Three-dimensional morphometric analysis of mandible in coronal plane after bimaxillary rotational surgery

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Abstract

Background: The aim of this report is to present a new reference for aesthetic mandible surgery using three-dimensional cone-beam computed tomography-based treatment planning for orthognathic surgery which can be implemented in surgical planning and perioperative procedure.

Methods: To make an objective standard for evaluating aesthetic mandibular outline, we make an aesthetic scoring criteria with consideration of asymmetry, broad mandibular border line, and prominent mandibular angle. Two maxillofacial surgeons and two orthodontists rated their aesthetic evaluation from 1 to 5. Experimental group consisting of 47 female and 38 male patients who had rotational orthognathic two-jaw surgery from 2010 to 2011 were chosen according to aesthetic scoring done by two maxillofacial surgeons and two orthodontists. A high aesthetic score (≥16) means the facial contour is symmetric, with no broad and narrow aesthetic mandible frontal profiles. Control A group consisted of ten female and ten male patients who had no orthognathic surgery experience and low aesthetic score (≤10). Control B group consisted of ten female and ten male patients who had no orthognathic surgery experience and had anesthetic mandibular frontal profile and a high aesthetic score (≥16). The three-dimensional image of the patient was taken from dental cone-beam CT (DCT) scanning (experimental group and control A group: 6 months DCT after surgery, control B group: 1st visit DCT). Each DCT was reformatted to reorient the 3D image using 3D analyzing program (OnDemand3D, cybermed Inc, CA, USA). After selection of 12 landmarks and the construction of reoriented horizontal, vertical, and coronal reference lines, 15 measurements were taken in 3D analysis of frontal mandibular morphology. Afterwards, horizontal and vertical linear measurements and angular measurements, linear ratio were obtained.

Results: Mean Go'_Rt-Me'_Go'_Lt angular measurement was 100.74 ± 2.14 in female patients and 105.37 ± 3.62 in male patients. These showed significant difference with control A group in both genders. Ratio of Go'_Rt-Go'_Lt-Me'_ length to some linear measurements (ratio of Me'-Cd'_RtCd'_Lt to Me'-Go'_RtGo'_Lt, ratio of Me'-Go'_ to Me'-Go'_RtGo'_Lt, ratio of Go'_Rt-Go'_Lt to Me'-Go'_RtGo'_Lt) showed significant difference with control A group in both genders.

Conclusion: This study was intended to find some standard measurement of mandible frontal view in 3D analysis of aesthetic patient. So, these potential measurement value may be helpful for orthognathic treatment planning to have more aesthetic and perspective outcomes.

Keywords: V-line, Frontal reference, Aesthetic mandibular outline, Orthognathic surgery, Rotational surgery
Background
The frequency of the bimaxillary orthognathic surgery has increased due to the aesthetic and functional outcomes involving rotational movement of the maxilla-mandibular complex. It leads to the reduction of the perpendicular length of the face [1], and the increased amount of posterior movement of the distal segment, reduction of posterior vertical height of the maxilla, and forward movement of the perialar area [2, 3]. As a result, the mandibular outline in frontal view has an aesthetic line, called as V-line, consistent with the preference of the modern people advancing the smooth and slender facial form.

On the other hand, even with the development of a diagnostic modality for facial skeleton, most of the planning for orthognathic surgery is still established by lateral profile analysis depending on two-dimensional lateral cephalometry [4, 5]. As a result, the exact antero-posterior movement of maxillomandibular complex is possible. On the contrary, there are no measurement points and values as a diagnostic tool to analyze frontal profile, especially the mandibular outline that affects substantially on aesthetic frontal looks. Hence, the mandibular outline in frontal view after surgery tends to be decided by the subjective preference of the operator. It is one of the causes of additional surgery to correct unsatisfactory facial contour after adaptation of the soft tissue.

There were some previous studies to investigate the reference point and referential measurement in frontal view with skull PA X-ray film. However, they had no perspective and utility because of the difficulty of positioning the reoriented natural head position and selecting the specific anatomical points to overlay a two-dimensional plain skull PA film.

Meanwhile, using conventional two-dimensional frontal cephalometric analysis was difficult to find the significant measurement point by overlapping bony structure due to instability that came from the motion of the patient [6, 7]. It became possible to overcome the problem of the conventional 2D frontal cephalometry to analyze frontal profile due to the development of a variety of three-dimensional(3D) representing analysis modality, such as 3D computed tomography, 3D magnetic resonance imaging, 3D ultrasonography, laser scanning, and digital stereophotogrammetry [8].

