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Abstract

Objective: The antilingular prominence (AP) is a well-known landmark used during planning of intraoral vertical ramus osteotomy (IVRO) in order to prevent inferior alveolar nerve (IAN) injury, but the location of this landmark is not always clear. In this study, we analyzed the anatomical relationship between the mandibular foramen (MF) and the lateral surface shape of the mandibular ramus for use during IVRO.

Patients and methods: We retrospectively analyzed 276 mandibular halves in 67 patients with mandibular deformity and 71 patients without deformity imaged at our department from April 2003 to March 2014. We defined 17 points on the mandibular ramus, and examined the anatomical relationships using multi-planar reconstruction (MPR) images and three-dimensional computed tomography (3DCT) created from preoperative CT data.

Results: The prevalence of the AP was 57.6% (159/276) of all cases. The MF was located inferior to the AP in all cases; it was posterior to the AP in 50.3% (80/159) of cases and the sigmoid notch (SN) in 24.6% (68/276) of cases. The minimum horizontal distance between the mandibular posterior ramus border and the MF was 9.28 mm in all cases.

Conclusion: The AP cannot always serve as a reference point to prevent IAN damage during IVRO. The osteotomy incision should be placed within 9 mm of the posterior mandibular ramus border in order to prevent intraoperative IAN damage. However, preoperative review of planned osteotomy incisions is necessary in every case.

Keywords: mandibular foramen, antilingular prominence, intraoral vertical ramus osteotomy, computed tomography, three-dimensional analysis

Abbreviations: antilingular prominence, AP; intraoral vertical ramus osteotomy, IVRO; multi-planar reconstruction, MPR; mandibular foramen, MF; sigmoid notch, SN; three-dimensional computed tomography, 3DCT

1. Introduction

Orthognathic surgery is now a common procedure in oral and maxillofacial surgery due to improvements in general anesthesia and orthodontics for maintaining oral health. Sagittal split ramus osteotomy (SSRO) is the most classic and common form of mandibular osteotomy; however, many alternative procedures have been advocated, including minor modified procedures, horizontal osteotomy, and reverse L osteotomy to achieve superior postoperative function and stability of the mandibular bone. Recently, intraoral vertical ramus osteotomy (IVRO) has been considered by many as a major procedure among them. IVRO is well known as a simple procedure, is beneficial in reducing the incidence of postoperative damage to the inferior alveolar nerve (IAN), and in previous reports, has fewer adverse effects on postoperative condylar function. The procedure has also become common in recent times due to a newly developed surgical saw specially designed for IVRO, which shortens surgical duration and minimizes hemorrhage, preventing the soft tissue injury.

IVRO was first devised by Caldwell et al. [1] several modifications of the intraoral approach have since been described by Winstanley [2] and Herbert et al. [3]. Most importantly, this procedure places the vertical osteotomy incision posterior to the mandibular foramen (MF), which is the entrance of the inferior alveolar nerve and vessel bundles. Unlike SSRO, IVRO employs a lateral approach to the mandibular ramus; therefore, the surgeon must anticipate the position of the MF along the outer surface of the mandibular ramus. Unless computed tomography (CT) is performed preoperatively, it is difficult to anticipate the correct location of the MF before surgery. Surgeons must become more familiar with the anatomic relationship of the MF in this procedure.

Commonly, when determining the osteotomy incisions for IVRO, the antilingular prominence (AP), a bony projection from the mandibular ramus lateral to the MF, is widely considered a landmark. It is recommended that the osteotomy begin 5–7 mm from the posterior mandibular ramus border behind the AP. However, in certain patients, the AP is difficult to visualize, or the relative positions of the MF and AP are unclear due to variations in the surface shape of the mandibular ramus [4]. Therefore, the surgeon performing this procedure should consider potential variations in the AP position and safely design the posterior vertical osteotomy incision accordingly.

In this study, we examined the anatomical relationship between the MF and the lateral surface shape of the mandibular ramus for use during mandibular osteotomy using multi-planar reconstruction (MPR) images and three-dimensional computed tomography (3DCT) images, and we defined three-dimensional reference points useful for determining the position of the mandibular foramen.

2. Patients and methods

2.1. Patients

The CT images of 276 mandibular halves in 138 Japanese patients treated at Okayama University Hospital for Oral and Maxillofacial Reconstructive Surgery from April 2003 to March 2014 were retrospectively reviewed. Of the 138 participants, 67 were diagnosed with mandibular prognathism (patient group, 28 males and 39 females; mean ± SD age 25.2 ± 9.1 years; range 17–60 years); the remaining 71 patients did not have any jaw deformity and underwent CT examination for other diseases (control group, 29 men and 42 women; mean ± SD age 24.9 ± 8.0 years; range 17–49 years). Patients with specific congenital diseases in the maxillofacial region and those lacking certain occlusal planes due to missing teeth were excluded. Patients in the control group were included according to the following criteria: (1) 17 years of age or older, (2) existence of a right mandibular central incisor and mandibular first molars, (3) class I occlusal relationship in the first molars using Angle’s classification, (4) no history of mandibular fracture or large bone defects in the posterior mandible, (5) no obvious mandibular deformity, and (6) acceptable quality of CT scans for determining the reference points.

2.2. CT *Imaging conditions and image reconstruction*

CT examination was performed with an Aquilion ONE unit (TOSHIBA, Tochigi, Japan) using the following parameters: slice thickness, 1 mm; tube voltage, 120 kV; and a variable tube current. MPR images (window level 300, window width 1500) and 3DCT images (window level 304, window width 270) were reconstructed with OsiriX (32-bit version 5.6 Pixmeo, Bernex, Switzerland).

2.3. Standard planes

The standard axial plane was defined as the plane passing through the three points forming the mesioincisal angle of the right mandibular central incisor and the apices of the distal cusp of the bilateral mandibular first molars (Fig. 1). The standard coronal plane was defined as the plane passing through the two points forming the apices of the distal cusp of the bilateral mandibular first molars on the standard axial plane (Fig. 1). The standard sagittal plane was defined as the plane perpendicular to the standard axial and coronal planes (Fig. 1).

2.4. Measurement points and planes for morphological analysis of the mandibular ramus

A total 17 anatomic measurement points were plotted on the MPR and 3DCT images (Table 1, Fig. 2). The X, Y, and Z-axes were adjusted on MPR images displaying the standard sagittal plane and the standard axial plane. The MF point was defined as most posterior point of the MF on the axial CT image (Fig. 3). The AP was defined as the apex of the bony prominence on the lateral surface of the mandibular ramus (Fig. 4). Each measurement plane was determined using the three points as shown in Table 2. The measurement point was determined by consensus of two oral surgeons (YG, TM) in our department after calibration, using CT data of 10 randomly selected subjects was performed by two researchers prior to the study to reduce statistical difference between the data sets.

2.5. Measurement and statistical methods

The six categories were examined by three-dimensional measurement based on the anatomical relationship between the MF and the lateral surface of the mandibular ramus (Table 3). The distances were calculated with Excel for Mac 2011 (version 14.4.3 Microsoft, Redmond, WA, USA) using the measurement plane and the XYZ coordinate of each selected point derived from OsiriX software. The anterior direction on the horizontal plane and superior direction on the vertical plane were designated as positive. Each side of the mandibular ramus was analyzed individually after applying the paired *t*-test to evaluate the influence of each side. The measurement data were compared between the two groups and genders using the Student's *t*-test, Fisher's exact test, and Pearson correlation coefficient. Differences between the two groups and genders were considered significant at $p < 0.05$. The statistical analyses and correlations were performed using the Statistical Package for PASW statistics 18 (IBM, Tokyo, Japan).

