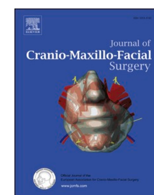
Journal of Cranio-Maxillo-Facial Surgery 53 (2025) 2320–2326

Contents lists available at ScienceDirect

Journal of Cranio-Maxillo-Facial Surgery

journal homepage: www.jcmfs.com



Temporal changes in mental foramen blood flow following orthognathic surgery

Elifhan Alagoz [a,*], Efza Dilhan Yildiz [b], Taha Pergel [c], Abdusselim Adil Peker [d], Irfan Sarica [a]

[a] Department of Oral and Maxillofacial Radiology Faculty of Dentistry, Bezmialem Vakif University, Fatih, Istanbul, 34093, Türkiye
[b] Faculty of Dentistry, Bezmialem Vakıf University, Fatih, Istanbul, 34093, Türkiye
[c] Department of Oral and Maxillofacial Surgery Faculty of Dentistry, Bezmialem Vakıf University, Fatih, Istanbul, 34093, Türkiye
[d] Department of Radiology Faculty of Medicine, Bezmialem Vakıf University. Fatih, Istanbul, 34093, Türkiye

ARTICLE INFO

Keywords:
Doppler ultrasonography
Orthognathic surgery
Mandibular blood flow
Sensory recovery
Postoperative hemodynamics

ABSTRACT

This prospective study aimed to assess temporal changes in vascularization and neurosensory function in the mental foramen region using Doppler ultrasonography (USG) and clinical sensory tests in patients undergoing orthognathic surgery. Sixteen patients with skeletal Class II or III malocclusion were included. Evaluations were performed at four time points: preoperatively (T0) and postoperatively at 1 week (T1), 1 month (T2), and 3 months (T3). Sensory assessments included pinprick, pressure (VAS), neurosensory sensitivity (VAS), brush, and two-point discrimination tests. Blood flow and mental foramen diameter were evaluated using a Philips eL18-4 MHz linear probe via Color and Power Doppler USG. Statistical analysis was performed using repeated-measures ANOVA with Greenhouse–Geisser correction or the Friedman test as appropriate; Bonferroni-adjusted post-hoc tests were applied. Accessory mental foramen was detected in 9.4 % of patients. The foramen diameter was significantly greater in males ($p = 0.025$). A significant reduction in blood flow was observed at T3 versus earlier time points ($p < 0.05$). Sensory scores showed significant time-dependent changes ($p < 0.0083$), with greatest deficits at T1 and partial recovery by T3. These findings suggest that vascular and neurosensory alterations in the mental foramen region are dynamic postoperatively. The reduction in flow at 3 months may impact long-term recovery. Doppler USG, being non-invasive and practical, offers valuable insight for surgical planning and follow-up.

1. Introduction

Orthognathic surgery is a well-established surgical approach for correcting skeletal and dentoalveolar discrepancies in the maxillofacial region, with the dual goals of improving function and aesthetics (Friedrich et al., 2024; Ngan and Moon, 2015). It plays a vital role in addressing jaw discrepancies, facial asymmetry, and malocclusions that cannot be managed by orthodontic treatment alone (Lin et al., 2025; Ngan and Moon, 2015; Vilanova et al., 2023). Surgical correction has been shown to improve mastication, speech, and appearance, contributing significantly to patients' overall quality of life (Lin et al., 2025; Vilanova et al., 2023; Zamboni et al., 2019). Among the common orthognathic techniques, Le Fort I osteotomy and bilateral sagittal split ramus osteotomy (BSSRO) are frequently employed to reposition the maxilla and mandible, respectively (Rios et al., 2022; Zawiślak et al., 2021). Bimaxillary procedures are often preferred in complex Class III skeletal patterns to achieve optimal three-dimensional harmony (Xianwen et al., 2017; Zawiślak et al., 2021).