Nevertheless, there are no studies using three-dimensional modality to find a useful reference point and measurement yet. So, we want to investigate a useful reference point and measurement in frontal view in order to help to make a surgical plan for more aesthetic results and perspective outcomes.

The purpose of this study is to evaluate the usefulness of 3D computerized tomographic analysis as a diagnostic tool of orthognathic surgical planning for getting aesthetic mandibular line in frontal view, and to determine the useful reference points and measurements to diagnose the frontal facial plane and make surgical plan for an enhanced functional and aesthetic surgical.

Methods
Subject
Evaluation for aesthetic mandibular border line in frontal view
To make an objective standard for evaluating aesthetic mandibular outline, we make an aesthetic scoring criteria with consideration of asymmetry, broad mandibular border line, and prominent mandibular angle (Table 1). Two maxillofacial surgeons and two orthodontists rated their aesthetical evaluation from 1 to 5 resulting in a total score from 5 to 20. A higher aesthetic score was considered as having a more aesthetic mandibular border line in frontal view.

The difference of aesthetical preference between the evaluators may affect the results of study, so we evaluated the inter-rater agreement with the Kappa coefficient. The Kappa coefficient to measure inter-rater agreement for aesthetic mandibular line was more than 0.75.

Experimental group and control A group
Clinical and surgical records along with a 6-month postoperative photograph after orthognathic surgery of patients diagnosed with the mandibular prognathism and operated in Department of Oral and Maxillofacial Surgery at Pusan National University Hospital from January 2010 to February 2011 were reviewed retrospectively. Two oral and maxillofacial surgeons and two orthodontists determined the experimental group as the patients with aesthetic mandibular lines with a total score of 16 points or greater by the aesthetic scoring criteria. Patients who had revisional surgery were excluded. Finally, 38 male patients and 47 female patients with a mean age of 22.7 years (range: 20–24 years) were selected as the experimental group. Because they had a high aesthetic score, so, we thought they had aesthetic mandibular outline and such a mandibular outline would be widely accepted as a beautiful face.

And, ten male patients and ten female patients with less than ten points were selected as control group A.

| Table 1 Aesthetic scoring criteria | Score | Criteria for mandibular inferior border line |
|-----------------------------------|-------|---------------------------------------------|
| 5                                 | No asymmetry, broad, prominent angle |
| 4                                 | No asymmetry, broad, but prominent angle |
| 3                                 | No broad but, asymmetry, prominent angle |
| 2                                 | No asymmetry but, broad, prominent angle |
| 1                                 | Asymmetry, broad, prominent angle |


Control group A have no aesthetic mandibular outline widely accepted in uncorrected population.

**Control group B**
Clinical records and photographs of patients who visited the Department of Orthodontics at Pusan National University Hospital, from January 2010 to February 2011 were reviewed retrospectively. Control group B was selected with inclusion criteria (Table 2) and had 16 points or greater with the aesthetic scoring criteria. Control group B have aesthetic mandibular outlines widely accepted in uncorrected population (Table 3).

**Method of study**

**Three-dimensional computerized tomography**
By using the dental cone-beam CT (Pax-Zenith 3D, VATECH, Yong-In, Korea, DCT) installed in Pusan University’s Dental Clinic Oral and Maxillofacial Radiology Department, the 3D image of the patient was taken (experimental group and control A group: 6 months DCT after surgery, control B group: 1st visit DCT).

**Reorientation of 3D computerized tomography image**
The DCT image of all patients was converted to the digital imaging and communication in medicine (DICOM) 3.0 File. DICOM file was reoriented with 3D image by using the OnDemand3D™ (3D analysis software program, Cybermed Inc., CA, USA). Then, multiplanar reformatted image was accomplished. The reference planes are horizontal reference plane, sagittal reference plane, and coronal plane that is perpendicular to two other reference planes (Table 4, Fig. 1). The reference points were measured on reoriented 3D MPR image (Fig. 2).

**The measurement of the reorientated 3D computerized tomography image**
To investigate linear and angular measurement, we needed to establish a second reference point on coronal plane. Second reference point is the meeting point of the coronal plane and the line perpendicular to the line connecting anatomical reference point to coronal plane. All measurements are investigated with second point on coronal plane (measurement plane (Fig. 3). This measuring concept was technically easy and convenient.