This study was approved by the ethics committee of Okayama University for research on human subjects (#1983). The requirement for informed consent was waived due to the retrospective study design.

3. Results

3.1. AP prevalence

The prevalence of the AP was 57.6% (159/276) of total cases (Table.4). In the patient group, an AP was present in 60.4% (81/134) of all patients, 67.9% (38/56) of males, and 55.1%

(43/78) of females. The prevalence of the AP in the control group was 54.9% (78/142) of all patients, 68.9% (40/58) of males, and 45.2% (38/84) of females. In both groups, the AP was more prevalent in males and was bilateral in most people. A significant difference was observed between the male and female patients in the control group ($p < 0.01$).

3.2. Anteroposterior and vertical positions of the MF relative to the AP

The anteroposterior distance between the AP and MF ranged 6.76 mm anterior and 7.13 mm posterior in the patient group. In the control group, the distances were 6.34 mm anterior and 6.06 mm posterior (Table 5). The MF was posterior to the AP in 50.3% (80/159) of patients and >5 mm posterior to the AP in 5.0% (8/159) of patients (Fig. 5). The anteroposterior position was significantly different between the patient and control groups ($p < 0.01$).

The vertical distance between the AP and MF ranged 1.93–22.75 mm inferior to the AP in the patient group, and was 3.66–17.49 mm inferior to the AP in the control group (Table 5). The MF was located below the AP vertically in all cases.

When the AP was designated as a reference point (0, 0) in the rectangular coordinate system, the MF was located anteroinferior to the AP in 70.4% (57/81) of individuals in the patient group, and posteroinferior to the AP in 71.8% (56/78) of patients in the control group (Fig. 5).

3.3. Vertical position of the MF relative to the occlusal plane

The vertical position of the MF ranged 9.64 mm superior and 10.83 mm inferior to the occlusal plane in the patient group, and ranged 10.59 mm superior and 4.97 mm inferior to the occlusal plane in the control group (Table 5). The mean vertical distance in the patient group was significantly shorter than that in the control group on both the left and right mandibles ($p < 0.01$, Fig. 6).

3.4. Anteroposterior position of the MF relative to the ramus border.

The mean distance between the MF and the ramus anterior border using a reference line parallel to the occlusal plane was 19.33 ± 2.3 mm (range: 13.63–26.13 mm) in the patient group and 20.52 ± 2.4 mm (range: 14.35–26.8 mm) in the control group (Table 5). The mean horizontal distance was significantly longer in the control group than in the patient group. The distance was significantly different between males and females in both groups ($p < 0.01$).

The mean distance between the MF and the ramus posterior border using a reference line parallel to the occlusal plane was 14.5 ± 2.3 mm (range: 9.82–25.61 mm) in the patient group and 14.66 ± 2.3 mm (range: 9.28–21.1 mm) in the control group (Table 5, Fig. 7). The mean horizontal distance was longer in the control group than in the patient group. The distance was significantly different between males and females in both groups ($p < 0.01$: Date not shown). However, there was no significant difference between the groups.

When the horizontal width of the ramus was designated as 1, the mean MF position was 0.43 ± 0.05 on the right side and 0.43 ± 0.04 on the left side in the patient group, and 0.42 ± 0.04 on the right side and 0.41 ± 0.05 on the left side in the control group (Table 5). The MF was located slightly posterior to the center of the mandibular ramus in both groups and was not statistically different between the groups. In the control group, the MF of females was located posterior to the ramus in most, a trend that was significant ($p < 0.01$: Date not shown).

There was a positive correlation between the ramus width diameter and the horizontal distance of the MF from the ramus posterior border according to the Pearson correlation coefficient (Fig. 8).

3.5. Anteroposterior and vertical positions of the MF relative to the sigmoid notch.

The anteroposterior distance from the sigmoid notch (SN) to the MF ranged 14.11 mm anterior and 6.94 mm posterior in the patient group. In the control group, the distance ranged

10.02 mm anterior and 6.12 mm posterior (Table 5). The MF was posterior to the SN in 24.6% (68/276) of all cases and >5 mm posterior to the SN in 1.4% (4/276) of all cases (Fig. 9). There was a significant difference in the anteroposterior position between the patient and control groups ($p < 0.01$).

The vertical distance from the SN to the MF ranged between 14.36–37 mm inferior to the SN in the patient group and 15.83–30.75 mm inferior to the SN in the control group (Table 4). A significant difference was observed between males and females in both groups ($p < 0.01$: Date not shown) and between the patient and control groups ($p < 0.05$).

When the SN was designated as a reference point (0, 0) in the rectangular coordinate system, the MF was located anteroinferior to the SN in 85.8% (115/134) of individuals in the patient group and 65.5% (93/142) of patients in the control group (Fig. 9).

4. Discussion

Ever since Caldwell et al. [1] described the AP as a "very slight rounded prominence" of the mandibular ramus lateral surface that could identify the MF position, numerous studies have used the AP as an anatomic landmark to avoid IAN damage during mandibular osteotomy. The AP is still widely considered an important landmark because several prior morphological studies have reported a high prevalence of the AP. Studies by Langston et al. [5] and Aziz et al. [6] showed that the AP was present in all subjects. Previous morphologic studies of the skeleton could only be performed using cadaver skull specimens, and it was difficult to subjectively assess such a small superficial prominence in these subjects; detecting it using routine radiography was also impossible. Therefore, in nearly all previous studies, the AP was located by visual inspection and manual palpation. However, in studies using cadaver skulls, the prevalence of the AP varied from 42–100% (Table 6) [5-14]. This difference may be caused by differences in the racial, age, and sex distributions of the sample populations, as well as in the procedure for determining the AP. There are clearly limitations to collecting cadaver skull specimens and subjectively determining the AP in these studies attempting to clarify the presence of the AP and the anatomic relationship between the AP and MF.

4.1. CT

Recent progress in CT has remarkably improved the radiographic diagnosis of soft and hard tissue lesions, and has facilitated the morphological analysis of organs by analyzing large patient populations. In particular, 3DCT enables investigators to visualize the skulls vertically on a monitor, and allows structures to be generated by 3D-reconstruction based on the data. Furthermore, with the improvements in 3D-analysis software, investigators can produce the correct standard plane and lines for measurement, and can assess the position of landmarks three-dimensionally. One benefit of the morphological analysis of skulls using CT is the ability to assess the large number of subjects encountered in clinical practice. Various lesions exist in the craniofacial region, and a wide range of ages undergo radiographic examinations. In our study, we analyzed the mandibular ramus shape obtained from CT data of 276 mandibles including 67 patients with mandibular deformity and 71 patients without deformity.

Cavalcanti et al. [15] reported that the measured values varied in a study examining the accuracy of the distance between two points in the maxillofacial area measured on 3DCT images of cadavers. Because the 3D images were projected onto image planes using imaging visualization, it is possible that the edge shape did not display the anatomy correctly. Further, the measurement point is determined by visual inspection of the 3D image; therefore, measurement may differ compared to that using the cadaver or according to the investigator. Recently, several reports showed that the MPR images created by CT imaging of jaw deformities were superior to 3DCT images in reproducibility and accuracy of the linear measurements for morphological studies of jaw deformities [16, 17].

