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Anatomic study to determine a safe surgical reference point for mandibular ramus osteotomy

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ABSTRACT

Objective: The purpose of this study was to identify a surgical reference point on the mandibular ramus that can be used during ramus osteotomy to prevent injury to the inferior alveolar nerve.
Materials and methods: A total of 125 subjects' mandibles were analyzed and compared on a three-dimensional (3D) model constructed from computed tomography (CT). 25 volunteer subjects with normal class I occlusion (group I, control), 50 consecutive subjects (25 females and 25 males) diagnosed with mandibular retrognathism (group II), and 50 consecutive subjects (25 females and 25 males) with prognathism (group III) were included. This study created a landmark (the midwaist point) at the halfway point on a horizontal plane between the most concave points on the anterior and posterior borders of mandibular ramus, with the vertical plane bisecting the horizontal plane. The midwaist point was compared to other anatomic landmarks including antilingula, lingula, and mandibular foramen for correlation.
Results: The distance from the midwaist point to lingula and mandibular foramen along the horizontal plane was not significantly different among three groups. Lingula and mandibular foramen were mostly located within 2 mm posterior of the midwaist point, whereas the locations of lingula and mandibular foramen along the vertical plane to the midwaist point were highly variable.
Conclusion: The midwaist point is an excellent intraoperative reference point that can help surgeons to identify the position of the lingual and the mandibular foramen, thus preventing inferior alveolar nerve injury.

1. Introduction

Maxillofacial deformities have multiple manifestations, such as mandibular prognathism, retrognathism, open-bite, and facial asymmetry. Patients with mandibular developmental deformities often require surgical correction via the sagittal split ramus osteotomy (SSRO) or intraoral vertical ramus osteotomy (IVRO) procedures (Yoshioka et al., 2008). Both of these procedures involve osteotomy of the ramus and pose a potential risk of injury to vital structures such as inferior alveolar nerve (Al Bishri et al., 2005; D'Agostino et al., 2010; Fujimura et al., 2006; Lee et al., 2011; Yoshioka et al., 2012). Damage to this nerve may result in permanent numbness or altered sensation of the lower lip and chin area, which can potentially affect patients' quality of life due to adverse effects on speech, eating, and drinking, leading to psychological and social interaction issues (Phillips et al., 2007). Therefore, a comprehensive understanding of structural landmarks on the mandible is essential for a safe surgical outcome during ramus osteotomy.

The anatomy of the mandible has been analyzed by many authors (Al da-Fontoura et al., 2002; Aziz et al., 2007; Hetson et al., 1988; Kim et al., 1997; Langston and Tebo, 1977; Martone et al., 1993; Pogrel et al., 1995; Smith et al., 1991; Yates et al., 1976), including using three-dimensional (3D) computed tomography (CT) scans (Fujimura et al., 2006; Tsuji et al., 2005; Yu and Wong, 2008). 3D CT reconstruction provides quantitative anatomic data on the live human mandible in any section without the magnification, distortion, and questionable reproducibility implicit when using conventional two-dimensional radiographic images (Hanzelka and Foltan, 2012; Moerenhout et al., 2009), or the shrinkage and subtle fracture of dry skulls (Yu and Wong, 2008). However, most of the subjects analyzed

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to date had a normal class I occlusion, and thus do not accurately represent prospective surgical patients. There have been a few comparisons of patients with developmental deformities undergoing SSRO or IVRO with normal controls. In this study, the relationship between normal anatomy and patients with mandibular deformity was determined with the aid of CT scans and an anatomic landmark was sought to help reduce the risk of inferior alveolar nerve injury during ramus osteotomy.

2. Materials and methods

The cohorts consisted of 125 CT scans from 25 normal volunteers and 100 attending our Dentofacial deformities (DFD) centre. Informed consents for participating in this study were obtained from all individuals. This work was approved by the local ethics committee of the Dental Hospital, Yonsei University, Seoul, Korea for research on human subjects.

2.1. Materials

2.1.1. Group I (control)

Group I comprised 25 volunteers [16 males and 9 females; age 24.30 ± 2.82 years (mean ± SD), range 22–27 years]. Clinical and cephalometric examinations and dental cast models were used to rule out DFD and malocclusion in these subjects. On clinical examination, all 25 subjects had a class I molar relationship, with a normal maxillofacial skeletal pattern, overbite, and overjet. On cephalometric examination, the architectural and structural analysis described by Delaire et al. (Delaire et al., 1981) was performed on lateral cephalograms to validate the normal position of the maxilla and mandible.

