonly seen under general anesthesia.

**Wan Abdul Rahman Wan Harun et al (2003)**[53] Showed that, there was no significant statistical difference in the mean landmark measurements done on 3D CAD image and direct measurement methods using the calliper and Co-ordinate Measuring Machine. It was noted that the use of anatomical regions and templates in MIMICS provided faster reproducibility and a convenient method to identify craniofacial landmarks, especially those involving angular measurements. This provides an important step in the development of automatic landmark identification and measurement of craniofacials.

**Dennis T. Lanigan (2004)**[13] States that, during sagittal split procedure, with the patient in open mouth position, the distance between posterior border of the ascending ramus and the facial nerve is usually less than 1cm. The facial nerve leaves the base of the skull at the Stylomastoid foramen and its main trunk then enters the parotid gland. After sagittal osteotomies, facial nerve injuries invariably occur distal to the Stylomastoid foramen.

**Lascala CA (2004)**[30] States that, Cone beam CT image underestimates the real distances between skull sites, differences are only significant for the skull base and therefore it is reliable for linear evaluation measurements of other structures more closely associated with dental and maxillofacial imaging.

**Coen Pramono D (2005)**[12] Panoramic radiographs analysis, integrated with a 3D CT reconstruction proved to have an advantage to quantify the amount of space between the mandible foramens and the sigmoid notches. This procedure had tremendous potential for aiding in planning the surgical procedure more accurately, and thus the risk of alveolar nerve injury was reduced during BSSRO.

**Joseph E. Ceillo Jr (2005)**[25] Discussed the anatomic position of the lingula and course of IAN, presence of mandibular third molars, and the desired direction and magnitude of distal segment movement should be carefully reviewed before performing SSRO thereby decreasing the incidence of unfavourable splits and associated trauma to the adjoining tissues.

**Tsuji.Y. et al (2005)**[50] Classified the position of the mandibular canal within the bone. (a) Separate type, bone marrow space evident; (b) contact type, outer surface of the canal and inner surface of buccal cortical bone in contact; and (c) fusion type, outer cortical plate of the canal not evident.

**Grant Hogan (2006)**[18] Reveals no evidence that the antilingula has any relationship to the entrance of the inferior alveolar nerve. It is a bony response to the muscles and tendons that insert in that area rather than having a relationship to the entrance of the inferior alveolar nerve.

**Kwon T.G et al (2006)**[28] In their study 3D CT was used for evaluating the 3D structural correlation between the cranial structures and facial landmarks, so that it would be possible to verify whether mandibular asymmetry is a result of primary mandibular deformity or if it is influenced by cranial base deformity and concluded that the severity of cranial asymmetry is not the dominant factor that determines the degree of facial asymmetry.

**Nizam A (2006)**[37] Showed that the accuracy of the replica models produced by the stereolithography apparatus is appropriate within a margin of error that is acceptable for clinical applications in dental and craniofacial surgery.

**Aziz Shahid R et al (2007)**[3] In their study showed that the position of the lingula was posterior-inferior in relation to the position of the antilingula. At a measurement of 5 mm posterior to the antilingula (at the level of the antilingula), there was no risk of damaging the neurovascular bundle.

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**Gintaras Juodzbalys (2010)[17]** In his study, panoramic radiographs, showed that the vertical Mandibular Canal position can be divided into four categories: 1) high MC (within 2 mm of the apices of the first and second molars), 2) intermediate MC, 3) low MC, and 4) other variations – these includes duplication or division of the canal, apparent partial or complete absence of the canal or lack of symmetry.

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# REVIEW OF LITERATURE

**Dal Pont (1961)**[41] Changed the lower horizontal cut to a vertical cut on the buccal cortex between the first and second molars, thereby obtaining broader contact surfaces and requiring minimal muscle displacement in bilateral sagittal split osteotomy.

**Hunsuck (1968)**[41] Modified Dal Pont's technique of BSSO, advocating a shorter horizontal medial cut, just past the lingula, and to minimize softtissue dissection on the medial aspect of the ramus. This modification reduced haemorrhage, manipulation of the neurovascular bundle and postoperative swelling.

**Simpson W(1974)**[44] In his study, showed that the ascending ramus was so thin that the lingual cut could only be extended as far as the post-lingular depression. However, by use of the fine chisel and a careful technique, the split in most of these cases extended backwards to the posterior aspect of the ascending ramus. In none of the cases did the ascending ramus shatter.

**Hans Peter M et al (1975)**[19] In their study, showed that the most frequent pathological postoperative findings are Par- and Hypo- aesthesia of the mental nerve and clicking in the TMJ. However, neither are usually disturbing to the patient. The clicking is not associated with other disorders in the joint area, such as pain or limited excursion of the condyle.

**Reitzik et al (1976)**[42] They found that the greatest distance that the lingula may lie above and behind the midpoint of the waist of the ascending ramus is 6 and 5 mm respectively; therefore the intersection of the horizontal and vertical bone cuts should be placed at a point 8 mm above and 11 mm behind the midpoint of the waist of the ascending ramus. This has proved to be the most useful method of avoiding the inferior dental bundle in practice, as this point is the easiest to determine at operation.

**Yates C et al (1976)**[56] Described antilingula as a highly variable anatomic landmark and in most instances is situated considerably anteriorly and superiorly to the inferior dental foramen. However, a cut made between 5 and 10 mm. distal to the antilingula is within a statistically safe area, in over 72 per cent of cases, to avoid encroaching upon the inferior alveolar foramen.

**Hayward et al (1977)**[20] A Boley gauge which allows one to read to the nearest 0.1 mm was used in their study to measure 107 mandibles to find the A-P position of mandibular foramen. The points of the callipers were filed to a point to facilitate greater accuracy. The measurements were taken from the anterior border of the ramus to the anterior portion of the mandibular foramen and then from the anterior portion of the mandibular foramen to the posterior border of the ramus. Their findings agree with the observations on the location of the mandibular foramen published by miller, who stated that the location of the mandibular foramen is just posterior to the middle of the ramus. This study indicates that the mandibular foramen is located in the third quadrant. Our findings indicate that the mandibular foramen, and thus the inferior alveolar nerve's entry into the ramus of the mandible, is located at or near the axis of rotation, as indicated by Moss.

**Nortje et al (1977)**[39] Classified mandibular canal into 4 types:

Type 1: Bilateral single high mandibular canals - single canals either touching or within 2 mm of the apices first and second permanent molars.

Type 2: Bilateral single intermediate mandibular canals – single canals not fulfilling the criteria for either high or low canals.

Type 3: Bilateral single low mandibular canals, single canals either touching or within 2 mm of the cortical plate of the lower border of the mandible.

Type 4: Variations including: asymmetry, duplications and absence of mandibular canal.

**Walter J. PEPEI SACK (1978)**[52] In his long-term postoperative follow-up of BSSO patients, showed that 95 % of the patients are satisfied, 60% have some impairment of sensation in the lower lip. This however goes unnoticed in 40 % of these cases. The temporo-mandibular joint does not appear to be affected. 73 % of the patients have excellent or good occlusion, while 18% have an unsatisfactory anterior occlusion due to some degree of relapse. The remaining 9% have poor occlusion without sign of relapse.

**Robert Bruce Macintosh (1981)**[43] In his study showed that an immediate postoperative Paraesthesia incidence of almost 85 % was observed after BSSO, which diminished to 9 % 1 year postoperatively. The prolonged paresthesias were most common in patients over 40 years of age; similarly, healing was prolonged in patients over 40, prompting the author's recommendation that 8 weeks intermaxillary fixation rather than 6 be employed in these patients. The overall relapse rate was approximately 30 %.

**William Simpson (1981)**[55] Discussed the importance in preoperatively assessing the antero-posterior width of the mandible for BSSO surgery. In some of his cases it is found that the A-P width of the mandible is inadequate to achieve the planned position because of lack of bony contact. He also discussed the neurological involvement following sagittal split osteotomy shows 20% mental nerve involvement and 2% facial nerve involvement.

**Christos S. Martis (1984)**[11] States that, Sagittal split osteotomy has been performed routinely for correction of mandibular prognathism, retrognathia, mild open bite, and asymmetry. With meticulous performance of the operation and long-term maxillomandibular fixation, complications can be negligible, and relapse, the most problematic postoperative issue, can be significantly reduced.

**Epker (1984)**[15] Surgical procedures involving mandibular osteotomies, the surgery becomes more complex with the addition of a second neuro-vascular bundle. He emphasized the necessity of the protection of the blood supply during those procedures. The interpretation of the panoramic radiographic is of great importance in its location and on surgical planning. The clinician should recognize the anatomical variations and modify the surgical technique if necessary.

**Paul H. Bailey (1984)**[40] States that, mandibular augmentation procedures requiring repositioning of the inferior alveolar neurovascular bundle may lead to both subjective and objective neurosensory alterations that may persist at long term follow up, and that the degree of subjective complaint may correlate poorly with, and may be of much greater magnitude than, the objectively tested level of neurosensory alteration.

**Irene Karabouta et al (1985)**[23] In his study, 280 patients with different types of mandibular deformities (prognathism, retrognathia, open bite, asymmetry) had been operated on by sagittal split osteotomy of the ramus. The patients, routinely checked preoperatively, were found to present subjective or objective TMJ dysfunction symptoms with an incidence of 40.8 %. After surgery the incidence of such symptoms in the same patients was 11.1%. The patients with no TMJ dysfunction symptoms preoperatively, presented such symptoms with an incidence of 3.7 % postoperatively, a percentage very low in comparison with other statistics.

**Langlais et al (1985)**[29] Classified bifurcated mandibular canal based on the panoramic findings:

Type1 : Unilateral or Bilateral bifurcated mandibular canal, extending towards retro-molar region

Type2 : Unilateral or Bilateral bifid mandibular canal limited to ramus Unilateral or Bilateral bifid mandibular canal extending into body

Type3 : Combination of types 1 and 2

Type4 : Originating from two mandibular canals

**Henry S. Zaytoun et al (1986)**[21] In his study twenty-six patients who had been treated for mandibular prognathism by either bilateral sagittal split osteotomy or transoral vertical ramus osteotomy were evaluated by neurosensory examination. Neuropathy was demonstrable in 28.8% of the 52 mental nerves examined. The incidence of neuropathy was significantly higher in the bilateral sagittal split osteotomy group than in the transoral vertical osteotomy group.

**Ghali G.E et al (1989)**[16] In their study, patients experiencing neurosensory alteration after orthognathic surgery are tested every other week. This is continued for 2 months or until symptoms improve. At the 2-month period there are three major indications for microneurosurgical intervention: 1) persistent anesthesia 2) hyperesthesia or 3) troublesome hypoesthesia. The sensation of static light touch and brush directional stroke are also believed to selectively discriminate for large, myelinated, quickly adapting, A alpha sensory nerve fibres. Pin prick selects for small, myelinated, A delta sensory nerve fibres; on the other hand, temperature discrimination selects for small, myelinated and unmyelinated, A delta and C sensory nerve fibres.