In this study, we analyzed the AP and MF positions on MPR images using an XYZ coordinate system and reference planes by displaying both MPR and 3DCT images on a single screen.

4.2. Antilingular prominence

In our study, the AP was observed in 57.6% (159/276) of total cases. This prevalence is slightly higher than that reported by Park et al. [14], who performed morphometry of the mandible using MPR imaging and 3DCT. They showed that the AP was identifiable in only 46.7%, 44.4%, and 45.3% of cases in class I skeletal occlusion groups (N = 25), class II groups (N = 50), and class III groups (N = 50). Each racial group is well known to have a characteristic skull shape. There have been few studies the analyzing the AP in Caucasian people, and it is unknown whether any racial difference of the AP exists. Future morphologic studies of the mandibular ramus using CT images should be performed on multiple racial groups.

In the past, the incidence of IAN injury during IVRO was as high as 36% when using the AP as a surgical landmark [18, 19]. This high incidence of nerve injury may be caused by the misunderstood concept of the AP position, which can vary.

We analyzed these positional relationships based on the plane and lines created by the mandibular ramus surface and occlusal plane. In our study, the MF position in the patient group was anteroinferior to the AP, which contradicts findings in studies of cadaver mandibular ramus, but this result is consistent with that in a report by Park et al. [14], who reported that many AP were located anteroinferior to the MF.

In previous cadaver studies, the MF or the lingula (LG) was located posteroinferior to the AP. Yates et al. [7] reported that the MF was located posteroinferior to the AP in 80% of total cases, and Pogrel et al. [10] reported that the LG was located posteroinferior to the AP in

68.3% of total cases. Therefore, to ensure a safe margin when planning the vertical osteotomy incision, it was recommended to incise 9 mm behind the AP in an earlier report [6]. This recommended safety marginal distance is consistent with our findings and useful intraoperatively if the AP location is clear. However, the AP location is not always apparent, and there is some risk when designing the vertical osteotomy line using only the AP preoperatively. Thus, the other landmarks should be used to prevent IAN injury.

4.3. Occlusal plane and the ramus anteroposterior border

The MF position has also been investigated in several studies. In a study of the MF vertical position, Osaka et al. [20], using the cadaver mandibles of 170 Indians, reported that 47.5% of the MF were located superior to the occlusal plane. In our study, this was observed in 53.7% (72/134) of the patient group and 65.5% (93/142) of the control group, and the distance between the MF and occlusal plane was significantly shorter in the patient group than in the control group (Fig. 6). Based on these results, the MF of the patient group was located relatively inferior compared to the control group. These findings may indicate that the mandibular shape varies in patients with jaw deformity, who may have a well or less developed ramus height, higher gonial angle, or inclination of the occlusal plane. Nevertheless, the relationship between the occlusal plane and MF were highly variable among jaw deformity patients.

Several studies have analyzed the MF position using a different reference line. Fontoura et al. [21] analyzed the distance between the MF and the ramus posterior border using a reference line parallel to the mandible inferior border in 140 cadaver Brazilian adult dentulous mandibles. The mean distance was 10.04 ± 1.86 mm (range: 6.3–18.3 mm), and 3.3% of the MF were located within 7 mm of the ramus posterior border. Monnazzi et al. [13] performed morphometry of 44 cadaver mandibles and found that the mean distance between the MF and the ramus posterior border was 14.35 ± 1.87 mm using a reference line parallel to the alveolar bone border plane. Some studies [22, 23] showed that the MF was also positioned slightly posterior to the center of the mandibular ramus horizontal width, but these reference lines were not determined clearly. Therefore, as in our study the occlusal plane has some advantages for assessment of the location of the MF because this is the only useful reference line intraoperatively.

In our study, the minimum horizontal distance between the mandibular ramus posterior border and MF was 9.82 mm in the patient group and 9.28 mm in the control group. The MF was not located 7 mm anterior to the mandibular ramus posterior border, which contradicts a report by Fontoura et al. [21]. Based on our results, the osteotomy incision for IVRO should be made within 9 mm of the mandibular ramus posterior border in order to avoid IAN damage intraoperatively.

4.4. Sigmoid notch

The SN marks the upper margin of the vertical osteotomy line. It is considered an anatomically specific shape occurring in all mandibles and is a relatively easy landmark to locate intraoperatively. In this study, we attempted to clarify whether the SN could be used as an imaging reference point for determining the MF position. A vertical line from the SN towards the occlusal plane was used as the reference line. Most MF were located anterior to the SN, but several of the MF were posterior to this line. These data indicate that the SN cannot be considered a reliable anatomic landmark, and an osteotomy incision positioned from the SN crossing vertically with the occlusal plane has a higher risk of IAN injury. Therefore, the osteotomy incision should be designed as a clear arch shape from the SN.

5. Conclusions

As shown in several previous studies, the presence of the AP and the relationship to the MF varies between individuals. The AP cannot always serve as a reference point to prevent IAN damage during IVRO. The occlusal plane is also a useful reference line for morphological analysis of the MF, but is an unreliable reference line when used alone, especially in jaw deformity patients who have various inclinations due to abnormal mandible growth. The osteotomy incision should be designed as a clear arch shape from the SN and placed within 9 mm of the posterior mandibular ramus border in order to prevent intraoperative IAN damage. However, preoperative review of planned osteotomy incisions is necessary in every case.

Conflict of interest

None of the authors have any conflict of interest to declare.

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Figure Legends

Fig. 1. Determination of the occlusal, and the standard axial, coronal and sagittal planes. The occlusal plane (horizontal line in A, C) was based on a standard axial plane (B) and defined as the plane passing through three points: PO1, the right mandibular central incisor (vertical line in B); PO2, the right mandibular first molar; and PO3, the left mandibular first molar. The standard coronal plane (A) was defined as the line connecting PO2 and PO3 (horizontal line in B, vertical line in C) on the standard axial plane (B). The standard sagittal plane (C) was defined as the plane perpendicular to the standard coronal and axial plane (A, B).

Fig. 2. Multi-planar reconstruction (MPR) of skull based on 3DCT data. Reference points of the mandibular ramus based on the 3DCT image are indicated as follows: occlusal plane (dashed line); MF, mandibular foramen; AP, antilingular prominence; SN, sigmoid notch; PO5, anterior ramus border right of the MF plane; PO6, posterior ramus border right of the MF plane; and PO14, 15, coronal point right of the MF plane.

Fig. 3. Anatomic measurements using MPR images. The MF point (A, B) was defined as most posterior point of the MF on the axial CT image (B). The B image refers to the axial image of the MF that has moved parallel from the standard axial plane (B of Fig 1); the C image shows the sagittal image passing through the point 5 and 6 on the standard axial plane (B); and the A image shows the coronal image through the MF perpendicular to the B and C image. MPR, multi-planar reconstruction; MF, mandibular foramen; PO5, anterior ramus border right of the MF plane; PO6, posterior ramus border right of the MF plane; and PO14, 15, coronal point right of the MF plane.