We investigated linear and angular measurement consisting of the second point to meet the coronal plane and the vertical line from each reference point to the coronal plane (Table 5, Fig. 4).

**Statistical analysis**
By using SPSS for Window version 12.0 (SPSS, Chicago, II, USA), Independent t test was performed in order to compare the difference between men and women within the experimental, and the difference between experimental group and control group in each group. A p value less than 0.05 was considered to be statistically significant.

**Results**
The average and standard deviation of each measurement of men and women in experimental group was calculated, and the comparison of significance between man and woman was evaluated (Table 3). Most of linear and angular measurement did not reveal a significant difference between men and women in experimental

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**Table 2** Inclusion criteria of control B group

| Class I canine and molar key                      |
|--------------------------------------------------|
| No history of orthognathic and orthodontic treatment |
| Normal dentition including crowding, spacing, supernumerary tooth, and ectopic eruption |
| No facial asymmetry                              |

**Table 3** Patients distribution

| Group          | Female/male | Mean age | Total aesthetic score |
|----------------|-------------|----------|-----------------------|
| Experimental   | 47/38       | 22.3 ± 4.3 | ≥ 16                  |
| Control A      | 10/10       | 23.3 ± 3.5 | < 10                  |
| Control B      | 10/10       | 25.2 ± 4.5 | ≥ 16                  |

**Table 4** Reference point and plane [21, 22] (Figs. 1, 2)

| Landmark | Description                                      |
|----------|--------------------------------------------------|
| PorionRt (PoRt) | The most superior point of the Rt. EAM          |
| PorionLt (PoLt) | The most superior point of the Lt. EAM          |
| Orbitale (Or) | The midpoint of the infraorbital margin         |
| PNS      | Tip of the posterior nasal spine                |
| GonionRt (GoRt) | Most inferior, posterior, outward point on the Rt. mandibular angle |
| GonionLt (GoLt) | Most inferior, posterior, outward point on the Lt. mandibular angle |
| Menton   | The most inferior point on the symphysis outline |
| CondylionRt (CdRt) | Most superior point on the head of the Rt. mandibular condyle |
| CondylionLt (CdLt) | Most superior point on the head of the Lt. mandibular condyle |
| Nasion   | The most anterior point of the nasofrontal suture on the midsagittal plane |
| Bagion   | The midpoint of the anterior border of the foramen magnum |

**Table 5**

| Plane | Description                                      |
|-------|--------------------------------------------------|
| HRP   | Horizontal reference plane: PoRt-OrRt-PoLt       |
| SRP   | Sagittal reference plane: perpendicular to HRP including Na-Ba line |
| CP    | Coronal plane: perpendicular to HRP and SRP, measurement plane |
group. However, angle of $\text{Go'}_{\text{Rt}}-\text{Me'}-\text{Go'}_{\text{Lt}}$ (A), $\text{Cd'}-\text{Go'}-\text{Me'}$ (C), distance from $\text{Me'}$ to line $\text{Cd'}_{\text{Rt}}-\text{Cd'}_{\text{Lt}}$ (H), ratio of length $\text{Me'}-\text{Go'}$ to length $\text{Me'}-\text{Go'}_{\text{Rt}}$ ($\text{I/F ratio}$) were statistically significant between men and women (Table 6).