**Brian R. Smith et al (1991)**[5] In their study, the following measurements were made on 50 dried mandibles with a microcaliper capable of measuring to the nearest 0.1 mm (Helios Microcaliper Inoxyd, Precision Gage Co, Chicago, IL): 1) the vertical distance from the tip of the lingula to the point at which the medial and lateral cortical plates became fused without any intervening medullary bone, measured perpendicular to the occlusal plane; 2) the vertical distance from the depth of the sigmoid notch to the point at which the medial and lateral cortical plates became fused; 3) the thickness of the ramus at the level of the lingula; 4) the thickness of the ramus at a level one-half the distance between the lingula and the depth of the sigmoid notch. They suggest that, based on considerations of fusion, there is no rationale to extend the medial osteotomy to the posterior border (a mean distance of 3 1.5 mm from the coronoid notch) because the incidence of fusion of the cortices increases posterior to the lingula, increasing the potential for an unfavourable fracture. Instead, these results support the work of Dal Pant, Hunsuck, Epker, and Jonsson, who all suggested extending the medial osteotomy only as far posteriorly as the lingual fossa. This is more easily achieved, with less periosteal stripping and less chance for haemorrhage. The mean length of the medial osteotomy would, therefore, be about 18 mm.

**Tammisalo T (1992)**[47] Conducted a study on the position of mandibular canal in relation to the superimposed roots of 173 impacted lower third molars was evaluated radiographically, the mandibular canal was located buccally to the roots of impacted lower third molars in 61% cases, lingually to the roots in 33% cases, between the roots in 3% cases and in 3% the relationship between the roots and canal was not able to determine.

**Takeuchi T et al (1994)**[46] In their study examined the changes in the shape of the foramen mandibulae over a period of 6 months after BSSO surgery during which the transient mental nerve paresthesia was recovered, and studied the distance from the foramen mandibulae to the spina mentalis (F-S distance) on 3 D film. The postoperative 3-D CT scan showed bone resorption in front of the foramen mandibulae, and the F-S distance was shortened by an average of 2.94 mm. These findings suggest that possible causes of the paresthesia are due to compression of the nerve trunk resulting from posterior movement of the mandibular ramus.

**Barbara Luka (1995)** [4] States that, with spiral CT the entire midfacial skeleton can be scanned by a single 40-sec acquisition. Facial asymmetry and deformity as well as type, shape and volume of a hard tissue implant can be determined by 3D visualization

**Kirk L. Fridrich et al (1995)**[27] Discussed the long term follow up after BSSO surgery shows the chance for neurosensory recovery is good despite intraoperative nerve manipulation. Patients seem to adapt and report normal neurosensory function even though objective testing indicates continued neurosensory deficit.

**Hooman M. Zarrinkelk et al (1996)**[22] States that, Vertical maxillary excess/retrognathia patients suffer from substantial deficiencies in their oromotor function. Surgical correction of this particular type of dentofacial deformity improves both the morphologic and functional deficits. Although some changes were not statistically significant, all were toward normalization of the presurgical values.

**John A Gregg (1996)**[24] It is suggested that protocols for assessing recovery from nerve injury should incorporate and quantify three different measures as much as possible. They are

1) Functional impairments (mastication, hygiene, speech, work, sleep, social interaction)

2) patient-perceived abnormality

3) stimulus-detection deficits (discriminitive, fine and crude touch, noxious, hot, cold, taste stimuli).

**Meredith August et al (1998)**[35] In their study discussed the incidence of persistent Functional Sensory Deficit more than 2 years post-BSSO increases with increasing age in a predictable and highly significant manner. Presurgical counselling should address this issue. Functional Sensory Deficit is also significantly associated with "bad splits."

**Marcelo G.P. Cavalcanti (1999)**[33] In his study, the results showed no statistically significant differences between the measurements made in 3D-CT and the physical measurements. The mean difference between the image and real measurements was less than 2 mm in all instances. It is concluded that measurement of the skull and facial bone landmarks by 3D reconstruction is quantitatively accurate for surgical planning and treatment evaluation of craniofacial fractures.

**Mirco Raffaini (2002)**[36] States that, bilateral sagittal split osteotomy for mandibular advancement is the surgical procedure of choice for the treatment of Class II malocclusion with mandibular deficiency. The major advantage of sagittal mandibular osteotomy under local anesthesia and intravenous sedation are the chance to control functionally the TMJ in actual conditions and without the distortions caused by gravity and muscular relaxation commonly seen under general anesthesia.

**Wan Abdul Rahman Wan Harun et al (2003)**[53] Showed that, there was no significant statistical difference in the mean landmark measurements done on 3D CAD image and direct measurement methods using the calliper and Co-ordinate Measuring Machine. It was noted that the use of anatomical regions and templates in MIMICS provided faster reproducibility and a convenient method to identify craniofacial landmarks, especially those involving angular measurements. This provides an important step in the development of automatic landmark identification and measurement of craniofacials.

**Dennis T. Lanigan (2004)**[13] States that, during sagittal split procedure, with the patient in open mouth position, the distance between posterior border of the ascending ramus and the facial nerve is usually less than 1cm. The facial nerve leaves the base of the skull at the Stylomastoid foramen and its main trunk then enters the parotid gland. After sagittal osteotomies, facial nerve injuries invariably occur distal to the Stylomastoid foramen.

**Lascala CA (2004)**[30] States that, Cone beam CT image underestimates the real distances between skull sites, differences are only significant for the skull base and therefore it is reliable for linear evaluation measurements of other structures more closely associated with dental and maxillofacial imaging.

**Coen Pramono D (2005)**[12] Panoramic radiographs analysis, integrated with a 3D CT reconstruction proved to have an advantage to quantify the amount of space between the mandible foramens and the sigmoid notches. This procedure had tremendous potential for aiding in planning the surgical procedure more accurately, and thus the risk of alveolar nerve injury was reduced during BSSRO.

**Joseph E. Ceillo Jr (2005)**[25] Discussed the anatomic position of the lingula and course of IAN, presence of mandibular third molars, and the desired direction and magnitude of distal segment movement should be carefully reviewed before performing SSRO thereby decreasing the incidence of unfavourable splits and associated trauma to the adjoining tissues.

**Tsuji.Y. et al (2005)**[50] Classified the position of the mandibular canal within the bone. (a) Separate type, bone marrow space evident; (b) contact type, outer surface of the canal and inner surface of buccal cortical bone in contact; and (c) fusion type, outer cortical plate of the canal not evident.

**Grant Hogan (2006)**[18] Reveals no evidence that the antilingula has any relationship to the entrance of the inferior alveolar nerve. It is a bony response to the muscles and tendons that insert in that area rather than having a relationship to the entrance of the inferior alveolar nerve.

**Kwon T.G et al (2006)**[28] In their study 3D CT was used for evaluating the 3D structural correlation between the cranial structures and facial landmarks, so that it would be possible to verify whether mandibular asymmetry is a result of primary mandibular deformity or if it is influenced by cranial base deformity and concluded that the severity of cranial asymmetry is not the dominant factor that determines the degree of facial asymmetry.

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Measurement of values in 3D CT Reconstructed Mandible using MIMICS Software

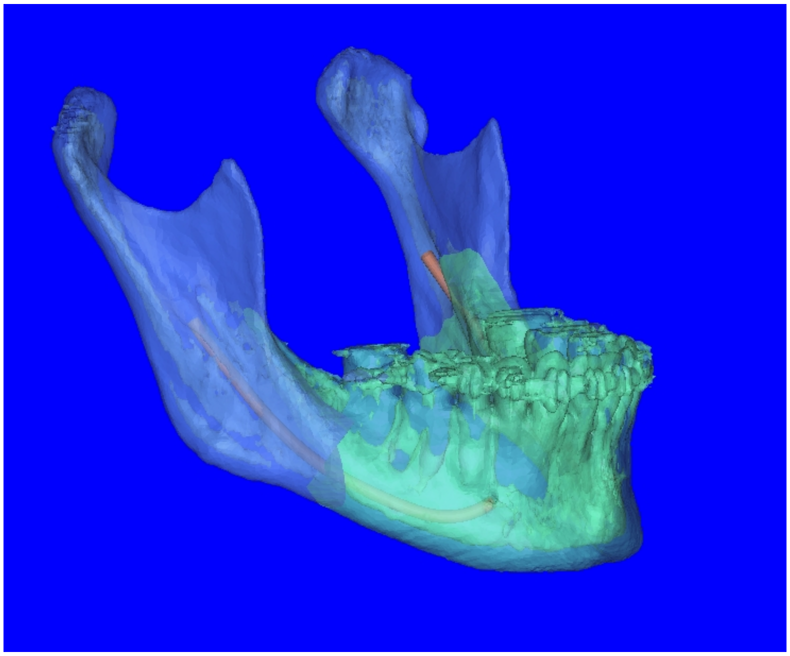


Fig 1: 3D CT image of Reconstructed Mandible

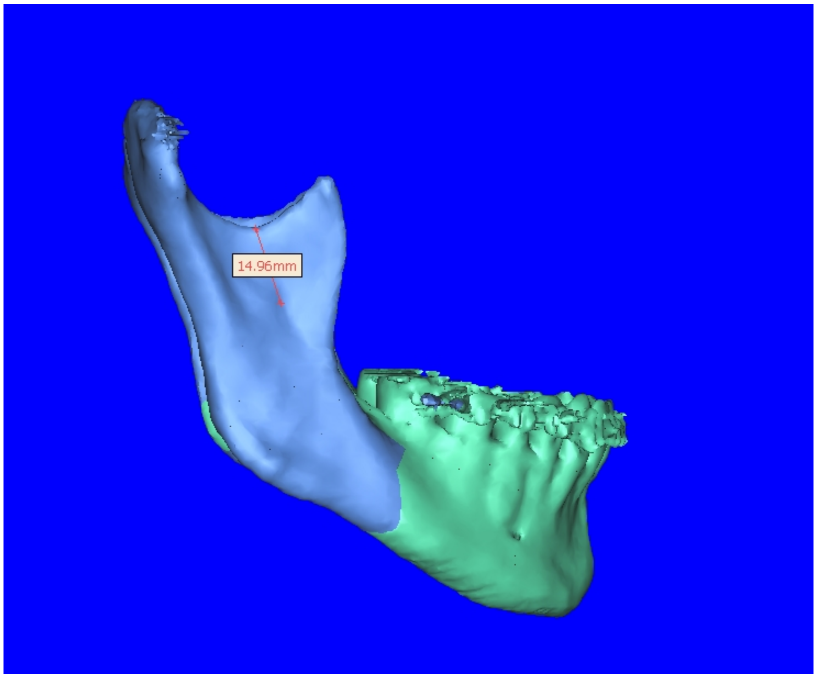



Fig 2: Sigmoid notch to Antilingula (A on right side)