Fig. 4. Measurement of the AP location using MPR images in axial (A) and coronal (B) CT. The AP was defined as apex of the bony prominence on the lateral surface of the mandibular ramus. The A image refers to the axial image of the AP that has moved parallel from the standard axial plane (B of Fig. 1) and the B image shows the coronal image of the AP that has moved parallel from the standard coronal plane (A of Fig 1). MPR, multi-planar reconstruction; AP, antilingular prominence.

Fig. 5. Anatomic relationship between the AP and MF in the patient (A) and control (B) groups. The AP was designated as a reference point (0, 0) in the rectangular coordinate system. AP, antilingular prominence; MF, mandibular foramen.

Fig. 6. Vertical position of the MF relative to the occlusal plane. The occlusal plane was designated as the x-axis. ** There was a significant difference between the patient (solid rectangle) and control (open rectangle) groups. MF, mandibular foramen.

Fig. 7. Anteroposterior position of the MF relative to the posterior ramus border. The posterior ramus border was designated as the y-axis. MF, mandibular foramen; patient group, solid circle; control group, open circle.

Fig. 8. Correlation between the ramus width diameter and the horizontal MF distance from the posterior ramus border in the patient (A) and control (B) groups. The distance between the MF and the posterior ramus border was designated as the x-axis, and the mandibular ramus width diameter was the y-axis. There was a positive correlation between the two variables using the Pearson correlation coefficient.

Fig. 9. Relationship between the AP and SN locations in the patient (A) and control (B) groups. The SN was designated as a reference point (0, 0) in the rectangular coordinate system. AP, antilingular prominence; SN, sigmoid notch.

Table1

Table 1

The 17 measurement points on MPR and 3DCT

#	points	Definition
1	Right mandibular central incisor	Mesioincisal angle of the right mandibular central incisor
2	Right mandibular first molar	Apex of the distal cusp of the right mandibular first molar
3	Left mandibular first molar	Apex of distal cusp of left mandibular first molar
4	Right mandibular foramen	Most posterior point of the right MF on the axial CT image
5	Anterior ramus border right of the MF plane	Most anterior point of the right mandibular ramus on the axial CT image of the right MF plane
6	Posterior ramus border right of the MF plane	Most posterior point of the right mandibular ramus on the axial CT image of the right MF plane
7	Right antilingular prominence	Apex of the bony prominence on the lateral surface of the right mandibular ramus
8	Left mandibular foramen	Most posterior point of the left MF on the axial CT image
9	Anterior ramus border left of the MF plane	Most anterior point of the left mandibular ramus on the axial CT image of the MF plane
10	Posterior ramus border left of the MF plane	Most posterior point of the left mandibular ramus on the axial CT image of the right MF plane
11	Left antilingular prominence	Apex of the bony prominence on the lateral surface of the left mandibular ramus
12	Right sigmoid notch	Lowest point of the right sigmoid notch
13	Left sigmoid notch	Lowest point of the left sigmoid notch
14,15	Coronal point right of the MF plane	Arbitrary point on the coronal CT image through #4, which is perpendicular to the line connecting points 5 and 6
16,17	Coronal point left of the MF plane	Arbitrary point on the coronal CT image through #8, which is perpendicular to the line connecting points 9 and 10

MF: mandibular foramen, CT: computed tomography, MPR: mulit-planar rescontruction, 3DCT: three-dimensional CT

Table2

Table 2

Measurement planes on reconstructed images

#	Plane	Definition
1	Occlusal plane	Plane through points #1,2,3
2	Horizontal plane on right MF	Plane through points #4,5,6
3	Horizontal plane on left MF	Plane through points #8,9,10
4	Coronal plane on right MF	Plane through points #4,14,15
5	Coronal plane on left MF	Plane through points #8,16,17

MF: mandibular foramen

Table3

Table 3

Description of measurements

Term	Definition	Points and Planes
AP	Antilingular prominence	R: point 7, L: point 11
AP-MF	Vertical and anteroposterior position of the MF from the AP	vertical/R : point #7 and plane #2, L : point #11 and plane #3
		horizontal/R : point #7 and plane #4, L : point #11 and plane #5
occlusal plane-MF	Vertical position of the MF from the occlusal plane	R: point #4 and plane #1
		L: point #8 and plane #1
anterior border-MF	Anteroposterior position of the MF from the ramus anterior border	R: point #5 and plane #4
		L: point #9 and plane #5
posterior border-MF	Anteroposterior position of the MF from the ramus posterior border	R: point #6 and plane #4
		L: point #10 and plane #5
SN-MF	Vertical and anteroposterior position of the MF from the SN	vertical/R : point #12 and plane #2, L : point #13 and plane #3
		horizontal/R : point #12 and plane #4, L : point #13 and plane #5

AP: antilingular prominence, MF: mandibular foramen, SN: sigmoid notch R: right L: left

Table4

Table 4. Prevalence of the AP

	Patient group (134 mandibles)		Control group (142 mandibles)	
	Identifiable mandible	Prevalence (%)	Identifiable mandible	Prevalence (%)
Males	38	67.9	40	68.9
Females	43	55.1	38	45.2
Total	81	60.4	78	54.9

AP: antilingular prominence

Table5

Table 5. Anatomic analysis of the MF position

	Patient group (N = 67)			Control group (N = 71)			
	Mean ± SD	Max	Min	Mean ± SD	Max	Min	p value[b]
Relationship between the AP[a] and the mandibular ramus landmarks (mm)							
H/AP-MF	0.97 ± 2.7	6.76	-7.13	-1.29 ± 2.6	6.34	-6.06	0.00000002 **
V/AP-MF	-11.38 ± 3.1	-1.93	-22.75	-11.19 ± 2.9	-3.66	-17.49	0.7579
H/SN-MF	4.66 ± 4.4	14.11	-6.94	0.96 ± 2.9	10.02	-6.12	0.0000000002 **
V/SN-MF	-24.18 ± 4.0	-14.36	-37	-23.14 ± 3.4	-15.83	-30.75	0.0244 *
Anteroposterior position of the MF (mm)							
H/anterior border-MF	19.33 ± 2.3	26.13	13.63	20.52 ± 2.4	26.8	14.35	0.00002 **
H/posterior border-MF	14.5 ± 2.3	25.61	9.82	14.66 ± 2.3	21.1	9.28	0.5698
Ratio of the MF position (The horizontal width of the ramus was designated as 1.)							
R/MF	0.43 ± 0.05	0.55	0.31	0.42 ± 0.04	0.52	0.33	0.0929
L/MF	0.43 ± 0.04	0.59	0.31	0.41 ± 0.05	0.58	0.32	0.1222
Inferosuperior position of the MF from the occlusal plane (mm)							
V/occlusal plane-MF	0.22 ± 4.32	9.64	-10.83	1.6 ± 3.47	10.59	-4.97	0.0037 **

[a] AP:antilingular prominence, MF: mandibular foramen, SN: sigmoid notch R: right, L: left, H: horizontal, V: vertical

[b] Significant difference between the patient group versus the control group: * $p < 0.05$; ** $p < 0.01$