Angle of $\text{Go'}_{\text{Rt}}-\text{Me'}-\text{Go'}_{\text{Lt}}$ (A), distance from line $\text{Go'}_{\text{Rt}}-\text{Go'}_{\text{Lt}}$ to line $\text{Cd'}_{\text{Rt}}-\text{Cd'}_{\text{Lt}}$ (G), distance from $\text{Me'}$ to line $\text{Cd'}_{\text{Rt}}-\text{Cd'}_{\text{Lt}}$ (H), ratio of distance from $\text{Me'}$ to line $\text{Cd'}_{\text{Rt}}-\text{Cd'}_{\text{Lt}}$ to distance from $\text{Me'}$ to line $\text{Go'}_{\text{Rt}}-\text{Go'}_{\text{Lt}}$ (H/F ratio), ratio of length of line $\text{Me'}-\text{Go'}$ to distance from $\text{Me'}$ to line $\text{Go'}_{\text{Rt}}-\text{Go'}_{\text{Lt}}$ (I/F ratio), ratio of length of line $\text{Go'}_{\text{Rt}}-\text{Go'}_{\text{Lt}}$ to distance from $\text{Me'}$ to line $\text{Go'}_{\text{Rt}}-\text{Go'}_{\text{Lt}}$ (G/F ratio), ratio of distance from $\text{Me'}$ to line $\text{Cd'}_{\text{Rt}}-\text{Cd'}_{\text{Lt}}$ to distance from $\text{Me'}$ to line $\text{Go'}_{\text{Rt}}-\text{Go'}_{\text{Lt}}$ (H/F ratio), ratio of distance from $\text{Me'}$ to line $\text{Go'}_{\text{Rt}}-\text{Go'}_{\text{Lt}}$ to distance from $\text{Me'}$ to line $\text{Go'}_{\text{Rt}}-\text{Go'}_{\text{Lt}}$ (H/F ratio), ratio of distance from $\text{Me'}$ to line $\text{Go'}_{\text{Rt}}-\text{Go'}_{\text{Lt}}$ to distance from $\text{Me'}$ to line $\text{Go'}_{\text{Rt}}-\text{Go'}_{\text{Lt}}$ (H/F ratio), ratio of length of line $\text{Go'}_{\text{Rt}}-\text{Go'}_{\text{Lt}}$ to distance from $\text{Me'}$ to line $\text{Go'}_{\text{Rt}}-\text{Go'}_{\text{Lt}}$ (G/F ratio), ratio of distance from $\text{Me'}$ to line $\text{Cd'}_{\text{Rt}}-\text{Cd'}_{\text{Lt}}$ to distance from $\text{Me'}$ to line $\text{Go'}_{\text{Rt}}-\text{Go'}_{\text{Lt}}$ (H/F ratio), ratio of distance from $\text{Me'}$ to line $\text{Go'}_{\text{Rt}}-\text{Go'}_{\text{Lt}}$ to distance from $\text{Me'}$ to line $\text{Go'}_{\text{Rt}}-\text{Go'}_{\text{Lt}}$ (H/F ratio), ratio of distance from $\text{Me'}$ to line $\text{Go'}_{\text{Rt}}-\text{Go'}_{\text{Lt}}$ to distance from $\text{Me'}$ to line $\text{Go'}_{\text{Rt}}-\text{Go'}_{\text{Lt}}$ (D/F ratio) showed a statistically significant difference between experimental group and control A group for women. And, distance from line $\text{Go'}_{\text{Rt}}-\text{Go'}_{\text{Lt}}$ to line $\text{Cd'}_{\text{Rt}}-\text{Cd'}_{\text{Lt}}$ (G), distance from $\text{Me'}$ to line $\text{Cd'}_{\text{Rt}}-\text{Cd'}_{\text{Lt}}$ (H), ratio of distance from $\text{Me'}$ to line $\text{Cd'}_{\text{Rt}}-\text{Cd'}_{\text{Lt}}$ to distance from $\text{Me'}$ to line $\text{Go'}_{\text{Rt}}-\text{Go'}_{\text{Lt}}$ (G/F ratio), ratio of distance from $\text{Me'}$ to line $\text{Cd'}_{\text{Rt}}-\text{Cd'}_{\text{Lt}}$ to distance from $\text{Me'}$ to line $\text{Go'}_{\text{Rt}}-\text{Go'}_{\text{Lt}}$ (H/F ratio), ratio of distance from $\text{Me'}$ to line $\text{Go'}_{\text{Rt}}-\text{Go'}_{\text{Lt}}$ to distance from $\text{Me'}$ to line $\text{Go'}_{\text{Rt}}-\text{Go'}_{\text{Lt}}$ (H/F ratio), ratio of distance from $\text{Me'}$ to line $\text{Go'}_{\text{Rt}}-\text{Go'}_{\text{Lt}}$ to distance from $\text{Me'}$ to line $\text{Go'}_{\text{Rt}}-\text{Go'}_{\text{Lt}}$ (D/F ratio) showed a statistically significant difference between experimental group and control A group for men.

Average angular measurement of $\text{Cd'}-\text{Go'}-\text{Me'}$ was 138.49 ± 1.57 in the experimental group and 118.90 ± 1.60 in control B group, but there was no statistically significant difference. The ratio of distance from $\text{Go'}_{\text{Rt}}-\text{Go'}_{\text{Lt}}$ to line $\text{Cd'}_{\text{Rt}}-\text{Cd'}_{\text{Lt}}$ to distance from $\text{Me'}$ to line $\text{Go'}_{\text{Rt}}-\text{Go'}_{\text{Lt}}$ (H/F ratio) showed a statistically significant difference between experimental group and control B group (Table 7).
to line $Go_{Rt}Go_{Lt}$ (H/F ratio) statistically significant difference between experimental group and control B group in men (Table 8).