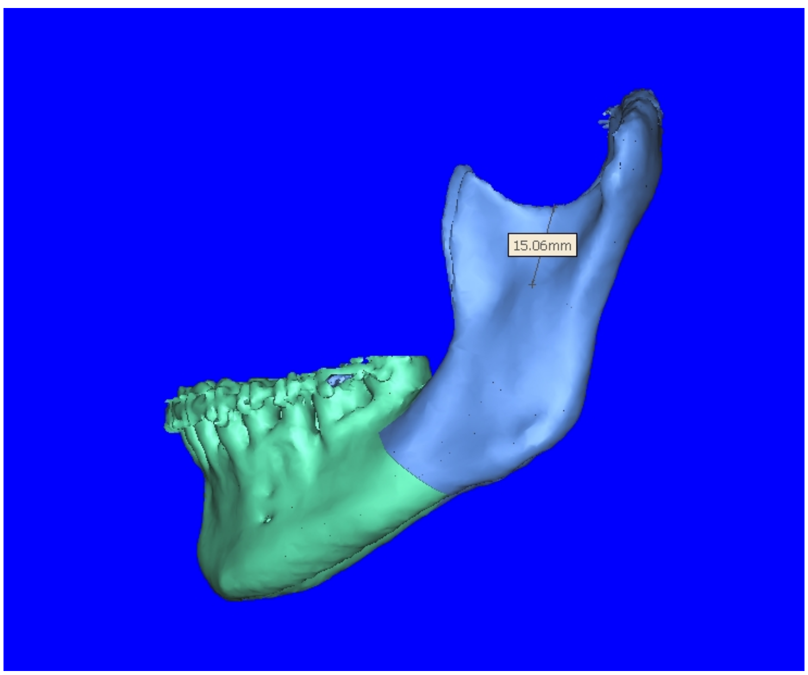



Fig 3:  Sigmoid notch to Antilingula (A on leftside)

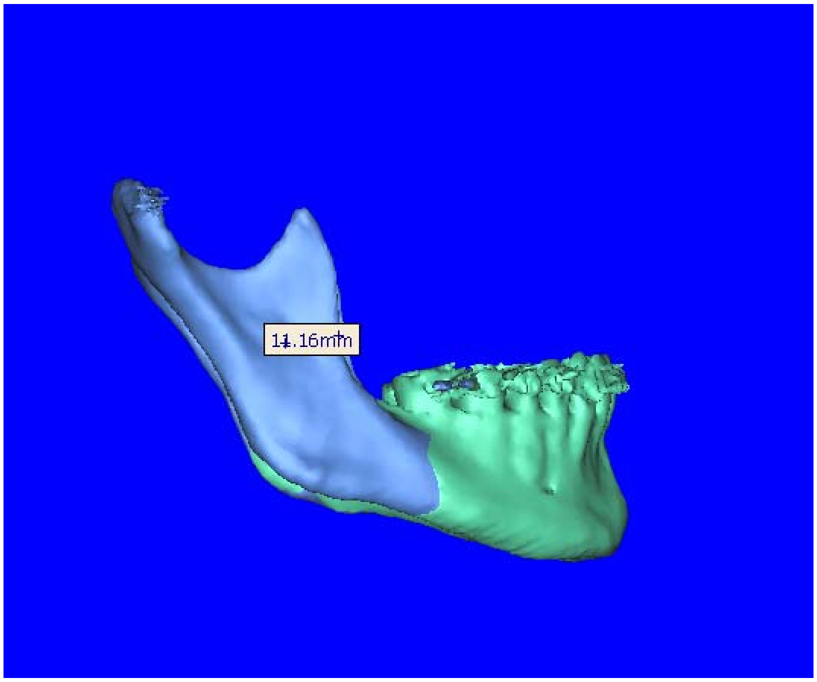



Fig 4: Antilingula to anterior border of ramus (B on right side)

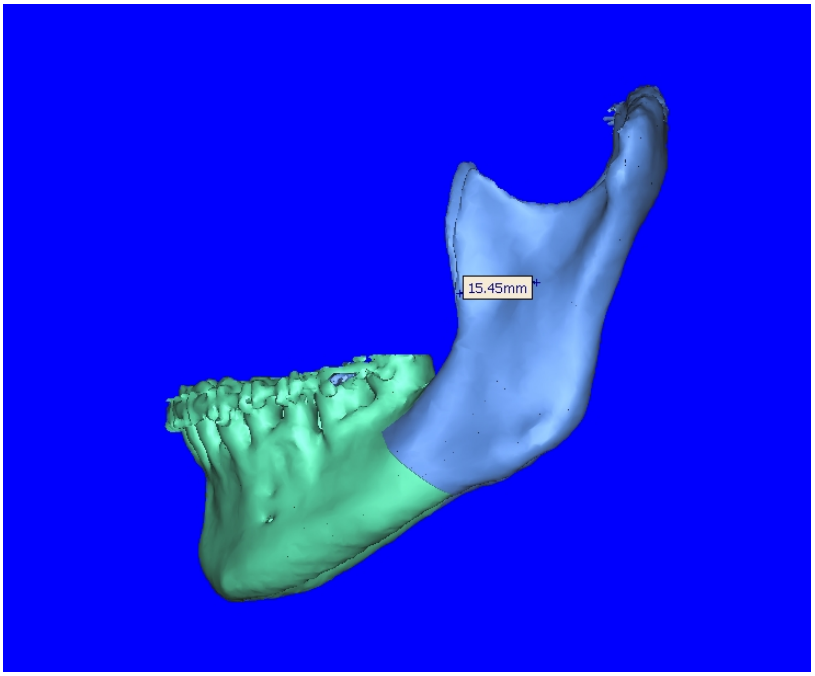



Fig 5: Antilingula to anterior border of ramus (B on left side)

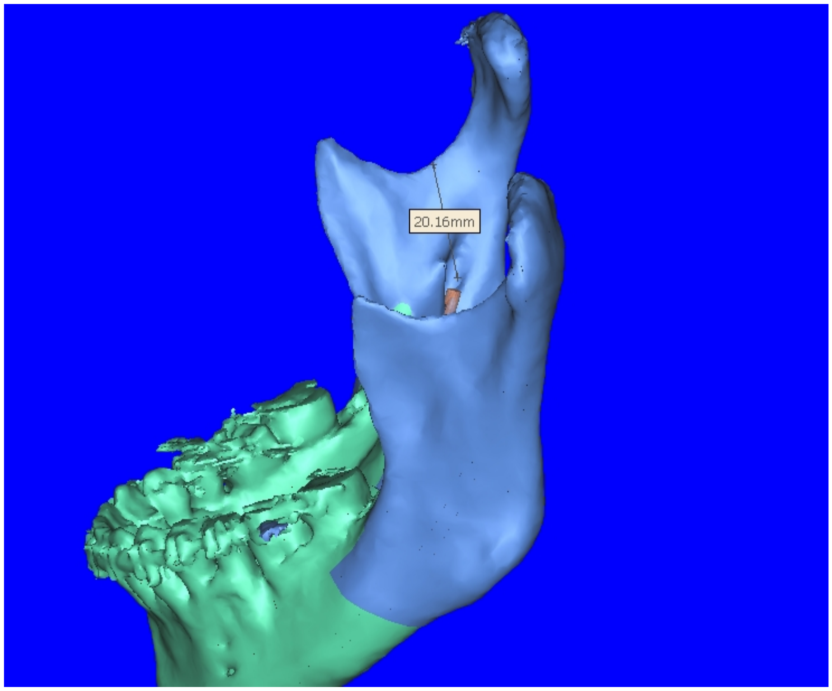



Fig 6: Sigmoid notch to mandibular foramen (C on right side)

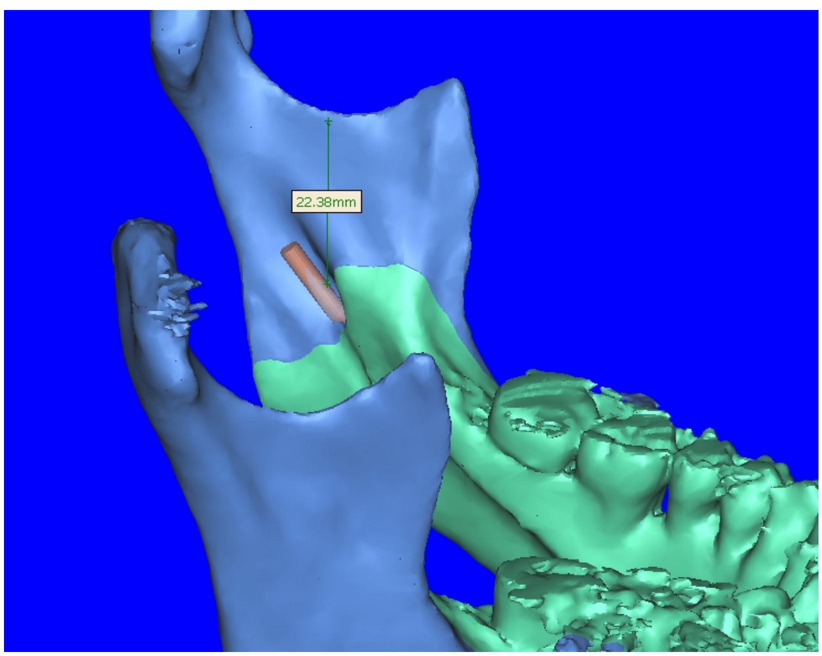



Fig 7: Sigmoid notch to mandibular foramen (C on left side)

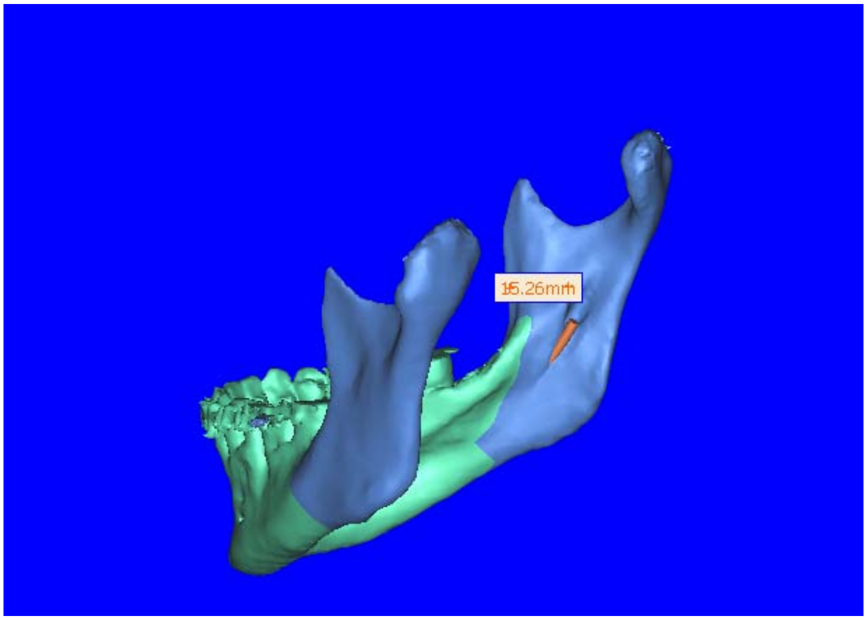



Fig 8:  Mandibular foramen to anterior border of ramus

(D on right side)

