Localisation of the Infraorbital and Mental Foramen in Orthognathic Surgery: a CBCT Study

Xin CHEN[1,#], Cheng TAO[2,#], Tie Mei WANG[2]

Objective: *To establish precise positional references for orthognathic surgery by examining the relative positioning of the infraorbital foramen (IOF) in relation to the anterior nasal spine (ANS) and the mental foramen (MF) in relation to the pogonion (Pog).*

Methods: *A cohort of 115 patients with CBCT images was randomly selected for analysis. Distances and positional relationships between the IOF and ANS, as well as the MF and Pog, were measured using 3D reconstruction images.*

Results: *On average, the ANS was situated 21.40 mm below the IOF, with a horizontal distance of 26.42 mm. The horizontal and vertical distances between the MF and Pog were 23.57 and 9.71 mm, respectively. Scatter plots centred on the ANS indicated that 83% (191/230) of the IOF were distributed in a 30- to 45-degree fan shape, the radius of which ranged from 30 to 40 mm. Similarly, 98% (226/230) of the MF occupied a 45-degree fan shape within a 20 to 30 mm radius in the bilateral superior quadrant centred on the Pog.*

Conclusion*: During maxillary osteotomy, there is a potential risk of damaging the infraorbital neurovascular bundle located 21.40 mm above the ANS. To mitigate the risk of IOF injury, caution is advised, particularly when retracting the flap below a 30-degree fan shape within a 30 to 40 mm radius centred on the ANS and a 45-degree fan shape within a 20 to 30 mm radius centred on the Pog. Special attention is warranted during flap elevation in this specified area.*

Keywords: *CBCT, infraorbital foramen, mental foramen, orthognathic surgery*

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Orthognathic surgery is commonly performed for the correction of dentofacial deformities and malocclusion.[1] Neurosensory impairment is a virtually universal outcome following osteotomy procedures, attributed not only to accidental nerve section but also to stretching or avulsion during surgery.[2]

The lower two-thirds of the skin in the craniofacial region is predominantly innervated by infraorbital and mental nerves. The infraorbital foramen (IOF) and mental foramen (MF), the respective foramina for these nerves, are frequently encountered in various orthognathic procedures.[2,3] While IOF is primarily at risk during maxillary osteotomy due to soft tissue retraction, permanent nerve damage is rare.[2] Conversely, the dissection and dissociation of MF pose a greater challenge, as the mental nerve may undergo retraction or even resection, leading to sensory dysfunction in the chin and lower lip.[4] Thus, the identification and preservation of both foramina are critical aspects of orthognathic surgery.

Although some studies have explored the relationship between these foramina and adjacent dental or bony landmarks,[5,6] dental structures can be displaced by preoperative orthodontics or third molar eruption. Common bony landmarks, such as the infraorbital rim, upper margin of the nasal aperture and jugale, may offer clinical information for maxillofacial fracture repair or local anesthesia.[7,8] However, these bony landmarks might remain elusive and seem invisible during orthognathic surgery. The anterior nasal spine

1 Department of Oral and Maxillofacial Surgery, Jiangyin People's Hospital Affiliated to Nantong University, Wuxi, Jiangsu Province, P.R. China.

2 Nanjing Stomatological Hospital, Affiliated Hospital of Medica School, Research Institute of Stomatology, Nanjing University, Nanjing, Jiangsu Province, P.R. China.

# These two authors contributed equally to this work.

Corresponding author: Dr Tie Mei WANG, Nanjing Stomatological Hospital, Affiliated Hospital of Medica School, Research Institute of Stomatology, Nanjing University, Nanjing 210008, Jiangsu Province, P.R. China. Tel: 86-25-83620351. Email: Tiemeiwang106@163.com