**Discussion**

The current operational plan for the conventional orthognathic surgery is based on analysis of lateral cephalometry to determine the moving amount and posteroanterior (PA) cephalometry to investigate maxillary canting and asymmetry of chin [9]. Occlusal plane angle and incisal inclination based on analysis of lateral cephalometry is an important measurement in the plan for rotational orthognathic surgery with maxillary posterior impaction [10]. And common rotational surgery is focused on anteroposterior movement and aesthetic improvement of lateral profile. However, most patients want not only proper maxillary anteroposterior position, but also aesthetic, slender, symmetric mandibular inferior border line in frontal view, so called V-line. However, the surgical plan for orthognathic surgery based on PA cephalometry to accomplish optimal postoperative frontal profile has a limited application in practical operation, with no guarantee of an aesthetic frontal face [11, 12]. Skeletal investigation based on 2D modality like PA cephalometry tracing is a limited adaptation for surgical planning because of the difficulty in positioning the reoriented natural head position and selecting specific anatomical points in overlay of structure. So, there is no referential measurement for surgical planning of the frontal profile. As a result, most surgeons have done lateral mandibular angle reduction, mandibular body contouring based on their experience and preference. There is no standard measurement.

Many clinicians have suggested several different methods to convert two-dimensional radiograph to three-dimensional image for solving the problem of 2D-based surgical plan [13–16]. But, former methods had several limitations to apply in practical operational procedure because of the radiographic magnification distortion, and the need to measure a reference point repeatedly on various image views. So, the establishment of plan for orthognathic surgery still depends on lateral cephalometry, and
Table 5: Linear measurement and angular measurement (Figs. 3, 4)

| Description | 
|-------------|
| Go¹<sub>in</sub>-Me<sup>¹</sup>Go¹<sub>Lt</sub> | Angle of Go¹<sub>in</sub>-Me<sup>¹</sup>Go¹<sub>Lt</sub> fitted on coronal plane (A) |
| Cd¹<sub>Rt</sub>-Me<sup>¹</sup>Cd¹<sub>Lt</sub> | Angle of Cd¹<sub>Rt</sub>-Me<sup>¹</sup>Cd¹<sub>Lt</sub> fitted on coronal plane (B) |
| Cd¹<sup>²</sup>-Go¹<sup>²</sup> | Angle of Cd¹<sup>²</sup>-Go¹<sup>²</sup> fitted on coronal plane (C) |
| Go¹<sub>in</sub>-Go¹<sub>Rt</sub> | Length of Go¹<sub>in</sub>-Go¹<sub>Rt</sub> fitted on coronal plane (D) |
| Cd¹<sub>Rt</sub>-Cd¹<sub>Lt</sub> | Length of Cd¹<sub>Rt</sub>-Cd¹<sub>Lt</sub> fitted on coronal plane (E) |
| Me¹<sup>²</sup>-Go¹<sub>Rt</sub> | Distance from Me to Go¹<sub>Rt</sub>-Go¹<sub>Lt</sub> line fitted on coronal plane (F) |
| Go¹<sub>in</sub>-Go¹<sub>Lt</sub> | Distance from Go¹<sub>in</sub> to Go¹<sub>Lt</sub> line to Cd¹<sub>Rt</sub>-Cd¹<sub>Lt</sub> line fitted on coronal plane (G) |
| Me¹<sup>²</sup>-Cd¹<sub>Rt</sub>-Cd¹<sub>Lt</sub> | Distance from Me to Cd¹<sub>Rt</sub>-Cd¹<sub>Lt</sub> line fitted on coronal plane (H) |
| Me¹<sup>³</sup>-Go¹<sup>³</sup> | Length of Me<sup>³</sup>-Go<sup>³</sup> fitted on coronal plane (I) |
| Me¹<sup>³</sup>-body | Distance from Me<sup>³</sup>-Go<sup>³</sup> line to the height of contour of mandibular body fitted on the coronal plane (J) |
| G/F ratio | Ratio of Go¹<sub>in</sub>-Go¹<sub>Rt</sub>-Cd¹<sub>Rt</sub> line to Me¹<sup>³</sup>-Go¹<sub>Rt</sub> line (K) |
| H/F ratio | Ratio of Me¹<sup>³</sup>-Cd¹<sub>Rt</sub>-Cd¹<sub>Lt</sub> to Me¹<sup>³</sup>-Go¹<sub>Rt</sub> line (L) |
| I/F ratio | Ratio of Me¹<sup>³</sup>-Go<sup>³</sup> to Me¹<sup>³</sup>-Go¹<sub>Rt</sub> line (M) |
| D/F ratio | Ratio of Go¹<sub>in</sub>-Go¹<sub>Lt</sub> to Me¹<sup>³</sup>-Go¹<sub>Rt</sub> line (N) |
| J/I ratio | Ratio of Me¹<sup>³</sup>-body to Me¹<sup>³</sup>-Go¹<sup>³</sup> (O) |