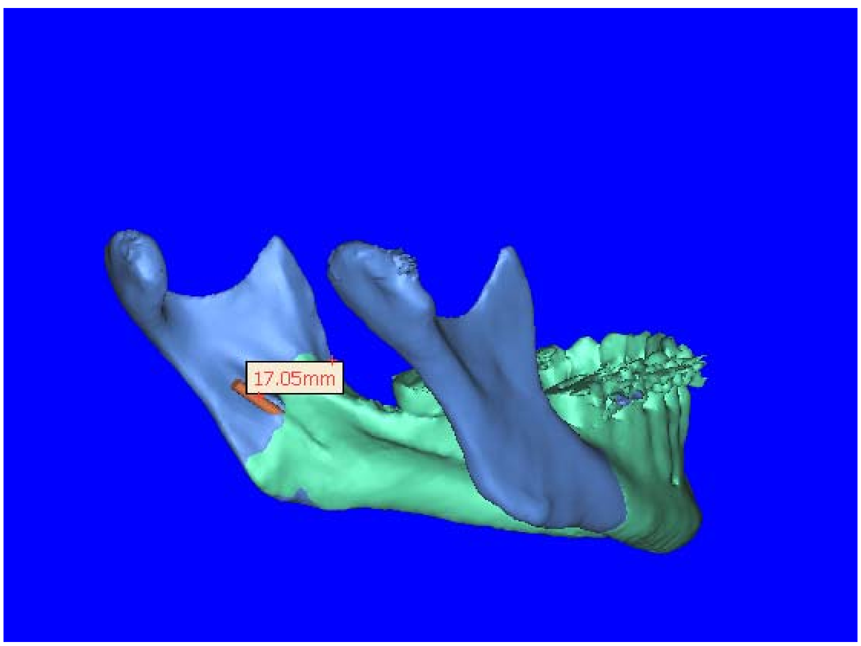



Fig 9: Mandibular foramen to anterior border of ramus

(D on left side)

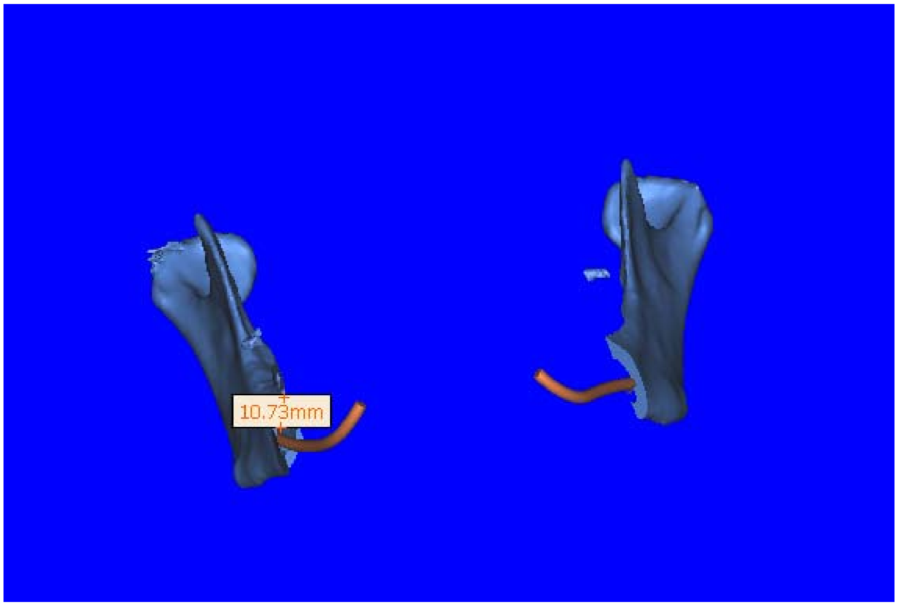



Fig 10: Mandibular canal to alveolar crest level at coronal section
(E on right side)

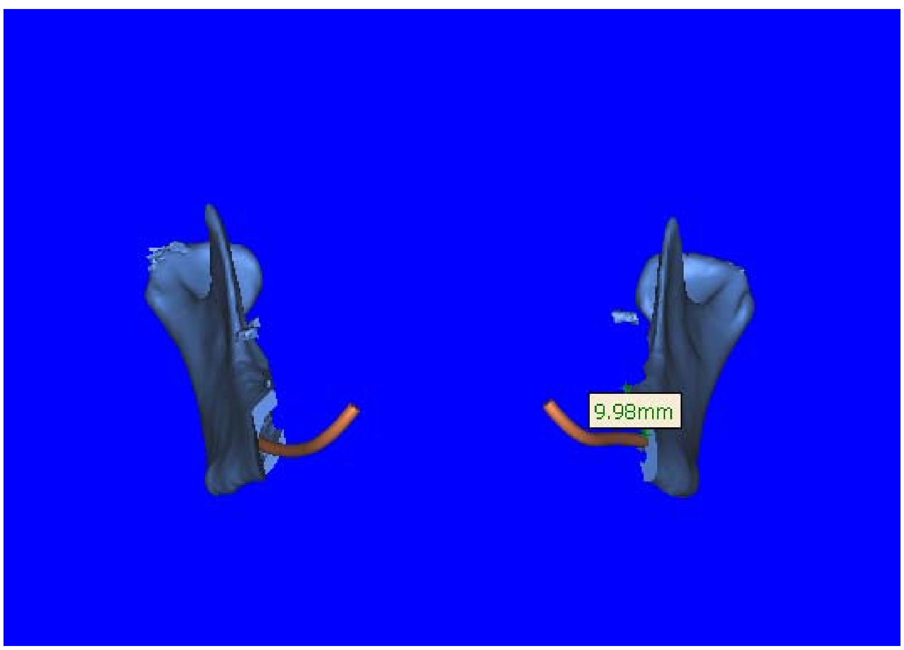



Fig 11: Mandibular canal to alveolar crest level at coronal section (E on left side)

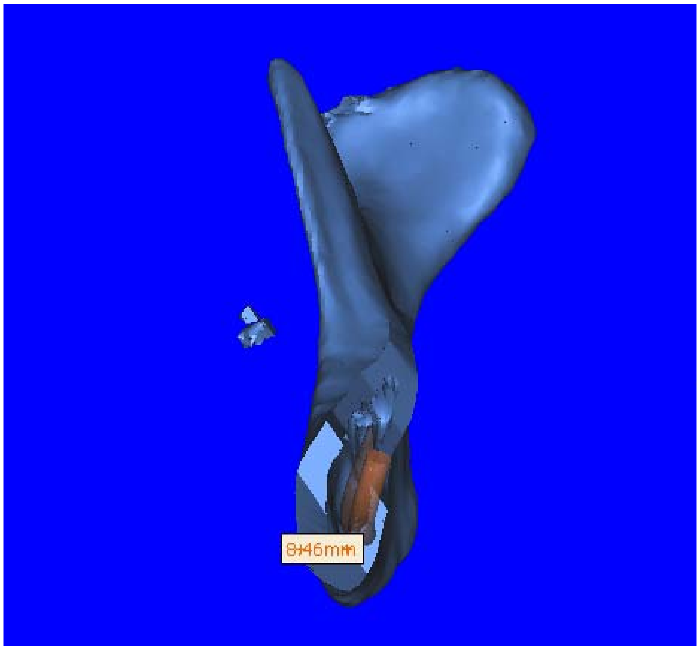



Fig 12: Mandibular canal to buccal plate at second molar

(F on right side)

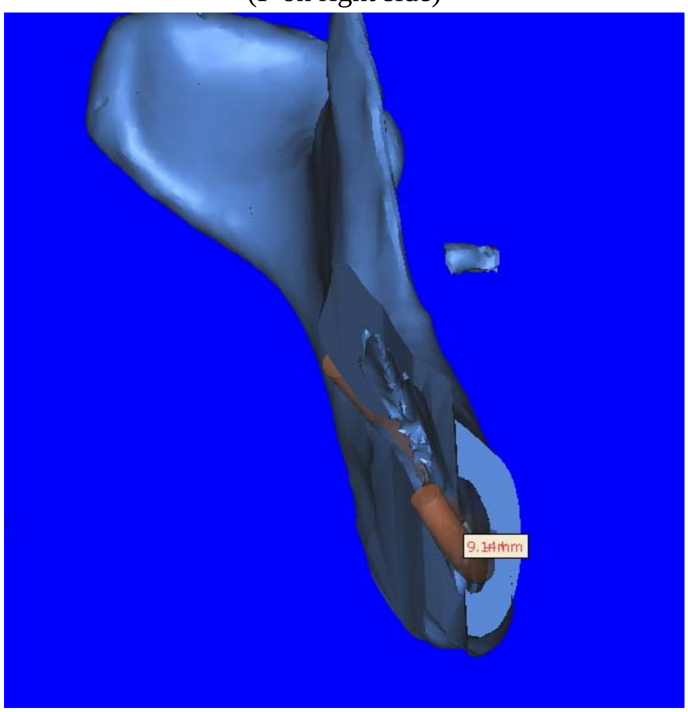



Fig 13: Mandibular canal to buccal plate at second molar

(F on left side)

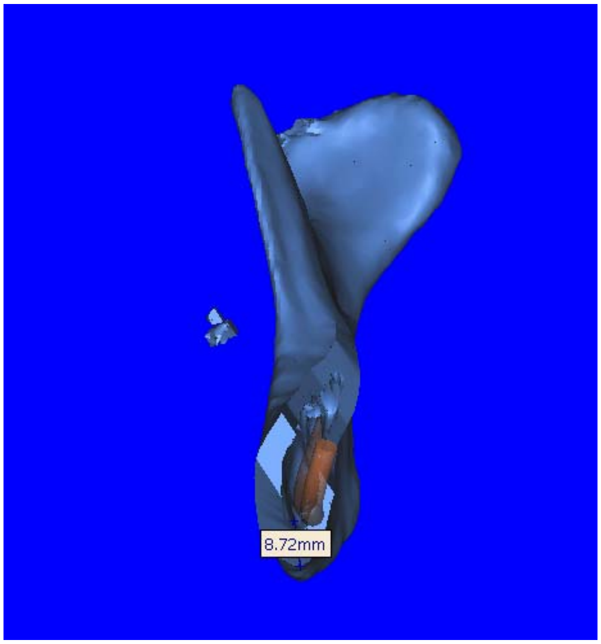



Fig 14: Mandibular canal to lower border at second molar

(G on right side)