Table6

Table 6. The previous studies describing the AP

Authors	Specimen (N)	AP prevalence (%)	Racial group	Method	Number of evaluators	Publication year
Yates et al. [7]	Dried mandibles (70)	44%	Icelandic, New Mexican, and unknown	Unkown	3	1976
Reitzik et al. [8]	Dried mandibles (100)	Unkown	Unkown	Unkown	Unkown	1976
Langston et al [5]	Dried mandibles (50)	100%	Indian	Visualization and palpation	Unkown	1977
Martone et al. [9]	Dried hemimandibles (63)	42%	North American	Unkown	Unkown	1993
Pogrel et al. [10]	Dried mandibles (20)	100%	Unkown	Palpation	3	1995
Aziz et al. [6]	Dried mandibles (18)	100%	Unkown	Visualization and palpation	Unkown	2007
Wong. [11]	3DCT images (40)	100%	Taiwanese	3DCT	Unkown	2008
Apinhasmit et al. [12]	Dried mandibles (92)	80.4%	Thai	Visualization and palpation	Unkown	2011
Monnazzi et al. [13]	Dried mandibles (44)	82.9%	Unkown	Palpation	2	2012
Park et al. [14]	3DCT images (125)	45.5%	Korean	3DCT and MPR	Unkown	2014

AP:antilingular prominence, 3DCT: three-dimensional computed tomography, MPR: multi-planar reconstruction

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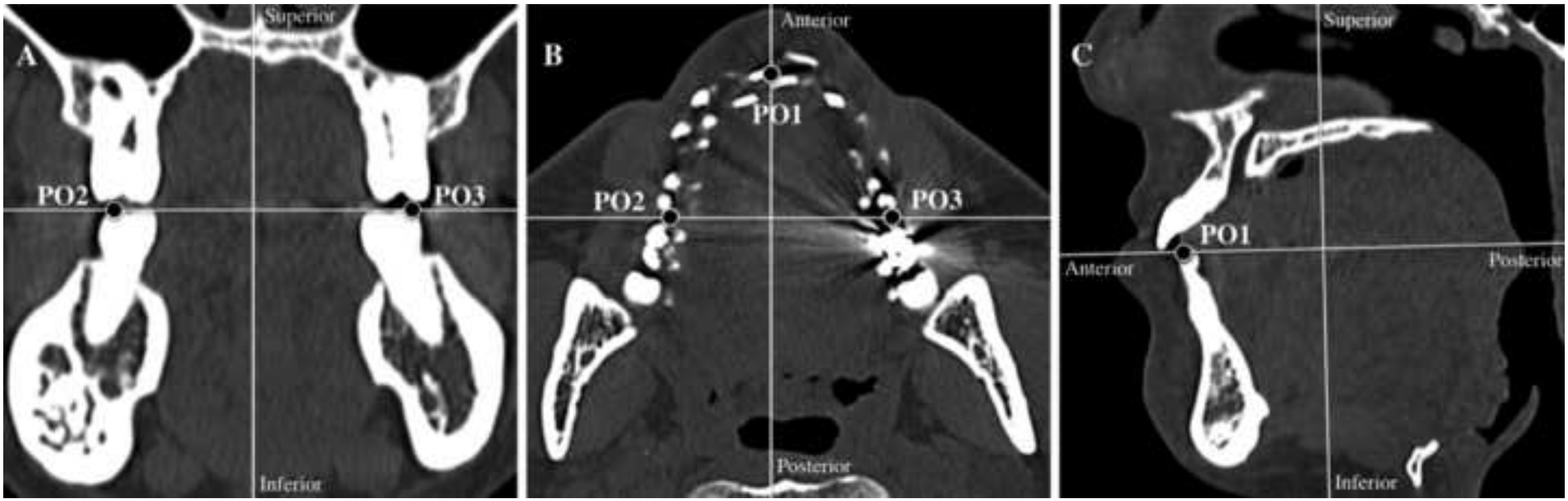

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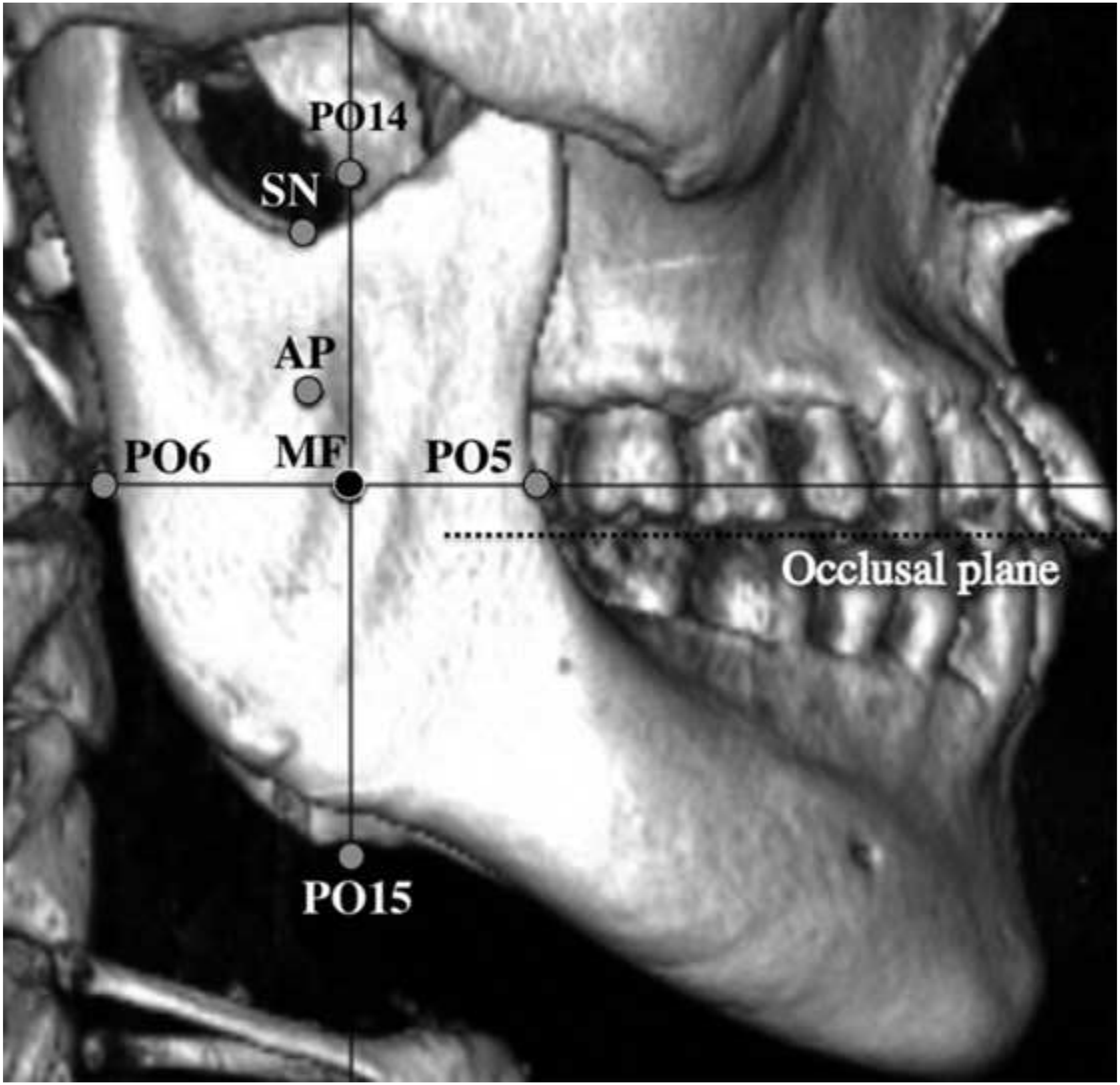