Table 6: Mean and standard deviation of linear and angular measurement on mandibular outer surface of male group and female group in the experimental group

| Description          | Female (n = 47) | Male (n = 38) | p value |
|----------------------|----------------|---------------|---------|
|                      | Mean   | SD       | Mean   | SD       |         |
| A                    | 100.74 | 2.14     | 105.37 | 3.62     | 0.001***|
| B                    | 65.04  | 2.62     | 64.97  | 2.94     | 0.38    |
| C(Rt)                | 138.49 | 1.57     | 134.52 | 2.57     | 0***    |
| C(Lt)                | 139.04 | 1.57     | 135.05 | 2.69     | 0***    |
| D                    | 92.57  | 3.81     | 38.5   | 3.94     | 0.81    |
| E                    | 109.64 | 5.45     | 115.47 | 5.15     | 0.6     |
| F                    | 36.17  | 2.89     | 36.05  | 3.84     | 0.08    |
| G                    | 49.43  | 3.45     | 53.21  | 4.04     | 0.29    |
| H                    | 85.60  | 4.03     | 89.26  | 5.64     | 0.04*   |
| I(Rt)                | 56.43  | 4.07     | 58.87  | 3.84     | 0.94    |
| I(Lt)                | 7.87   | 1.23     | 8.34   | 1.32     | 0.50    |
| J(Rt)                | 56.40  | 3.98     | 58.92  | 3.82     | 0.94    |
| J(Lt)                | 7.85   | 1.23     | 8.32   | 1.30     | 0.72    |
| G/F ratio            | 1.38   | 0.16     | 1.49   | 0.21     | 0.14    |
| H/F ratio            | 2.38   | 0.16     | 2.49   | 0.21     | 0.14    |
| I/F ratio            | 1.56   | 0.07     | 1.64   | 0.13     | 0.02*   |
| D/F ratio            | 2.57   | 0.15     | 2.76   | 0.26     | 0.11    |
| I/J ratio            | 7.31   | 1.09     | 7.18   | 0.95     | 0.42    |

<sup>*</sup>p < 0.05, <sup>***</sup>p < 0.001. A angle of Go¹<sub>in</sub>-Me<sup>¹</sup>Go¹<sub>Rt</sub> (°), B angle of Cd¹<sup>²</sup>Go¹<sup>²</sup> (°), C angle of Cd¹<sup>²</sup>-Me<sup>²</sup> (°), D length of Go¹<sub>in</sub>-Go¹<sub>Rt</sub> line (mm), E length of Cd¹<sub>Rt</sub>-Cd¹<sub>Lt</sub> line (mm), F distance from Me<sup>³</sup> to Go¹<sub>Rt</sub> line (mm), G distance from Go¹<sub>in</sub>-Go¹<sub>Rt</sub> line to Cd¹<sub>Rt</sub>-Cd¹<sub>Lt</sub> line (mm), H distance from Me¹<sup>³</sup>-Cd¹<sub>Rt</sub>-Cd¹<sub>Lt</sub> line (mm), I length of Me<sup>³</sup>-Go<sup>³</sup> line (mm), J distance from Me²<sup>³</sup>-Go<sup>³</sup> line-mandible outer surface of body (mm)
study, the standard plane is horizontal reference plane (HRP) accomplished by both the porion side and right side orbitale and sagittal reference plane (SRP) perpendicular to FH plane passing through basion. CT image of patient was reorganized into 3D reconstructive image and reoriented according to HRP and SRP, and coronal plane perpendicular to HRP and SRP is the practical measurement plane.