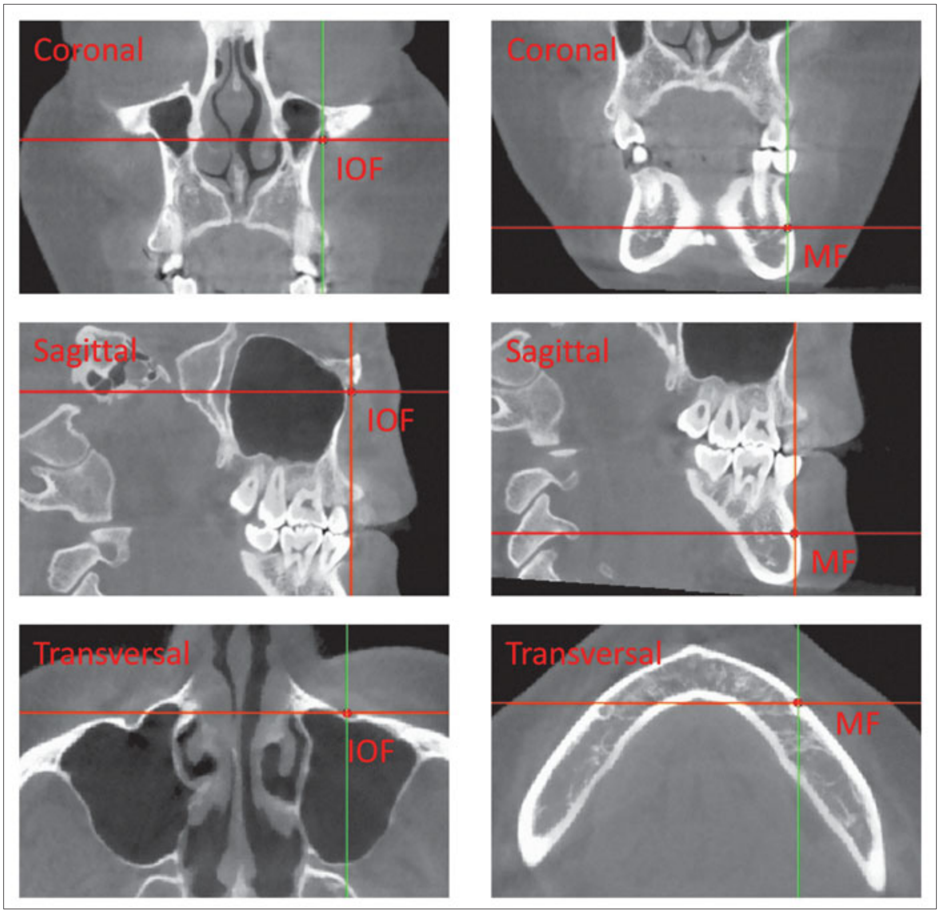

Fig 1 Location of the IOF and MF.

(ANS) and pogonion (Pog) stand out as more prominent bony landmarks, consistently exposed and preserved throughout these procedures.[5,9]

The present study aims to establish the position of the IOF relative to the ANS and MF relative to Pog, providing a more accessible reference for the precise location of both foramina in orthognathic surgery.

Materials and methods

CBCT images from 115 patients were collected between October 2019 and October 2020. The patients were randomly selected from all those who attended Nanjing Stomatological Hospital. The inclusion criteria encompassed complete written records, CBCT images without metal artifacts and motion artifacts, absence of facial trauma, maxillofacial surgery, significant periodontal disease, open bite or craniomaxillofacial dysplasia, and an age range from 20 to 25 years. Participants were informed of the inclusion of their demographic and imaging data in the study, and all provided approval. All procedures performed in studies involving human participants were in accordance with the ethical standards of the institutional and/or national research committee and with the 1964 Helsinki declaration and its later amendments or comparable ethical standards. This study was approved by the local ethics committee of Nanjing Stomatological Hospital (No: JX-2020NL-06). CBCT examinations were conducted by the same professional imaging specialist following a standardised protocol on a NewTom VGi machine (NewTom, Imola, Italy) with uniform parameter settings (tube voltage 110 kV, tube current 9.47 to 15.90 mA, field of view 5 × 5 cm, exposure time 4.3 seconds, voxel size 0.1 mm). Mimics 15.0 software (Materialisen, Leuven, Belgium) in the oral radiology department of our hospital was used for image measurements.

Reference planes were established as previously described.[10] Briefly, the axial plane was aligned parallel to the Frankfort horizontal plane (FH plane), while the sagittal and coronal planes were perpendicular to each other and to the FH plane. The IOF was identified as the most superolateral point on the exterior end of the infraorbital canal, and the MF was the most anterior point of the opening transmitting the inferior alveolar nerve on the mandibular surface (Fig 1). Horizontal distances from the frontal projection point of the IOF to ANS and the MF to Pog were denoted as "w1" and "w2", representing the width of both points, while vertical distances were recorded as "h1" and "h2", indicating the height of both points (Fig 2). In addition, the 3D distance from MF to Pog was measured. All distances were first determined by locating the corresponding points on the 2D image, and then calculated based on the coordinates of these points. We classified the patients into three categories according to the Angle classification method by analysing the positional relationship of the maxillary and mandibular first molars on sagittal images. We then marked the FH and mandibular plane (MP) on sagittal images and measured the Frankfort-mandibular plane angle (FMA). Patients were classified as high-angle if the FMA was greater than 32 degrees, low-angle if it was less than 22 degrees, and average-angle if it was between 22 and 32 degrees.