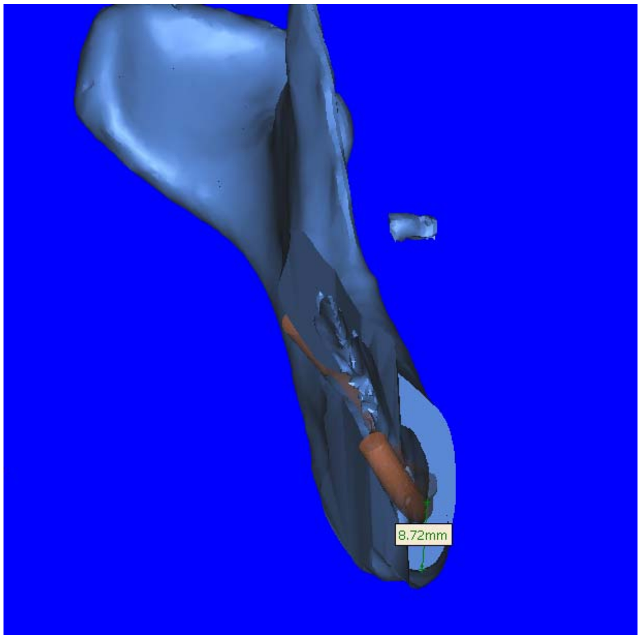



Fig 15: Mandibular canal to lower border at second molar

(G on left side)

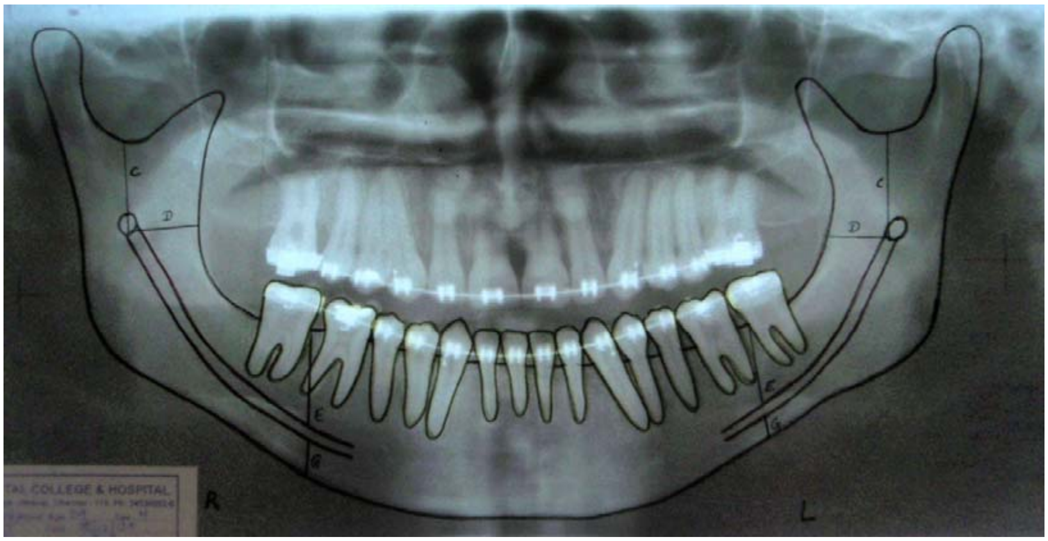



Fig 16: Measurements made in OPG

## Intra operative measurements

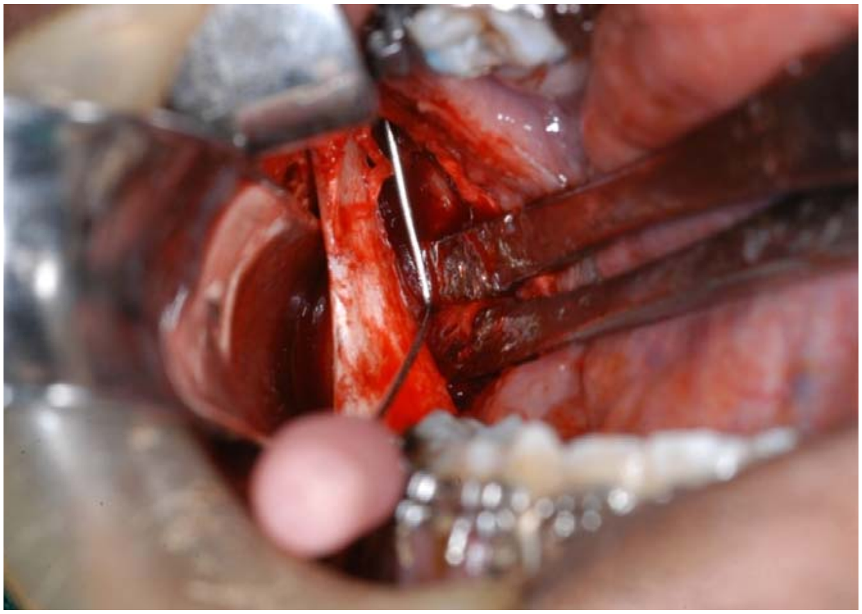


Fig 17: Sigmoid notch to Mandibular foramen (C)

Fig 18: Mandibular foramen to anterior border (D)

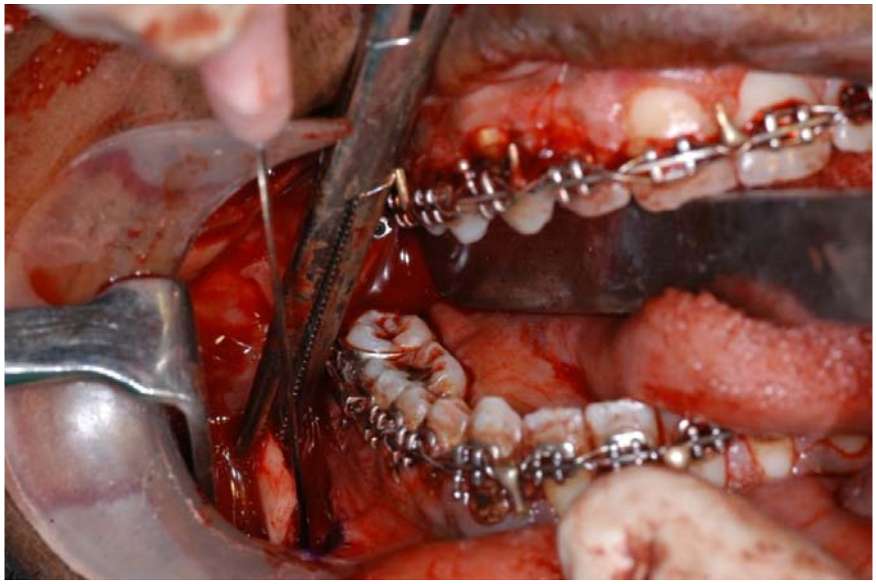


Fig 19: Mandibular foramen to alveolar crest level (E)

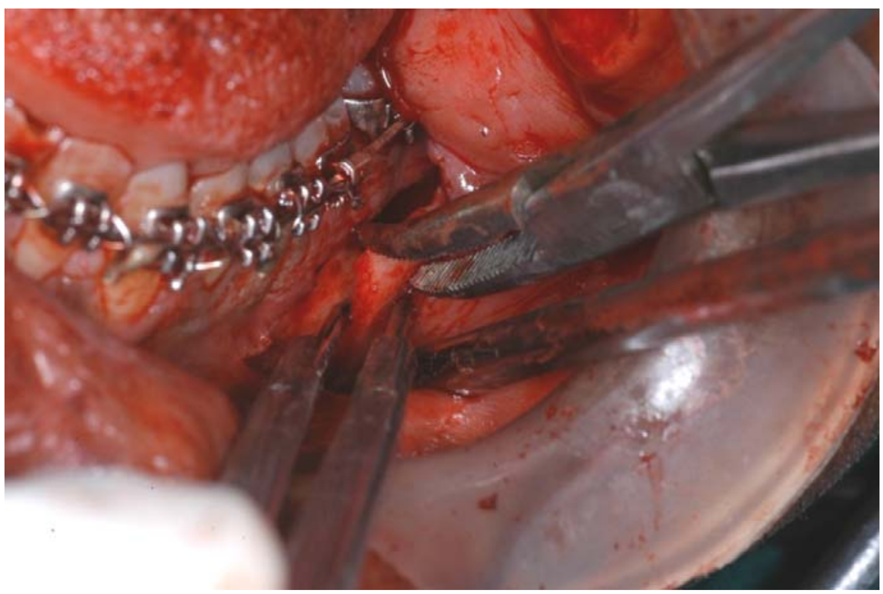


Fig 20: Mandibular canal to buccal plate at second molar region (F)

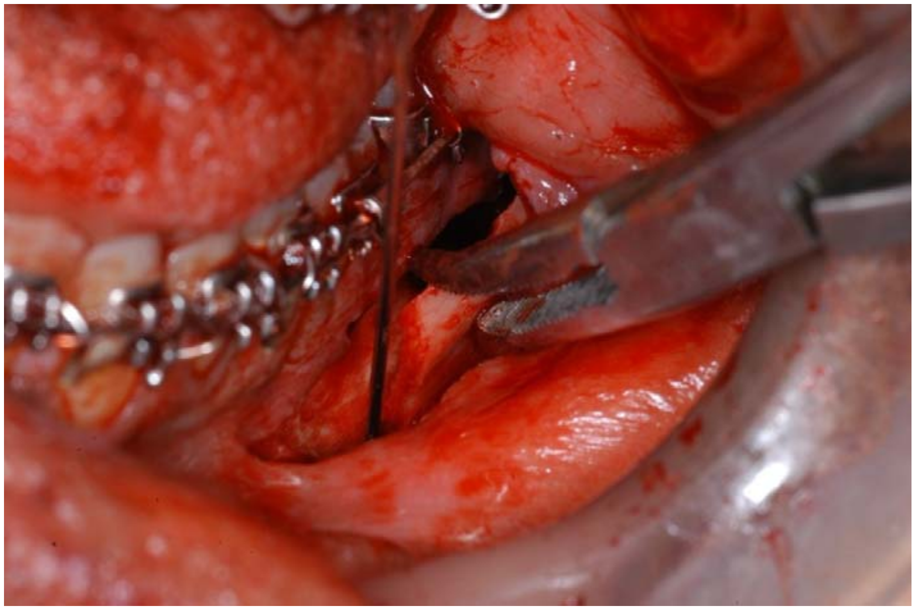
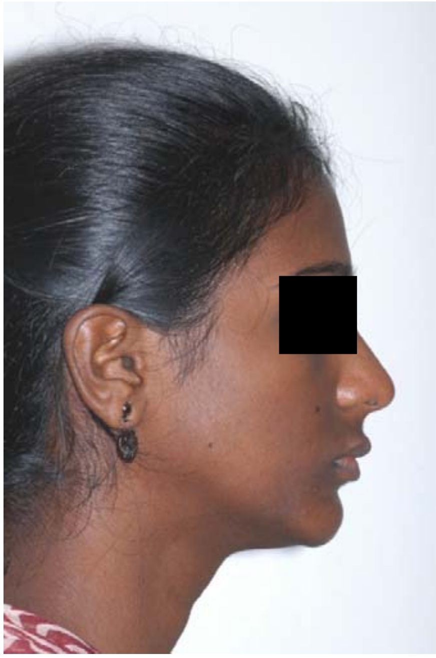


Fig 21: Mandibular canal to lower border of mandible

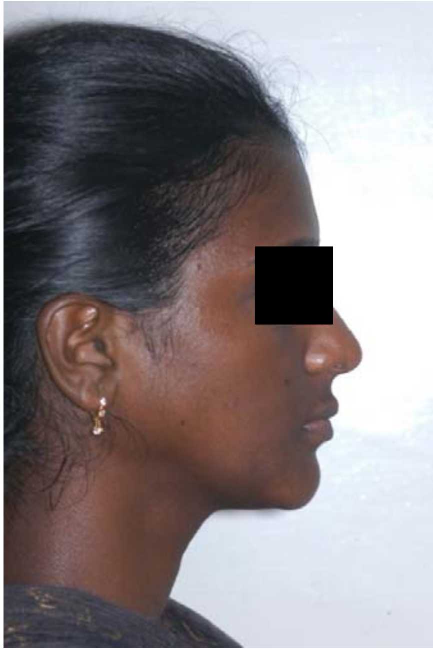
at second molar region (G)

Preoperative and Postoperative Lateral view photographs of three patients included in the study

Patient name: Solaimalar, Age/Sex: 21yrs/ F



Preoperative photograph



Postoperative photograph

Patient name : Purusothaman , Age/sex: 24yr/ M

Preoperative photograph

Postoperative photograph

Patient name: Vaithyanathan, Age/Sex:  28yrs/ M


Preoperative photograph

Postoperative photograph

# Results

The mean distance from anterior border of ramus to mandibular foramen and antilingula were 15.50mm and 15.11mm respectively. The minimum and maximum distances were 14.08-18.01mm for the mandibular foramen and 11.16-18.83mm for the antilingula.