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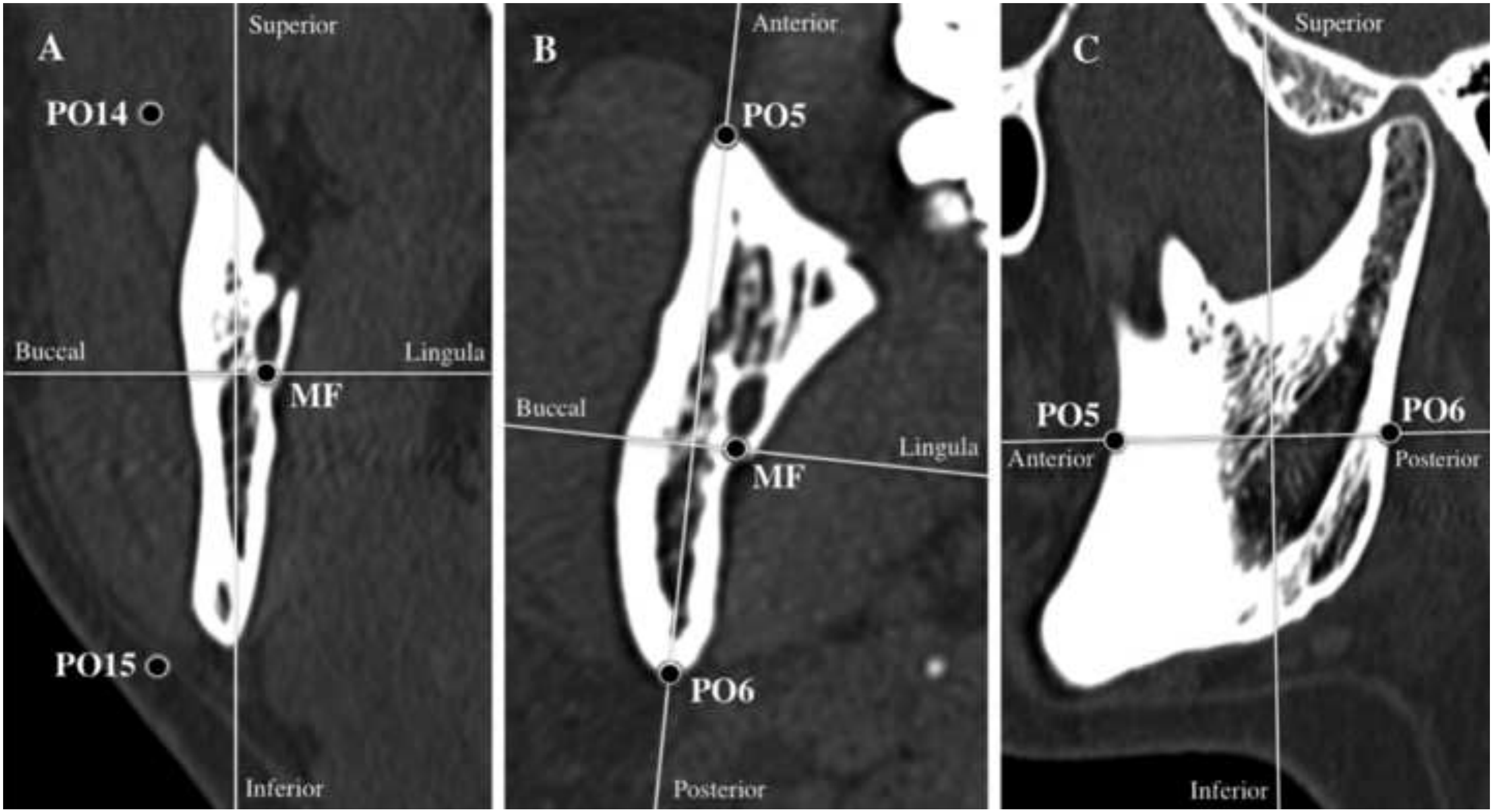

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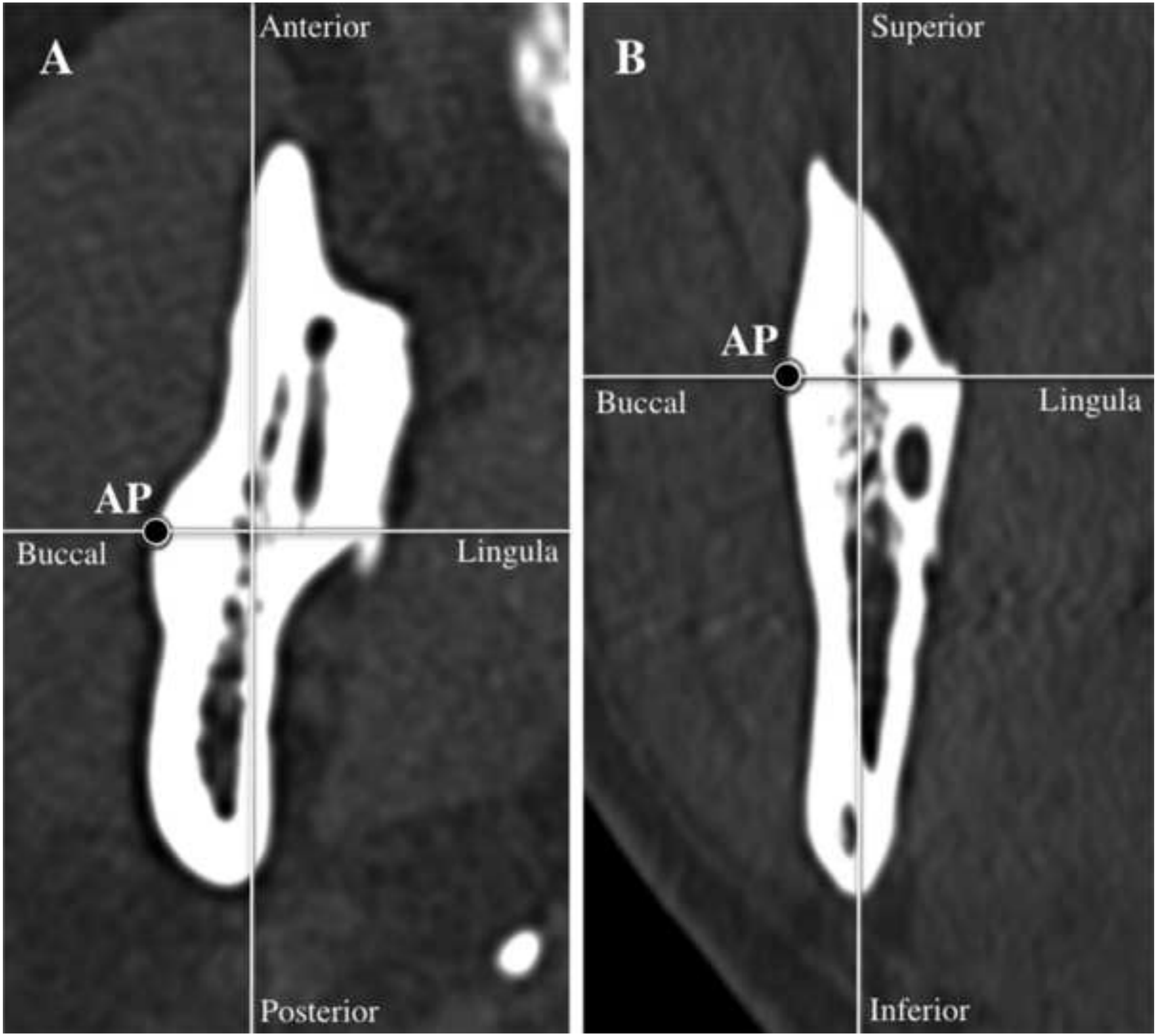