Two independent oral radiologists with a minimum of 3 years' experience in CBCT image interpretation performed measurements individually. Intraobserver reliability was assessed by repeating measurements of 30% randomly selected samples after a 1-month interval. Another 30% subjects were randomly chosen for re-evaluations to assess inter-observer variability using intraclass correlation coefficient (ICC).

Data were collected for both sides, and side differences were analysed using a paired *t* test. The paired *t* test was also employed to analyse width differences between the IOF and MF. Sex differences were evaluated using an independent samples *t* test. A one-way between-subjects analysis of variance (ANOVA) was conducted to compare the differences in distances among different Angle classifications. Differences in distances among different facial types were also analysed using a one-way ANOVA. Statistical analyses were conducted using SPSS (version 19.0), and results with $P < 0.05$ were deemed statistically significant.

Results

This study included a total of 115 CBCT examinations from 58 men and 57 women, with a mean age of 22 years. This resulted in a sample of 230 sides for the analysis of the location of the IOF and MF.

Both intra- ($ICC \geq 0.918$, $P < 0.001$) and interobserver reproducibility ($ICC \geq 0.906$, $P < 0.001$) were excellent (Table S1 and S2, provided on request). The mean of the independent measurements taken by the two operators was adopted.

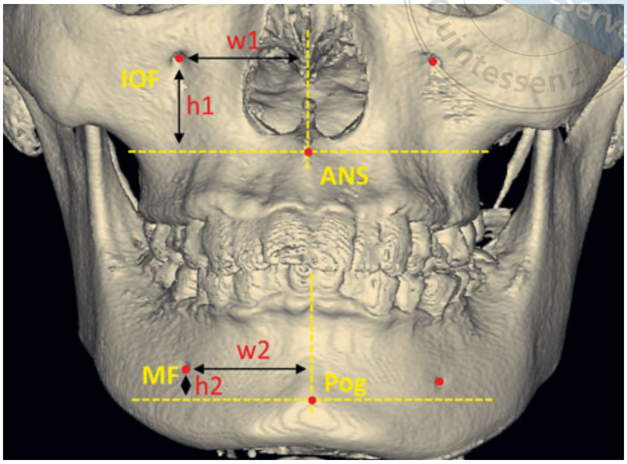

Fig 2 Measurement diagram: the width (w1) and height (h1) of the IOF to the ANS on the frontal projection, and the width (w2) and height (h2) of the MF to the Pog on the frontal projection.

On average, the ANS was positioned 21.40 mm below the IOF, with a horizontal distance of 26.42 mm. The horizontal, vertical and 3D distances between MF and Pog was 23.57, 9.71 and 29.87 mm, respectively. Men exhibited a 1.60 mm broader width of the IOF (95% confidence interval [CI] 1.06 to 2.14 mm, $P = 0.000$) and a 2.45 mm larger height of the IOF (95% CI 1.77 to 3.13 mm, $P = 0.000$) compared to women. Moreover, the 3D distance between Pog and MF was found to be 0.9 mm longer in men compared to women (95% CI 0.37 to 1.49 mm, $P = 0.000$), while no significant sex-based differences were observed for the MF in width and height (Table 1). The width of the IOF was 2.85 mm larger than that of the MF (95% CI 2.55 to 3.14 mm, $P = 0.000$) (Table 2). There were no significant differences in the distance between both sides ($P > 0.05$).

There was a significant difference in the width and the 3D distance from MF to Pog at the $P < 0.05$ level across the three Angle classifications ($P = 0.000$). Post hoc analysis with a Bonferroni correction revealed that patients with a distal molar relationship had an MF-Pog width that was 0.73 mm greater compared to those with a mesial molar relationship ($P = 0.014$) and 0.80 mm greater compared to those with a neutral molar relationship ($P = 0.000$). Additionally, the MF-Pog 3D distance in patients with a distal molar relationship was 2.16 mm longer compared to those with a mesial molar relationship ($P = 0.000$) and 1.70 mm longer compared to those with a neutral molar relationship ($P = 0.000$) (Table 3). A significant difference in the height of the MF was also observed at the $P < 0.05$ level among the three different facial types. The post-hoc Bonferroni correction indicated that patients with a low-angle

Table 1 Width and height of the IOF relative to the ANS and the MF relative to the Pog in men and women.