The average horizontal distance between antilingula and mandibular foramen did not differ significantly (0.65mm). But the value ranges between -3.20 to 3.97mm.

The average distance from the sigmoid notch to the mandibular foramen and antilingula were 17.30mm and 14.23mm respectively. The value ranges between 11.31-21.85mm for the mandibular foramen and 9.26mm-16.63mm for the antilingula. The average distance from antilinugla to mandibular foramen in vertical direction was 3.01 mm. It ranges from 0.0mm to 6.75mm.

When viewed at coronal section at the mandibular second molar region, the average distance from the mandibular canal to alveolar crest, buccal cortex and inferior border of mandible were 12.69mm, 6.42mm and 6.44mm respectively. The ranges were 10.31-14.99mm for the alveolar crest, 4.09-9.14mm for the buccal plate and 3.98-8.72mm for the inferior border of the mandible from the mandibular canal.

Tables 1a, 2a, 3a, 4a, 5a, 6a, 7a and 8a shows measurements between different anatomic reference points considered for evaluating mandibular anatomy in 3D scan images done using MIMICS software for the eight patients included in the study.

Tables 1b, 2b, 3b, 4b, 5b, 6b, 7b and 8b shows measurements between different anatomic reference points considered for evaluating mandibular anatomy intraoperatively during BSSRO for the eight patients included in the study.

Tables 1c, 2c, 3c, 4c, 5c, 6c, 7c and 8c shows measurements between different anatomic reference points considered for evaluating mandibular anatomy in pre-operative OPG.

Tables 10, 11 and 12 represent mean values and range of values obtained from 3D CT scan image, OPG and intraoperative measurements respectively.

Table 13 shows comparison of mean values obtained from 3D CT scan image, OPG and intraoperative measurements

It shows that the value obtained from the CT scan and the values obtained from the Intraoperative procedure have high correlation and they did not differ from each other by more than 0.5mm. Measurements made from the OPG is significantly different from the values obtained from CT scan and intra operative values.

The neurosensory deficit assessed by cotton wool test and pin prick test is shown in table 14. Almost 100% of the population had neurosensory deficit on the immediate post operative period and every one recovered at 2 months post operatively.

The position of the nerve was assessed intra operatively and in all 8 patients, nerve was not encountered and it stayed in the distal fragment. None of our patients had direct nerve injury.

Patient name: Purusothaman,

Age/Sex : 24yrs/M

**Table 1a**

| **Anatomic reference points considered for evaluating mandibular anatomy in 3D scan images** | **Right side (in mm)** | **Left side (in mm)** |
|---|---|---|
| S-antilingula(A) | 14.96 | 15.06 |
| Antilingula –anterior border(B) | 11.16 | 15.45 |
| S-mandibular foramen(C) | 20.16 | 22.38 |
| Mandibular foramen-anterior border(D) | 15.26 | 17.05 |
| Antilingula –mandibular foramen (horizontal)(W) | 3.97 | 1.60 |
| Antilingula –mandibular foramen(vertical)(H) | 5.20 | 7.32 |
| Mandibular canal-alveolar crest level at coronal section (E) | 10.73 | 9.98 |
| Mandibular canal-buccal plate at second molar(F) | 8.46 | 9.14 |
| Mandibular canal-lower border at second molar(G) | 8.72 | 8.72 |

**Table 1b**

| **Anatomic reference points considered for evaluating mandibular anatomy intraoperatively** | **Right side (in mm)** | **Left side (in mm)** |
|---|---|---|
| S-mandibular foramen(C) | 22.00 | 22.00 |
| Mandibular foramen-anterior border(D) | 16.50 | 20.00 |
| Mandibular canal-alveolar crest level at coronal section (E) | 11.00 | 11.00 |
| Mandibular canal-buccal plate at second molar(F) | 8.50 | 9.00 |
| Mandibular canal-lower border at second molar(G) | 8.50 | 8.50 |

**Table 1c**

| **Anatomic reference points considered for evaluating mandibular anatomy in OPG** | **Right side (in mm)** | **Left side (in mm)** |
|---|---|---|
| S-mandibular foramen(C) | 25 | 25 |
| Mandibular foramen-anterior border(D) | 18 | 16 |
| Mandibular canal-alveolar crest level at coronal section (E) | 20 | 21 |
| Mandibular canal-lower border at second molar(G) | 9 | 9 |

Patient name: Lakshmanan,

Age/Sex : 32yrs/M

**Table 2a**

| **Anatomic reference points considered for evaluating mandibular anatomy in 3D scan images** | **Right side (in mm)** | **Left side (in mm)** |
|---|---|---|
| S-antilingula(A) | 16.51 | 15.38 |
| Antilingula –anterior border(B) | 18.83 | 19.39 |
| S-mandibular foramen(C) | 20.79 | 18.13 |
| Mandibular foramen-anterior border(D) | 18.01 | 18.72 |
| Antilingula –mandibular foramen (horizontal)(W) | -0.82 | -0.67 |
| Antilingula –mandibular foramen(vertical)(H) | 4.28 | 2.75 |
| Mandibular canal-alveolar crest level at coronal section (E) | 14.99 | 15.07 |
| Mandibular canal-buccal plate at second molar(F) | 7.74 | 6.43 |
| Mandibular canal-lower border at second molar(G) | 6.29 | 5.58 |

**Table 2b**

| **Anatomic reference points considered for evaluating mandibular anatomy intraoperatively** | **Right side (in mm)** | **Left side (in mm)** |
|---|---|---|
| S-mandibular foramen(C) | 18.00 | 18.00 |
| Mandibular foramen-anterior border(D) | 18.00 | 19.00 |
| Mandibular canal-alveolar crest level at coronal section (E) | 15.00 | 15.00 |
| Mandibular canal-buccal plate at second molar(F) | 6.50 | 6.00 |
| Mandibular canal-lower border at second molar(G) | 6.50 | 5.00 |

**Table 2c**

| **Anatomic reference points considered for evaluating mandibular anatomy in OPG** | **Right side (in mm)** | **Left side (in mm)** |
|---|---|---|
| S-mandibular foramen(C) | 21 | 23 |
| Mandibular foramen-anterior border(D) | 17 | 23 |
| Mandibular canal-alveolar crest level at coronal section (E) | 15 | 18 |
| Mandibular canal-lower border at second molar(G) | 15 | 14 |

Patient name: Vinothkumar,

Age/Sex : 21yrs/M

**Table 3a**

| **Anatomic reference points considered for evaluating mandibular anatomy in 3D scan images** | **Right side (in mm)** | **Left side (in mm)** |
|---|---|---|
| S-antilingula(A) | 15.10 | 14.82 |
| Antilingula –anterior border(B) | 13.64 | 12.83 |
| S-mandibular foramen(C) | 21.85 | 19.27 |
| Mandibular foramen-anterior border(D) | 14.08 | 14.21 |
| Antilingula –mandibular foramen (horizontal)(W) | 0.44 | 1.38 |
| Antilingula –mandibular foramen(vertical)(H) | 6.75 | 4.45 |
| Mandibular canal-alveolar crest level at coronal section (E) | 14.00 | 14.01 |
| Mandibular canal-buccal plate at second molar(F) | 6.78 | 6.84 |
| Mandibular canal-lower border at second molar(G) | 7.36 | 7.04 |

**Table 3b**

| **Anatomic reference points considered for evaluating mandibular anatomy intraoperatively** | **Right side (in mm)** | **Left side (in mm)** |
|---|---|---|
| S-mandibular foramen(C) | 19.00 | 18.00 |
| Mandibular foramen-anterior border(D) | 14.50 | 14.50 |
| Mandibular canal-alveolar crest level at coronal section (E) | 13.00 | 13.00 |
| Mandibular canal-buccal plate at second molar(F) | 6.50 | 6.50 |
| Mandibular canal-lower border at second molar(G) | 7.50 | 7.00 |

**Table 3c**

| **Anatomic reference points considered for evaluating mandibular anatomy in OPG** | **Right side (in mm)** | **Left side (in mm)** |
|---|---|---|
| S-mandibular foramen(C) | 22 | 21 |
| Mandibular foramen-anterior border(D) | 18 | 16 |
| Mandibular canal-alveolar crest level at coronal section (E) | 22 | 20 |
| Mandibular canal-lower border at second molar(G) | 15 | 14 |

Patient name: Rajarishi,

Age/Sex : 23yrs/M

**Table 4a**

| **Anatomic reference points considered for evaluating mandibular anatomy in 3D scan images** | **Right side (in mm)** | **Left side (in mm)** |
|---|---|---|
| S-antilingula(A) | 14.30 | 12.38 |
| Antilingula –anterior border(B) | 17.93 | 16.97 |
| S-mandibular foramen(C) | 16.76 | 16.07 |
| Mandibular foramen-anterior border(D) | 14.73 | 17.69 |
| Antilingula –mandibular foramen (horizontal)(W) | -3.20 | 0.72 |
| Antilingula –mandibular foramen(vertical)(H) | 2.46 | 3.69 |
| Mandibular canal-alveolar crest level at coronal section (E) | 11.95 | 11.51 |
| Mandibular canal-buccal plate at second molar(F) | 5.80 | 5.09 |
| Mandibular canal-lower border at second molar(G) | 6.35 | 7.02 |