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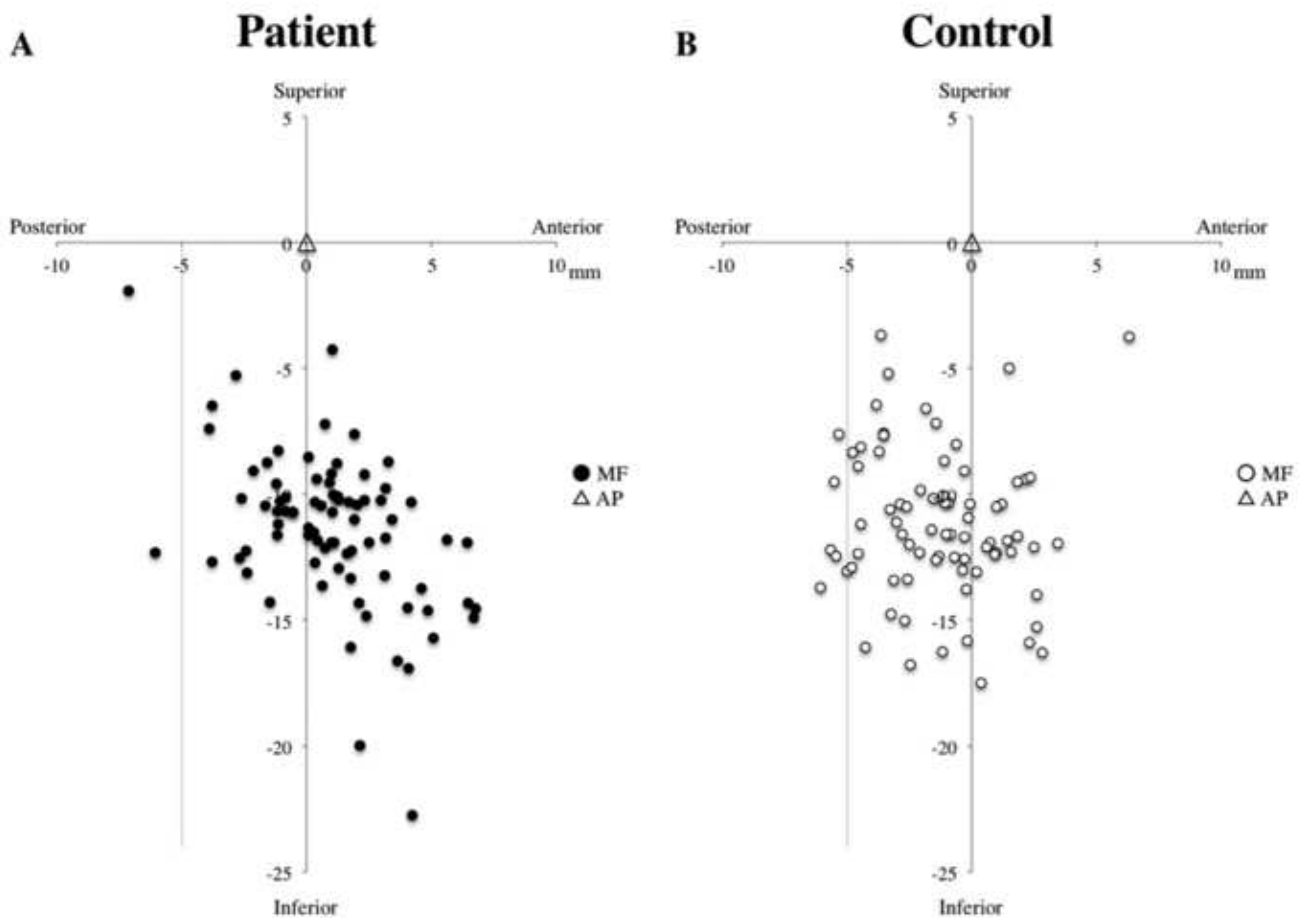

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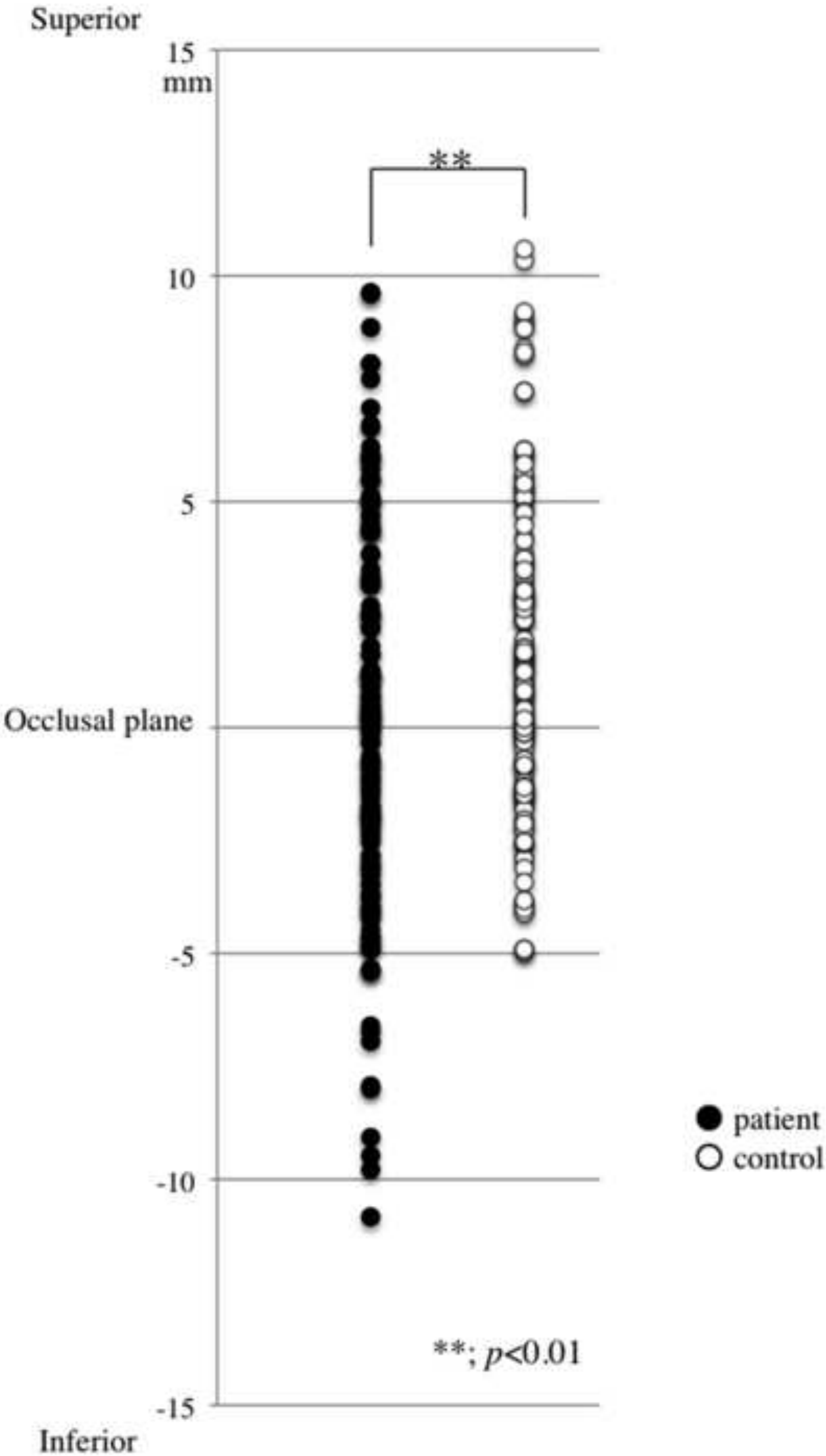