		Men	Women	Mean difference	95% CI	*P* value
IOF	w1 (mm)	27.21 ± 2.12	25.61 ± 2.03	1.60	1.06, 2.14	0.000
	h1 (mm)	22.61 ± 2.57	20.16 ± 2.66	2.45	1.77, 3.13	0.000
MF	w2 (mm)	23.89 ± 1.57	23.24 ± 1.40	0.65	−0.26, 1.04	0.375
	h2 (mm)	9.85 ± 2.85	9.57 ± 3.00	0.27	−0.49, 1.03	0.478
	3D (mm)	30.32 ± 2.16	29.40 ± 2.15	0.93	0.37, 1.49	0.001

Width (w1) and height (h1) of the IOF to the ANS on the frontal projection; width (w2), height (h2) and 3D distance (3D) of the MF to the Pog on the frontal projection. The width, height and 3D distance of both points were presented as mean ± standard deviation (SD) and an independent samples *t* test was applied for sex comparison.

Table 2 Width of the IOF relative to the ANS and MF relative to the Pog.

	IOF	MF	Mean difference	95% CI	*P* value
Width (mm)	26.42 ± 2.22	23.57 ± 1.52	2.85	2.55, 3.14	0.000

The width and height of both points were presented as mean ± standard deviation (SD). A paired *t* test was also adopted to analyse the width difference.

Table 3 Width and 3D distance of the MF relative to Pog in different Angle classifications.

	Class I	Class II	Class III	*P* value	P_{IandII}	$P_{IandIII}$	$P_{IIandIII}$
w2 (mm)	23.23 ± 1.55	23.30 ± 1.35	24.03 ± 1.48	0.000	1.000	0.001	0.014
3D (mm)	29.28 ± 2.00	28.81 ± 1.76	30.98 ± 2.11	0.000	0.561	0.000	0.000

The width and 3D distance of MF were presented as mean ± standard deviation (SD). A one-way between-subjects ANOVA was adopted to analyse the width and distance difference. A Bonferroni correction was used for post-hoc comparisons.

Table 4 Height of the MF relative to the Pog in different facial types.

	Group L	Group A	Group H	*P* value	P_{LandA}	P_{LandH}	P_{AandH}
h2 (mm)	8.20 ± 2.40	11.34 ± 2.47	12.30 ± 2.19	0.000	0.000	0.000	0.424

Group L, low-angle group; group A, average-angle group; group H, high-angle group. The height of the MF was presented as mean ± standard deviation (SD). A one-way between-subjects ANOVA was adopted to analyse the height. A Bonferroni correction was used for post-hoc comparisons.

facial type had an MF-Pog height that was 0.33 mm greater compared to those with an average-angle facial type (*P* = 0.000) and 0.64 mm greater compared to those with a high-angle facial type (*P* = 0.000) (Table 4).

Scatter plots centred on the ANS and Pog revealed that both the IOF and MF were distributed in a 45-degree fan shape in the superior quadrant (Fig 3 and 4). Specifically, 83% (191/230) of the IOF appeared in a 30- to 45-degree fan shape with a radius from 30 to 40 mm, and 98% (226/230) of the MF occupied a 45°-degree fan shape with a radius from 20 to 30 mm.

Discussion

Among the critical anatomical considerations in orthognathic surgery are the neurovascular bundles associated with the IOF and MF. While numerous anatomical studies have explored aspects such as the shape, extra openings and positions of these foramina relative to adjacent dental roots, these landmarks are not always visible during orthognathic procedures. Therefore, utilising readily available structures like ANS and Pog becomes pivotal for guiding orthognathic procedures.