**Table 4b**

| **Anatomic reference points considered for evaluating mandibular anatomy intraoperatively** | **Right side (in mm)** | **Left side (in mm)** |
|---|---|---|
| S-mandibular foramen(C) | 16.50 | 16.00 |
| Mandibular foramen-anterior border(D) | 17.00 | 18.00 |
| Mandibular canal-alveolar crest level at coronal section (E) | 12.00 | 13.00 |
| Mandibular canal-buccal plate at second molar(F) | 5.00 | 5.00 |
| Mandibular canal-lower border at second molar(G) | 6.00 | 6.50 |

**Table 4c**

| **Anatomic reference points considered for evaluating mandibular anatomy in OPG** | **Right side (in mm)** | **Left side (in mm)** |
|---|---|---|
| S-mandibular foramen(C) | 15 | 16 |
| Mandibular foramen-anterior border(D) | 14 | 18 |
| Mandibular canal-alveolar crest level at coronal section (E) | 22 | 26 |
| Mandibular canal-lower border at second molar(G) | 12 | 15 |

Patient name: Solaimalar,

Age/Sex : 21yrs/F

**Table 5a**

| **Anatomic reference points considered for evaluating mandibular anatomy in 3D scan images** | **Right side (in mm)** | **Left side (in mm)** |
|---|---|---|
| S-antilingula(A) | 9.26 | 9.08 |
| Antilingula –anterior border(B) | 12.29 | 11.98 |
| S-mandibular foramen(C) | 11.31 | 19.00 |
| Mandibular foramen-anterior border(D) | 14.45 | 14.14 |
| Antilingula –mandibular foramen (horizontal)(W) | 2.16 | 2.16 |
| Antilingula –mandibular foramen(vertical)(H) | 2.05 | 9.92 |
| Mandibular canal-alveolar crest level at coronal section (E) | 13.51 | 11.23 |
| Mandibular canal-buccal plate at second molar(F) | 4.09 | 6.38 |
| Mandibular canal-lower border at second molar(G) | 4.67 | 5.37 |

**Table 5b**

| Anatomic reference points considered for evaluating mandibular anatomy intraoperatively | Right side (in mm) | Left side (in mm) |
|---|---|---|
| S-mandibular foramen(C) | 13.50 | 16.50 |
| Mandibular foramen-anterior border(D) | 15.00 | 14.50 |
| Mandibular canal-alveolar crest level at coronal section (E) | 13.50 | 12.00 |
| Mandibular canal-buccal plate at second molar(F) | 4.50 | 6.00 |
| Mandibular canal-lower border at second molar(G) | 5.00 | 5.50 |

**Table 5c**

| Anatomic reference points considered for evaluating mandibular anatomy in OPG | Right side (in mm) | Left side (in mm) |
|---|---|---|
| S-mandibular foramen(C) | 14 | 20 |
| Mandibular foramen-anterior border(D) | 15 | 20 |
| Mandibular canal-alveolar crest level at coronal section (E) | 15 | 18 |
| Mandibular canal-lower border at second molar(G) | 5 | 7 |

Patient name: Swaminathan,

Age/Sex : 20yrs/M

**Table 6a**

| **Anatomic reference points considered for evaluating mandibular anatomy in 3D scan images** | **Right side (in mm)** | **Left side (in mm)** |
|---|---|---|
| S-antilingula(A) | 16.63 | 16.58 |
| Antilingula –anterior border(B) | 15.16 | 13.30 |
| S-mandibular foramen(C) | 16.63 | 15.69 |
| Mandibular foramen-anterior border(D) | 14.39 | 14.48 |
| Antilingula –mandibular foramen (horizontal)(W) | 1.87 | -1.18 |
| Antilingula –mandibular foramen(vertical)(H) | 0.00 | 1.11 |
| Mandibular canal-alveolar crest level at coronal section (E) | 10.31 | 10.59 |
| Mandibular canal-buccal plate at second molar(F) | 7.36 | 7.25 |
| Mandibular canal-lower border at second molar(G) | 6.32 | 6.95 |

Table 6b

| **Anatomic reference points considered for evaluating mandibular anatomy intraoperatively** | **Right side (in mm)** | **Left side (in mm)** |
|---|---|---|
| S-mandibular foramen(C) | 17.50 | 16.50 |
| Mandibular foramen-anterior border(D) | 14.50 | 15.00 |
| Mandibular canal-alveolar crest level at coronal section (E) | 10.50 | 11.00 |
| Mandibular canal-buccal plate at second molar(F) | 7.00 | 7.00 |
| Mandibular canal-lower border at second molar(G) | 6.50 | 7.00 |

Table 6c

| **Anatomic reference points considered for evaluating mandibular anatomy in OPG** | **Right side (in mm)** | **Left side (in mm)** |
|---|---|---|
| S-mandibular foramen(C) | 23 | 25 |
| Mandibular foramen-anterior border(D) | 16 | 16 |
| Mandibular canal-alveolar crest level at coronal section (E) | 21 | 25 |
| Mandibular canal-lower border at second molar(G) | 10 | 6 |

Patient name: Vaithyanathan,

Age/Sex : 28yrs/M

Table 7a

| **Anatomic reference points considered for evaluating mandibular anatomy in 3D scan images** | **Right side (in mm)** | **Left side (in mm)** |
|---|---|---|
| S-antilingula(A) | 14.78 | 14.17 |
| Antilingula –anterior border(B) | 17.01 | 17.39 |
| S-mandibular foramen(C) | 15.96 | 15.50 |
| Mandibular foramen-anterior border(D) | 17.01 | 17.12 |
| Antilingula –mandibular foramen (horizontal)(W) | 0.09 | -0.27 |
| Antilingula –mandibular foramen(vertical)(H) | 1.18 | 1.33 |
| Mandibular canal-alveolar crest level at coronal section (E) | 13.74 | 13.94 |
| Mandibular canal-buccal plate at second molar(F) | 4.19 | 4.62 |
| Mandibular canal-lower border at second molar(G) | 7.81 | 9.22 |

Table 7b

| **Anatomic reference points considered for evaluating mandibular anatomy intraoperatively** | **Right side (in mm)** | **Left side (in mm)** |
|---|---|---|
| S-mandibular foramen(C) | 16.50 | 16.00 |
| Mandibular foramen-anterior border(D) | 17.00 | 17.00 |
| Mandibular canal-alveolar crest level at coronal section (E) | 13.50 | 14.00 |
| Mandibular canal-buccal plate at second molar(F) | 5.00 | 5.00 |
| Mandibular canal-lower border at second molar(G) | 8.00 | 8.00 |

Table 7c

| **Anatomic reference points considered for evaluating mandibular anatomy in OPG** | **Right side (in mm)** | **Left side (in mm)** |
|---|---|---|
| S-mandibular foramen(C) | 22 | 21 |
| Mandibular foramen-anterior border(D) | 16 | 20 |
| Mandibular canal-alveolar crest level at coronal section (E) | 18 | 19 |
| Mandibular canal-lower border at second molar(G) | 10 | 10 |

Patient name: Thanavi Ramaswamy

Age/Sex : 21yrs/F

Table 8a

| **Anatomic reference points considered for evaluating mandibular anatomy in 3D scan images** | **Right side (in mm)** | **Left side (in mm)** |
|---|---|---|
| S-antilingula(A) | 12.29 | 14.66 |
| Antilingula –anterior border(B) | 15.35 | 15.53 |
| S-mandibular foramen(C) | 14.94 | 15.66 |
| Mandibular foramen-anterior border(D) | 16.06 | 19.03 |
| Antilingula –mandibular foramen (horizontal)(W) | 0.71 | 3.50 |
| Antilingula –mandibular foramen(vertical)(H) | 2.65 | 1.00 |
| Mandibular canal-alveolar crest level at coronal section (E) | 11.86 | 10.56 |
| Mandibular canal-buccal plate at second molar(F) | 6.97 | 4.86 |
| Mandibular canal-lower border at second molar(G) | 3.98 | 4.32 |

Table 8b

| Anatomic reference points considered for evaluating mandibular anatomy intraoperatively | Right side (in mm) | Left side (in mm) |
|---|---|---|
| S-mandibular foramen(C) | 15.00 | 16.50 |
| Mandibular foramen-anterior border(D) | 16.00 | 19.00 |
| Mandibular canal-alveolar crest level at coronal section (E) | 12.00 | 12.00 |
| Mandibular canal-buccal plate at second molar(F) | 7.00 | 6.00 |
| Mandibular canal-lower border at second molar(G) | 5.00 | 5.00 |

Table 8c

| Anatomic reference points considered for evaluating mandibular anatomy in OPG | Right side (in mm) | Left side (in mm) |
|---|---|---|
| S-mandibular foramen(C) | 18 | 19 |
| Mandibular foramen-anterior border(D) | 20 | 21 |
| Mandibular canal-alveolar crest level at coronal section (E) | 17 | 16 |
| Mandibular canal-lower border at second molar(G) | 8 | 8 |

Table 9

| | Male | Female |
|---|---|---|
| Number of patients in the study | 6 | 2 |
| Range of age in years | 20 - 32 | 21 |

Table 10: Mean value and range of values obtained from 3D CT scan images (MIMICS)

| Anatomical reference points considered for evaluating mandibular anatomy | Side | Mean value (in mm) | Range of values (in mm) |
|---|---|---|---|
| Sigmoid notch- Antilingula(A) | R | 14.23 | 9.26 - 16.63 |
| | L | 14.02 | 9.08 – 16.58 |
| Antilingula-Anterior border of ramus(B) | R | 15.11 | 11.16 – 18.83 |
| | L | 15.35 | 11.98 – 19.39 |
| Sigmoid notch-Mandibular foramen(C) | R | 17.30 | 11.31 – 21.85 |
| | L | 17.11 | 15.50 – 22.38 |
| Mandibular foramen –Anterior border of ramus(D) | R | 15.50 | 14.08 – 18.01 |
| | L | 16.55 | 14.14 – 19.03 |
| Antilingula-Mandibular foramen(horizontal)(W) | R | 0.65 | -3.20 – 3.97 |
| | L | 0.90 | -0.27 – 3.50 |
| Antilingula-Mandibular foramen(vertical)(H) | R | 3.01 | 0 - 6.75 |
| | L | 3.94 | 1.11 – 9.92 |
| Mandibular canal - alveolar crest level at coronal section(E) | R | 12.69 | 10.31 – 14.99 |
| | L | 12.11 | 9.98 - 15.07 |
| Mandibular canal – buccal plate at second molar(F) | R | 6.42 | 4.09 – 8.46 |
| | L | 6.32 | 4.62 – 9.14 |
| Mandibular canal- lower border of mandible at second molar(G) | R | 6.44 | 3.98 – 8.72 |
| | L | 6.12 | 4.32 – 9.22 |

**Table 11: Mean value and range of values obtained from OPG**

| Anatomical reference points considered for evaluating mandibular anatomy | Side | Mean value (In mm) | Range of values (in mm) |
|---|---|---|---|
| Sigmoid notch-Mandibular foramen(C) | R | 20 | 14 – 25 |
| | L | 21.25 | 16 – 25 |
| Mandibular foramen –Anterior border of ramus(D) | R | 16.75 | 14 – 20 |
| | L | 18.75 | 16 – 23 |
| Mandibular canal - alveolar crest level at coronal section(E) | R | 18.75 | 15 – 22 |
| | L | 20.37 | 16 – 26 |
| Mandibular canal- lower border of mandible at second molar(G) | R | 9.12 | 8 – 15 |
| | L | 10.37 | 6 – 14 |