In this study, we did not select the anatomical reference point directly on 3D reconstructed image. Instead, we coordinated multiplanar reformatted reference plane that is horizontal, sagittal, and coronal plane to set up the reference point. This has the advantage of simplicity and ease in comparison to setting up a reference point on complicated X, Y, and Z-axes converted from a 3D reconstructed image.

There were several locations to consider. First, it was the gonion location. There was a trouble deciding the accurate gonion location of patient performing mandibular angle reduction. However, we resolved this issue by setting the most inferolateral point of the proximal segment to gonion. Second, there was a trouble deciding on HRP, including porion and orbitale. Setting up HRP with three points among porions and orbitale of both sides is difficult in asymmetric patients, but we found the nasion and basion to set up SRP, and we set up HRP to the plane perpendicular to SRP which contains three points or passed near four points. Third, the head of condyle (condylon) was located inside zygomatic arch. However, by using 3 type multiplanar reformatted image, condylon could be easily selected.

In a comparative study of the experimental group, control A group, control B group, and significant test

### Table 7
Mean and standard deviation of linear and angular measurement on mandibular outer surface of female in the experimental group, control A group, control B group, and significant test

| Experimental group | Control A | Control B |
|--------------------|-----------|-----------|
| Mean               | SD        | Mean      | SD        | p       |
| A 100.74           | 2.14      | 133.50    | 6.06      | 0.001   |
| B 65.04            | 2.62      | 64.60     | 2.91      | 0.056   |
| C(Rt) 138.49       | 1.57      | 118.90    | 1.60      | 0.91    |
| C(Lt) 139.04       | 1.57      | 119.60    | 2.01      | 0.17    |
| D 92.57            | 3.81      | 95.00     | 5.08      | 0.53    |
| E 109.64           | 5.45      | 109.00    | 4.64      | 0.33    |
| F 36.17            | 2.89      | 18.80     | 3.01      | 0.68    |
| G 49.43            | 3.45      | 67.60     | 6.70      | 0.011   |
| H 85.60            | 4.03      | 86.40     | 7.68      | 0.011   |
| I(Rt) 56.43        | 4.07      | 51.10     | 3.87      | 0.88    |
| J(Rt) 7.87         | 1.23      | 7.70      | 1.42      | 0.92    |
| I(Lt) 56.40        | 3.98      | 51.10     | 3.87      | 0.88    |
| J(Lt) 7.85         | 1.23      | 7.70      | 1.42      | 0.92    |
| G/F 1.38           | 0.16      | 3.69      | 0.75      | 0.68    |
| H/F 2.38           | 0.16      | 4.69      | 0.75      | 0.03    |
| I/F 1.56           | 0.07      | 2.77      | 0.35      | 0.01    |
| D/F 2.57           | 0.15      | 5.15      | 0.69      | 0.01    |
| I/J 7.31           | 1.09      | 6.79      | 1.19      | 0.06    |

*p < 0.05, **p < 0.01, ***p < 0.001. A angle of Go’r-Me’G-Go’Lt, B angle of C’dGo’Me’Lt, C angle of C’dGo’Me’Lt, D length of Go’r-Go’Lt line (mm), E length of C’dGo’-C’dGo’ line (mm), F distance from Me’ to Go’r-Go’Lt line (mm), G distance from Go’r-Go’Lt line to C’dGo’-C’dGo’ line (mm), H distance from Me’-C’dGo’-C’dGo’ line (mm), I length of Me’-G line (mm), J distance from Me’-Go’ line-mandibular outer surface of body (mm)

### Table 8
Mean and standard deviation of linear and angular measurement on mandibular outer surface of male in the experimental group, control A group, control B group, and significant test

| Experimental group | Control A | Control B |
|--------------------|-----------|-----------|
| Mean               | SD        | Mean      | SD        | p       |
| A 105.37           | 3.62      | 132.30    | 9.87      | 0.012   |
| B 64.97            | 2.94      | 61.90     | 5.45      | 0.035   |
| C(Rt) 134.52       | 2.57      | 117.80    | 3.88      | 0.13    |
| C(Lt) 135.05       | 2.69      | 118.10    | 3.75      | 0.47    |
| D 38.5             | 3.94      | 99.50     | 4.25      | 0.53    |
| E 115.47           | 5.15      | 113.80    | 5.73      | 0.62    |
| F 36.05            | 3.84      | 20.30     | 4.42      | 0.34    |
| G 53.21            | 4.04      | 72.80     | 7.33      | 0.03    |
| H 89.26            | 5.64      | 93.10     | 8.35      | 0.12    |
| I(Rt) 58.87        | 3.84      | 52.80     | 3.77      | 0.05    |
| J(Rt) 8.43         | 1.32      | 7.90      | 1.60      | 0.69    |
| I(Lt) 58.92        | 3.82      | 52.80     | 3.77      | 0.06    |
| J(Lt) 8.32         | 1.30      | 7.90      | 1.60      | 0.67    |
| G/F 1.49           | 0.21      | 3.85      | 1.47      | 0.03    |
| H/F 2.49           | 0.21      | 4.85      | 1.47      | 0.03    |
| I/F 1.64           | 0.13      | 2.75      | 0.80      | 0.03    |
| D/F 2.76           | 0.26      | 5.21      | 1.58      | 0.04    |
| I/J 7.18           | 0.95      | 7.00      | 1.84      | 0.21    |