In our study, the width of the IOF measured 26.4 mm, aligning with measurements from Indian (28.5 mm)[3] and Spanish (27.0 mm)[11] populations but slightly higher than the 24.7 mm reported in Lebanese subjects[7] using CBCT. Variations could possibly be due to racial differences and the measurement methods, as the authors obtained the relative value in an undefined coronal plane.[7] The mucoperiosteal flap on the labial buccal side of the anterior maxilla needs to be elevated to expose the inferior margin of the piriform aperture and the region 5 mm above the dental roots during Lefort I osteotomy.[5] It is important to highlight the potential risk of direct injury to infraorbital neurovascular

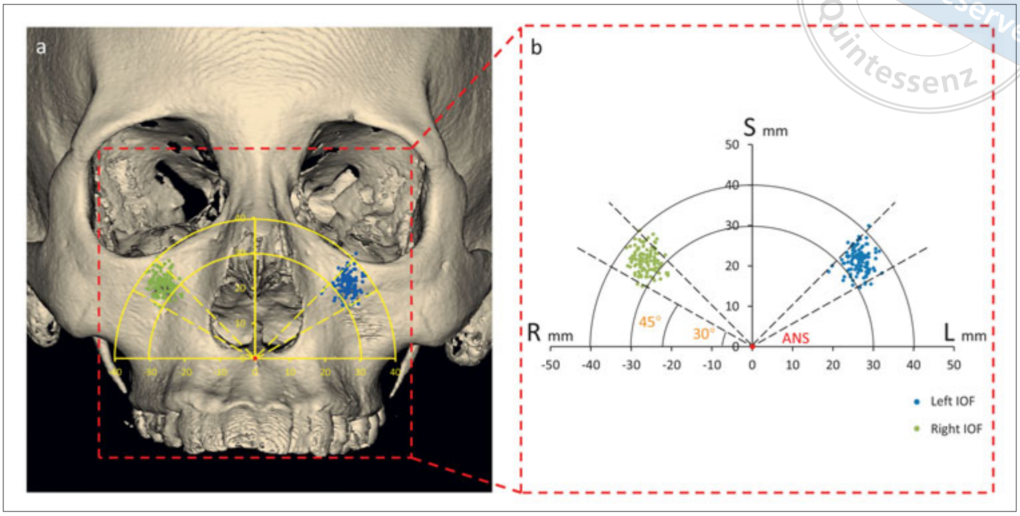

Fig 3a and b Positional relationship between the IOF and ANS. Scatter plot of the IOF relative to the ANS on the frontal projection.

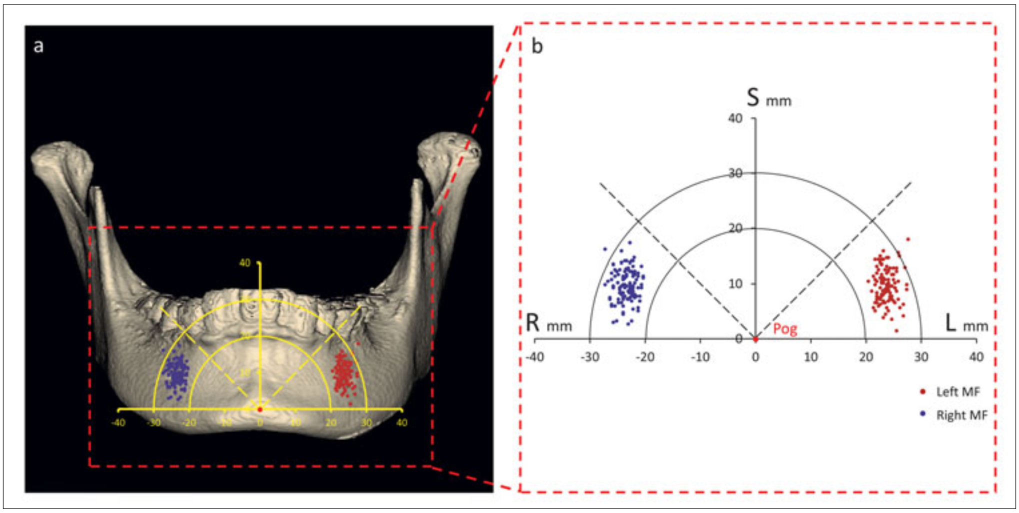

Fig 4a and b Positional relationship between the MF and the Pog. Scatter plot of the MF relative to the Pog on the frontal projection.

bundles 21.4 mm above the ANS during higher osteotomies or fixation placement, particularly in Lefort I osteotomy. Additionally, infraorbital nerve injuries, including upper lip paraesthesia, may result from traction.[2,12] Researchers have utilised the lateral marginal of the piriform aperture and the inferior rim of the orbit to locate the IOF during fracture operations.[7,8,13] A similar study, based on 518 adult crania, found that the IOF was located midway between the nasospinale and jugale[14]; however, these nearby bony landmarks might escape exposure during Lefort I osteotomy. To establish an ideal location for the IOF, we created a scatter plot diagram centred on the ANS, the most prominent identifiable hard structure in the surgical field.[15] The majority of the IOF appeared in a 30- to 45-degree fan shape in the bilateral superior quadrant, indicating that the line between the retractor and ANS should exceed 45 degrees in the mesial region and should not surpass 30 degrees in the distal region. It is advisable to follow the principle of safety when lowering the retractor, especially on the maxillary surface below the 30-degree fan shape within a 30- to 40-mm radius centred on the ANS.