2.1.2. Groups II (mandibular retrognathism) and III (mandibular prognathism)

The subjects in groups II and III were selected from a total of 423 patients who attended our DFD canter in 2011 for orthodontic and orthognathic treatment. Exclusion criteria were set as follows: 1) age less than 18 years, 2) previous mandibular surgery, 3) mandibular symphysis in the patients was positioned over 2 mm off the facial midline, indicating facial asymmetry, 4) patients who had specific congenital deformities, trauma, or significant temporomandibular joint disease, and 5) patients who had not undergone CT imaging before orthodontic and orthognathic treatment for diagnosis.

291 subjects were excluded from the study. The remaining 132 subjects were evaluated using the same protocol as used for the normal volunteers in group I. In order to increase the accuracy of study via 1:1 comparison among the sexes and groups, 25 consecutive subjects in each cohort were selected according to the dates when patients presented to the centre for evaluation. Thus, fifty patients who were diagnosed with mandibular retrognathism were enrolled into group II (25 males and 25 females; age 22.02 ± 3.24 years, range 18–27 years). Another 50 patients diagnosed with mandibular prognathism were enrolled into group III (25 males and 25 females; age 21.26 ± 4.12 years, range 18–28 years).

2.2. Image acquisition and 3D reconstruction

Each subject underwent CT imaging with a high-speed Advantage CT system (GE Medical Systems, Milwaukee, WI, USA), using a high-resolution bone algorithm protocol (200 mA, 120 kV, scanning time of 1 s, scan thickness of 1 mm, 512 × 512 pixel reconstruction matrix, and 0.48 × 0.48 × 1.0 mm voxels). The CT image data was saved in DICOM file format, transferred to a personal computer, and reconstructed into reformatted 3D images using SimPlant Pro Crystal (Materialise Dental, Leuven, Belgium) software after adjusting the threshold for visible pixels.

2.3. Reference points and planes for mandibular ramus analysis

The reference points (Fig. 1) were selected to represent ramus antilingula (AntiLG), lingua (LG), mandibular foramen (MF), sigmoid notch (SN), antegonial notch (AN), and anterior and posterior borders of the ramus (AB and PB, respectively). They were marked on 3D surface images and then adjusted on the axial, coronal, and/or sagittal images of the multiplanar reformatting setting (Gribel et al., 2011). Among the reference points, AntiLG was not always identifiable on CT images, thus it was only marked when visible.

The horizontal plane was determined between the most concave points of anterior and posterior border of the ramus (Fig. 2). The vertical plane was designated by bisecting perpendicular to the horizontal plane. The posterior direction on the horizontal plane and the superior direction on the vertical plane were designated as '+'. A surgical landmark (the midwaist point) was then created at the intersection between the horizontal and vertical planes on the lateral surface of the ramus (Fig. 2a). These points and planes are summarized and defined in Table 1 and depicted in Figs. 1 and 2.

2.4. Measurements

The right and left sides of the mandible were analyzed separately to produce individual data after applying the paired *t*-test to evaluate the influence of each side. The thickness of the mandibular ramus was measured at the level of the SN and AN, passing near the LG. The thickest portion (MaxTh) of the ramus was noted at the mandibular antegonial notch and the thinnest portion (MinTh) was identified in the vicinity of the mandibular foramen (Appendix Fig. 1). The width and height of the ramus (RW and RH, respectively) were measured as the distances between the AB and PB and between the SN and AN, respectively. The relative location of the LG along the width and height of the ramus (H-LG/RW and V-LG/RH, respectively), and the horizontal and vertical relationship between the midwaist point and mandibular ramus landmarks such as the AntiLG ($H\text{-}MW^{AntiLG}$ and $V\text{-}MW^{AntiLG}$, respectively), LG ($H\text{-}MW^{LG}$

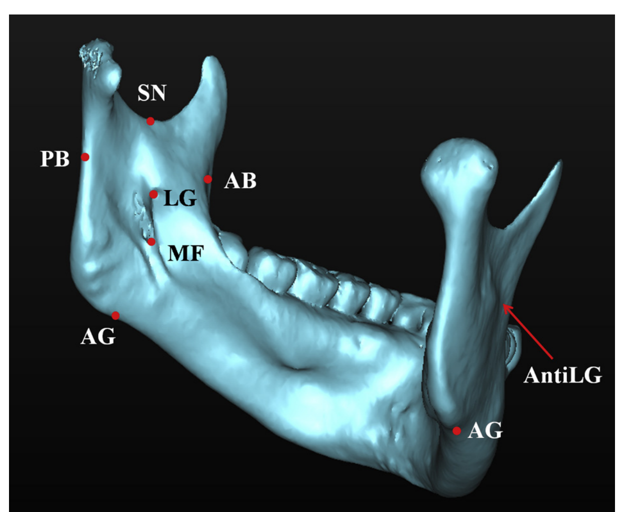

Fig. 1. Reference points in the mandibular ramus: AB, anterior border; PB, posterior border; SN, sigmoid notch; AN, antegonial notch; LG, lingula; AntiLG, antilingula; MF, mandibular foramen.