*p < 0.05, **p < 0.01, ***p < 0.001. A angle of Go’r-Me’G-Go’Lt, B angle of C’dGo’Me’Lt, C angle of C’dGo’Me’Lt, D length of Go’r-Go’Lt line (mm), E length of C’dGo’-C’dGo’ line (mm), F distance from Me’ to Go’r-Go’Lt line (mm), G distance from Go’r-Go’Lt line to C’dGo’-C’dGo’ line (mm), H distance from Me’-C’dGo’-C’dGo’ line (mm), I length of Me’-G line (mm), J distance from Me’-Go’ line-mandibular outer surface of body (mm)
measurement. Mean value of $\text{Cd}^{\prime} - \text{Go}^{\prime} - \text{Me}^{\prime}$ angle is not statistically significant between experimental group and control A group, but there is an apparent difference. So, it may be a useful measurement (134° and 117° in men group, 138°, and 118° in women). Ratio of $\text{Go}^{\prime \text{Rt}} \text{Go}^{\prime \text{Lt}} / \text{Cd}^{\prime \text{Rt}} \text{Cd}^{\prime \text{Lt}} \text{Lt}$ ratio of $\text{Me}^{\prime} \text{Cd}^{\prime \text{Rt}} \text{Cd}^{\prime \text{Lt}}$ to $\text{Me}^{\prime} \text{Go}^{\prime \text{Rt}} \text{Go}^{\prime \text{Lt}}$ ratio of $\text{Me}^{\prime} \text{Go}^{\prime}$ to $\text{Me}^{\prime} \text{Go}^{\prime \text{Rt}} \text{Go}^{\prime \text{Lt}}$, ratio of $\text{Go}^{\prime \text{Rt}} \text{Go}^{\prime \text{Lt}}$ to $\text{Me}^{\prime} \text{Go}^{\prime \text{Rt}} \text{Go}^{\prime \text{Lt}}$, are observed with statistically significant differences. So, this measurement could be helpful in making a surgical plan for a more aesthetic frontal profile, especially aesthetic mandibular inferior outline in frontal view.

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Authors’ contributions
Dr. STL designed this study and carried out all processes with other authors. Dr. NKC, Dr. JMS participated in data collection. Dr. SHS made contributions to the interpretation of data and revision of manuscript. All authors read and approved the final manuscript.

Competing interests
The authors declare that they have no competing interests.

Consent for publication
Not applicable.

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Not applicable.

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Conclusion
In Results described above, the difference was in the measured value between men and women. However, angle of $\text{Go}^{\prime \text{Rt}} - \text{Me} - \text{Go}^{\prime \text{Lt}}$ fitted on coronal plane, ratio of $\text{Me}^{\prime} - \text{Cd}^{\prime \text{Rt}} \text{Cd}^{\prime \text{Lt}}$ to $\text{Me}^{\prime} \text{Go}^{\prime \text{Rt}} \text{Go}^{\prime \text{Lt}}$, ratio of $\text{Me}^{\prime} \text{Go}^{\prime}$ to $\text{Me}^{\prime} \text{Go}^{\prime \text{Rt}} \text{Go}^{\prime \text{Lt}}$, ratio of $\text{Go}^{\prime \text{Rt}} \text{Go}^{\prime \text{Lt}}$ to $\text{Me}^{\prime} \text{Go}^{\prime \text{Rt}} \text{Go}^{\prime \text{Lt}}$, are observed with statistically significant differences. So, this measurement could be helpful in making a surgical plan for a more aesthetic frontal profile, especially aesthetic mandibular inferior outline in frontal view.
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