The occurrence of a long-term neurosensory deficit in the lower lip has been reported to be as high as 20% after isolated genioplasty.[4] A critical intraoperative consideration is the prevention of injury, including stretching, sectioning and avulsion, to the inferior alveolar nerve adjacent to the MF. Evidence suggests that the MF is often located below the apex of the second premolar[16,17]; however, this method might not be effective in orthognathic surgery, where premolars might undergo extraction during preoperative orthodontics. In anterior mandibular orthognathic surgeries, the Pog is consistently kept exposed and intact. Hence, the present authors chose the prominent Pog as the landmark for MF location. In our study, the width of the MF measured 23.6 mm, aligning with cadaveric measurements ranging from 22.0 to 25.8 mm.[3,11] Understanding the width of the MF is crucial in defining safe areas in anterior mandibular subapical osteotomy. Additionally, the MF distribute in a 45-degree fan shape, with a radius ranging from 20 to 30 mm centred on the Pog, indicates the danger zone for elevating a mucoperiosteal flap. Minimising iatrogenic nerve injury caused by retractors and saws is feasible, as the MF can be well visualised and protected with atraumatic retraction after dissociation and exposure.[4]

Gupta[3] conducted a study measuring horizontal distances between the facial foramina and midline in 79 adult skulls, and found no sex difference in MF width (22.5 mm in men, 20.5 mm in women). The present study yielded a similar result, indicating that the width and height of the MF relative to Pog showed no sex difference; however, the 3D distance is approximately 0.9 mm longer in men than in women. This suggests that the hazardous area for flap elevation shows slight differences in the sagittal direction. Interestingly, the IOF tended to be located in a more inferior and medial position in women compared to men. Recognising sex differences in IOF width and height is crucial, as total disassociation of the IOF is necessary in certain surgeries, such as Le Fort II osteotomy. Additionally, the horizontal and vertical positional relationships of MF to Pog can be estimated separately based on different molar relationships and facial types, which holds significant clinical relevance. Nevertheless, the majority of IOF appeared in a 30- to 45-degree fan shape centred on ANS. Safe zones for retraction can be employed universally in adults undergoing anterior maxillary osteotomy or Le Fort I osteotomy.

The longitudinal axis passing through the IOF and MF tends to incline outwards as the horizontal distance from the IOF to ANS was 2.9 mm longer than that from the MF to Pog. The result obtained in the present study was contrary to the popular belief that the IOF and MF were situated on the same vertical plane.[3,18] This discrepancy may arise from considering the individual diameters of both foramina and obtaining values relative to the same midline.[3] In the present study, the foramina were positioned relative to adjacent prominent landmarks such as ANS and Pog, offering more valuable anatomical information, especially for individuals diagnosed with asymmetric dentomaxillofacial deformities.

Accessory foramina may exist, and injury to any branch could result in sensory defects.[6,8,19] The frequency and location of accessory foramina warrant thorough analysis and classification. Additionally, it is important to note that the present study was based on apparently normal samples. Patients with dentomaxillofacial deformities are pertinent candidates for orthognathic surgery, and these individuals might exhibit variants in bony structures.

Conclusion

During maxillary osteotomy, there is a potential risk of injuring infraorbital neurovascular bundles, specifically in procedures situated 21.40 mm above the ANS. To prevent injury to the IOF, it is crucial to minimise excessive flap retraction, especially beneath the 30-degree fan-shaped region within a radius of 30 to 40 mm centred on the ANS. The MF predominantly resides in the superior part relative to the Pog within a 45-degree fan-shaped area with a radius of 20 to 30 mm. Special attention should be paid to flap elevation in this particular region to ensure the safety of the procedure.

Conflicts of interest

The authors declare no conflicts of interest related to this study.

Author contribution

Drs Xin CHEN and Cheng TAO contributed to the data collection, analysis, manuscript draft and revision; Dr Tie Mei WANG contributed to the study design, supervision and manuscript revision.

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