**Table 12 Mean value and range of values obtained from intraoperative measurements**

| Anatomical reference points considered for evaluating mandibular anatomy | Side | Mean value (In mm) | Range of values (in mm) |
|---|---|---|---|
| Sigmoid notch-Mandibular foramen(C) | R | 17.25 | 13.50 – 22 |
| | L | 17.44 | 16 – 22 |
| Mandibular foramen –Anterior border of ramus(D) | R | 16.06 | 14.50 – 18 |
| | L | 17.12 | 14.50 – 20 |
| Mandibular canal - alveolar crest level at coronal section(E) | R | 12.56 | 10.50 – 15 |
| | L | 12.62 | 11 – 15 |
| Mandibular canal – buccal plate at second molar(F) | R | 6.62 | 4.50 – 8.50 |
| | L | 6.31 | 5 – 9 |
| Mandibular canal- lower border of mandible at second molar(G) | R | 6.62 | 5 – 8.50 |
| | L | 6.62 | 5 – 8.50 |

**Table 13: Comparison of mean values obtained from 3D CT scan images, OPG and Intraoperative values**

| Anatomic reference points considered for evaluating mandibular anatomy | Mean values obtained from MIMICS (in mm) | Mean values obtained from OPG (in mm) | Intra-operative values (in mm) |
|---|---|---|---|
| S-mandibular foramen(C) | 17.20 | 20.62 | 17.35 |
| Mandibular foramen-anterior border of ramus(D) | 16.02 | 17.75 | 16.59 |
| Mandibular canal-alveolar crest level at coronal section (E) | 12.4 | 19.56 | 12.59 |
| Mandibular canal-lower border of mandible at second molar(G) | 6.28 | 9.75 | 6.62 |

**Table 14: Percentage of neurosensory deficit present for the eight patients included in the study during post operative follow up**

| Post-operative review | Cotton wool test | Pin prick test |
|---|---|---|
| 1st Day Post-op | 100% | 100% |
| 1st Week Post-op | 75% | 50% |
| Second Week Post-op | 12.5% | 12.5% |
| Fourth Week Post-op | 0% | 0% |
| 2months Post-op | 0% | 0% |
| 6months Post-op | 0% | 0% |

# DISCUSSION

All modifications of the SSRO include an osteotomy on the medial aspect of the ascending ramus. Because of the position and course of the mandibular canal, the inferior alveolar nerve is at great risk of injury during saggital split ramus osteotomy[41].

The importance of the location of the mandibular foramen in regard to the SSRO lies in both horizontal and vertical dimensions because of the placement of horizontal medial ramus osteotomy[25]. The distance from the ascending ramus to the distal surface of the mandibular foramen is important because the horizontal medial ramus osteotomy must extend to or beyond the posterior aspect of the mandibular foramen to preserve the IAN and facilitate the SSRO, yet minimize the potential for any unfavorable condylar fracture. The distance vertically measured from mandibular foramen to coronoid notch where the osteotomy is done is important[25, 57].

Performing an osteotomy too far superiorly, above the mandibular foramen, may induce a fracture line in purely cortical bilaminar bone, inducing this fracture induces an unfavorable sagittal split[25]. To reduce injuries to the inferior alveolar nerve during surgery, knowledge of the anatomic location and course of the mandibular canal is imperative[31, 41].

The normal anatomy of the mandibular canal was examined and attempts were made to determine its buccolingual location through cadaveric study and conventional X-ray studies. The IOPA, OPG, tomograms and Submentovertex radiograph were used to localize the mandibular foramen. A poor radiography result, such as shift of the X-ray apparatus tube, low sharpness or poor contrast may influence in the prediction during the surgical plan. In some cases the superior and inferior border of the mandibular canal could not be visualized properly in the OPG[12]. In our study, OPG showed irregular magnification, and the linear measurements were not useful to transfer them intraoperatively.

Surgical landmarks were derived from dry human skulls to locate the course of mandibular canal which can be examined 3 dimensionally and sectioned at any desired plane and position. This approach has its drawbacks. Dry human skulls cannot provide data such as age, sex and race and there may be shrinkage or breakage of fine structure. There are a lack of data by this method for young patients, who are the majority receiving SSRO for surgical correction[57].

Eldho Markose et al 2009 assessed the accuracy and reproducibility of measurement in three different kinds of materials in 3D CT using MIMICS software and found that the measurements were accurate and reproducible[51]. Sridevi Padmanabhan et al 2010 compared the linear measurement made on dry skull with that of CT scan using MIMICS software[51, 53]. They found that digital image measurement were comparable to anatomical measurement and were more reliable[51]. So in our study we have used spiral computed tomography data and MIMICS software for producing and measuring three dimensional images.

Spiral CT (also referred as helical or volume acquisition CT) involves simultaneous translator movement of the object while the X-ray source rotates so that continuous data acquisition is achieved while scanning the entire volume of interest. The spiral CT scanner provides adequate data to create 3D image with reduced radiation and scanning time because of the continuous scanner, and rotation with table top movement.[37]

MIMICS is the standard software for 3D image processing and editing based on scanned data. The soft ware can translate multitude image modalities including CT, MRI and Micro CT into complete 3D model very easily and quickly. It can process any number of 2D image slices. It has powerful automatic and manual segmentation tools for gray value images[26, 53].

Various studies have demonstrated to identify the location of mandibular foramen using dry skull. Various external landmarks were represented on the lateral aspect of the ramus to identify the location of the mandibular foramen on the medial aspect of the ramus which includes antilingula, Xi point, mid-waist point and occlusal plane[20, 54]. In our study we evaluated in 3D CT scan images the reliability of antilingula to represent the mandibular foramen.

The antilingula is a bony tubercle on the lateral surface of mandibular ramus. However it is not always present or obvious. Christopher H.Martone[10] have found that only in 44% of cases antilingula was identifiable. In our study, we have found antilingula in all 8 patients in the CT scan. But Antilingula was not dissected intraoperatively in our patients, since it may result in extensive masseteric muscle stripping and may compromise the vascularity of the osteotomized segments as well as it would produce extensive swelling post operatively[10, 57].

In this study the relationship between antilingula and the mandibular foramen in vertical and horizontal dimensions is found using 3D CT scan data, vertical measurement ranges from 0 to 6.75mm and the horizontal measurement ranges from -3.20 to 3.97mm. This is in accordance with other studies. These values suggest antilingula shows a high degree of variance and cannot be used to locate the mandibular canal on the medial side of the ramus during BSSO.

Traditionally, a Boley gauge, Vernier caliper, or needlepoint divider is used to make linear measurements. In our study we used needle point divider to make measurements in OPG and intra operatively and digital tools to make measurements in CT scan using MIMICS software[51, 53]. Needle point divider is not as accurate as Vernier caliper, but it was not having much clinical significance in our study.

It is not uncommon to find the IAN just beneath the cortex along the ascending ramus and without careful review of a preoperative panorex radiograph, surgeon may needlessly damage the IAN with a rotary bur as the drill is moved down the ascending ramus.[25] In our study there was not much difference (0.5mm) between the measurements made in CT scan and during intra operative procedure. In our study, we have identified the mandibular foramen with minimal dissection on the medial aspect of the mandibular ramus. None of our patients had encountered bad split or direct nerve injury complication intra operatively.

Yoshida et al reported that the closer the mandibular canal to buccal cortex the greater the risk of IAN damage[32, 25]. Therefore, it has been proposed that the location of the lateral vertical osteotomy be along the external oblique ridge between first and second molar where the mandibular canal wall and the buccal cortex are at their greatest distance. [32] In our study the average distance between the buccal cortex and the mandibular canal was 6.42mm.

Turvey proposed an alternative method to decrease the risk of IAN impairment by placing the lateral vertical osteotomy in the retromolar region to minimize the length of the nerve exposure during the split[25].

Joseph E. Cillo[25] have discussed the various modification of the SSRO based on the skeletal and mandibular canal anatomy in a particular individual. In our study we did all our SSRO by Epker's modification with due care to the inferior alveolar canal since we identified the location of the mandibular canal in the CT scan using MIMICS software. We have recorded the nerve position intra operatively into 4 types as follows. 1.nerve is not visible, 2- the nerve was visible but remained in the distal fragment, 3- The nerve was free between both fragments, 4- the nerve has to be dissected from the lateral fragment or superficially damaged, 5- Deeper damage into the nerve trunk, 6- nerve transected. In the study group, either the nerve was not visible or visible, but remained in the distal fragment. None of our patients encountered bad split during the SSRO.

In this study neurosensory evaluation was done using pin prick test and cotton wool test during post operative follow-up. On the first postoperative day all the eight patients had IAN neurosensory deficit. During the 1st week post op day 75% showed negative response to cotton wool test and 50% showed negative response to pinprick test. 7 of the 8 patients had normal IAN neurosensory function on 2nd week post op day. All the patients had recovered normal neurosensory function on the first month post operative day.

Carter and Keen (1971)[7] found three basic variations in the intra-mandibular course of the inferior alveolar nerve and C. J. Nortje (1977)[39] found Duplication or division of the mandibular canal in 0.9 % of the panoramic radiographs. Langlais; Broadus; Glass, (1985)[29] showed 0.95% of bifid canals from 6000 panoramic radiographs they examined[39]. None of our patients had bifid canal or any variation in the course of the IAN.

The surgeon must choose a particular modification in the SSRO by taking into account of the anatomic position of the mandibular foramen, course of the inferior alveolar nerve. By carefully reviewing the preoperative Panorex, CT scan and taking all these easily identifiable variables into account before performing SSRO, one can expect a decrease in the incidence of direct and indirect nerve damage.

# SUMMARY AND CONCLUSION

Spiral CT scan were taken in all patients undergoing BSSRO, prior to the surgical procedure. The CT data were imported into the MIMICS software and three dimensional image was created and analysed to assess the anatomical position of the mandibular foramen and inferior alveolar nerve.

From our study we conclude as follows.

1. Spiral CT data is accurate in reproducing the surgical anatomy of the mandible. The Values obtained from CT scan accurately correlate with the measurement made intra operatively.
2. OPG represents the location and course of the inferior alveolar nerve, but measurements made from the OPG will not be useful intraoperatively due to irregular magnification.
3. The average anatomical measurements will not be useful to make osteotomy during SSRO, since there was wide range of variation in the anatomical position. It is better to take CT scan and assess the nerve position in every individual cases rather than taking average measurements.
4. The antilingula is not a reliable landmark to assess the position of the mandibular foramen.

5. Accurate identification of the course of Inferior alveolar nerve significantly reduces the incidence of neurosensory deficit.

Although all the patients in our study had a satisfactory outcome, further studies are needed with a larger sample size to confirm these findings.

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