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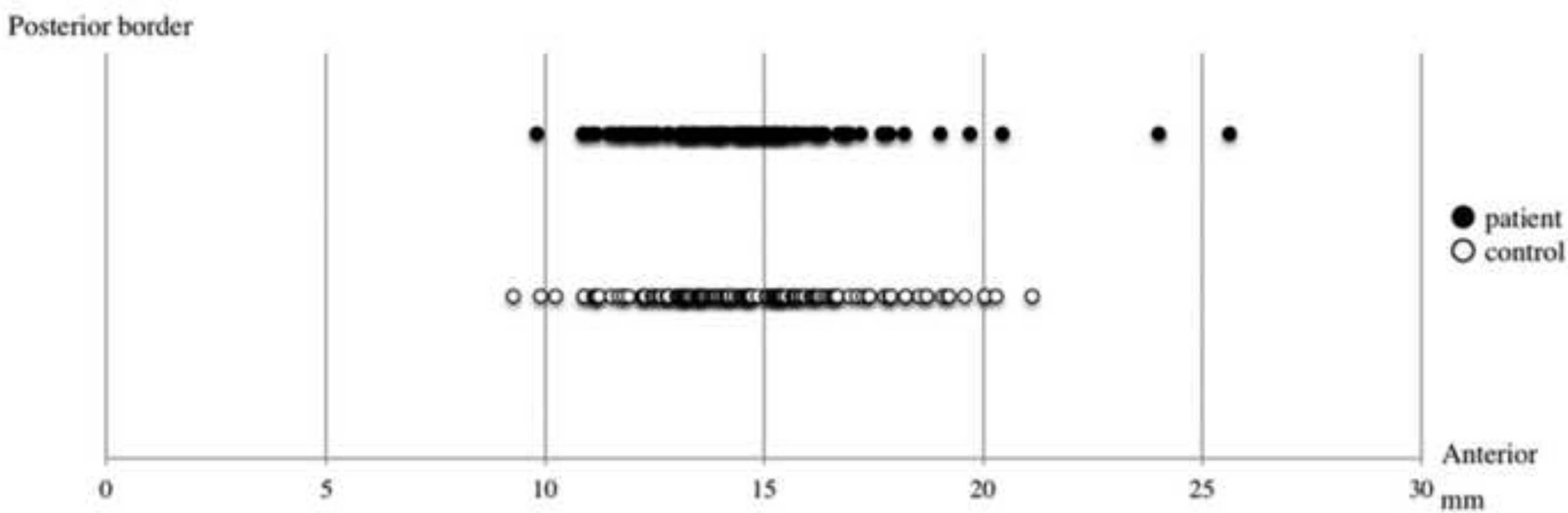

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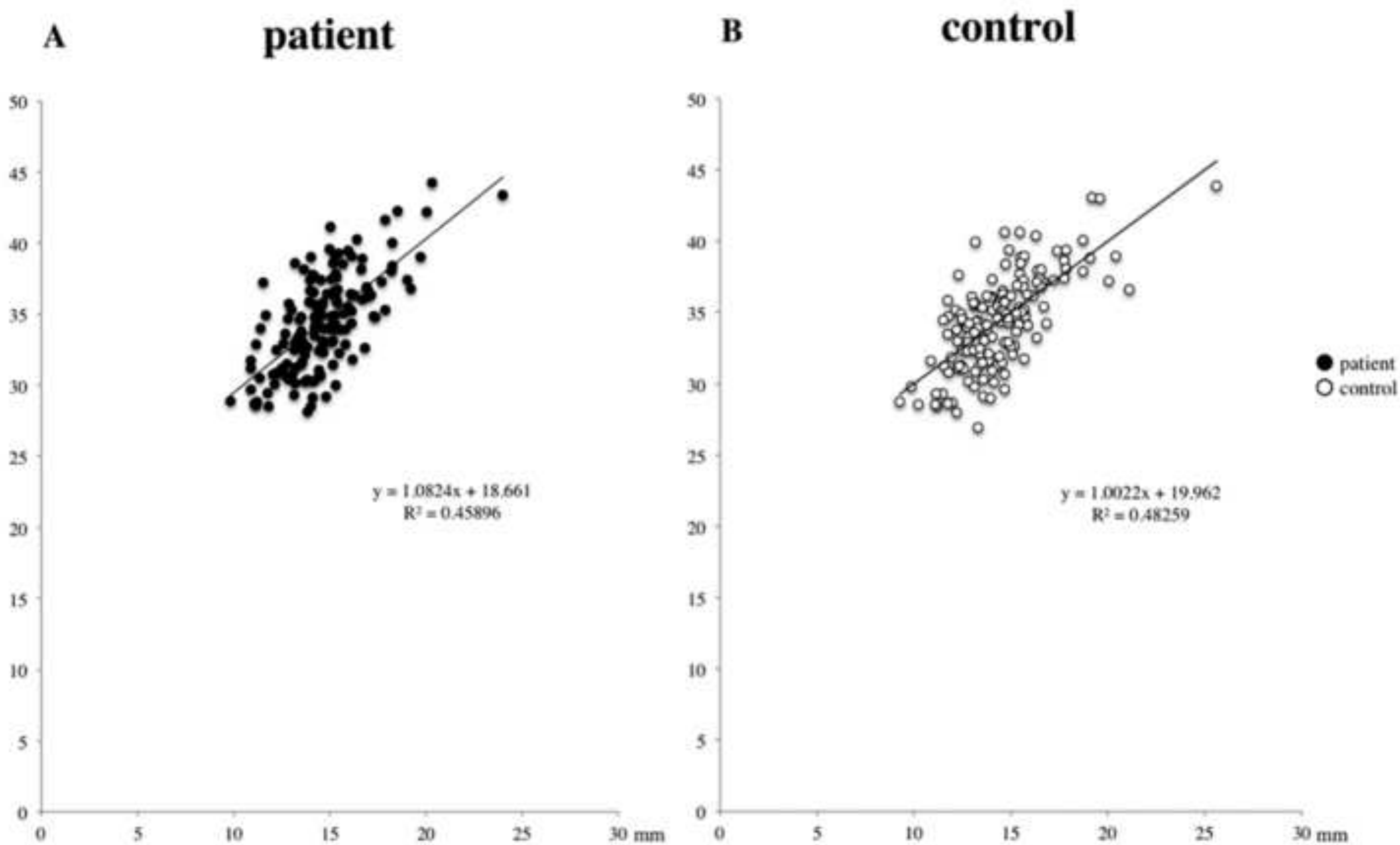

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