During these interventions, the mental foramen and its neurovascular contents—including the mental nerve and vessels—may be exposed to mechanical stress or surgical trauma (Rahpeyma and Khajehahmadi, 2018; Yoshimoto et al., 2022). Such manipulations can lead to postoperative neurosensory disturbances and altered perfusion in the mental foramen region (Chhikara et al., 2023; Peleg et al., 2021; Rahpeyma and Khajehahmadi, 2018; Verweij et al., 2015; Yoshimoto et al., 2022). Accurate identification of the foramen and assessment of regional blood flow are essential to prevent or manage such complications (Çağlayan et al., 2019; Krishnan et al., 2024; Kumar et al., 2021). While modalities like CBCT or panoramic radiography are widely used for anatomical visualization, they lack the ability to dynamically assess

* Corresponding author. Department of Oral and Maxillofacial Radiology Faculty of Dentistry, Bezmialem Vakıf University Vatan Street, Adnan Menderes Avenue, Fatih, Istanbul, 34093, Türkiye.
E-mail addresses: elifhan.alagoz@bezmialem.edu.tr, dt.elifhanatlihan@gmail.com (E. Alagoz).

https://doi.org/10.1016/j.jcms.2025.11.006
Received 19 September 2025; Received in revised form 11 October 2025; Accepted 7 November 2025
Available online 19 November 2025
1010-5182/© 2025 European Association for Cranio-Maxillo-Facial Surgery. Published by Elsevier Ltd. All rights are reserved, including those for text and data mining, AI training, and similar technologies.

vascular status and involve ionizing radiation (Krishnan et al., 2024; Kumar et al., 2021; Pelé et al., 2021).

In recent years, ultrasonography (USG) has emerged as a non-invasive, radiation-free alternative for evaluating the mental foramen region (Artas and Yalcin, 2023). High-resolution linear probes allow for anatomical localization, while color Doppler USG enables real-time assessment of regional hemodynamics (Artas and Yalcin, 2023). However, studies examining vascular changes in the mental foramen post-orthognathic surgery remain limited, and most rely on subjective sensory testing without concurrent evaluation of perfusion (Baydan and Soylu, 2024, Kim et al.). To date, no comprehensive study in the literature has examined Doppler USG flow at the level of the mental foramen in relation to orthognathic surgery. Therefore, evaluating postoperative vascular changes alongside clinical sensory testing would address a significant gap in the current body of knowledge.

The aim of this study was to investigate dynamic changes in blood flow at the level of the mental foramen following orthognathic surgery using Doppler USG. Furthermore, we aimed to assess the diagnostic value of USG by correlating vascular measurements with neurosensory test outcomes.

2. Materials and methods

This prospective study included a total of 17 volunteer patients aged between 18 and 55 who presented to the Department of Oral and Maxillofacial Surgery at Bezmialem Vakif University Faculty of Dentistry between July 2024 and February 2025 with malocclusion complaints and were diagnosed with orthognathic surgery indication based on detailed clinical and radiographic evaluations. The study was approved by the Clinical Research Ethics Committee of Bezmialem Vakif University (approval number: 142577; date: 27.02.2024) and conducted in accordance with the principles of the Declaration of Helsinki. Written informed consent was obtained from all participants prior to their inclusion in the study.

2.1. Participant selection

Patients who had reached skeletal maturity, were aged between 18 and 60 years, and were diagnosed with skeletal Class II or Class III malocclusion requiring orthognathic surgery were eligible for inclusion. Exclusion criteria were the presence of systemic disease, a history of surgery or trauma in the mandibular region, preoperative neurosensory dysfunction of the inferior alveolar nerve, pregnancy or suspected pregnancy, and any local or systemic condition that may contraindicate general anesthesia.

Seventeen patients were initially included in the study. However, one patient was excluded due to failure to attend the 3-month postoperative follow-up visit, resulting in missing long-term data. Therefore, statistical analyses were performed on the data of 16 patients who completed all follow-up evaluations. The excluded patient ($n = 1$) did not differ significantly from the included participants in terms of sex (χ^2, $p = 1.000$) or skeletal malocclusion type (χ^2, $p = 1.000$). Due to single-case comparison, age was not subjected to *t*-test analysis. These findings suggest that drop-out bias is unlikely.

2.2. Data collection

All participants were initially evaluated through extraoral and intraoral examinations to determine their eligibility according to the inclusion criteria. Those deemed eligible underwent panoramic radiographic imaging (Planmeca Promax 2D, Helsinki, Finland) and a detailed clinical examination. The mental foramen, mental foramen diameter, mental artery, and arterial blood flow were assessed using USG. Additionally, subjective neurosensory tests, including the pinprick test, pressure VAS, neurosensory sensitivity VAS, two-point discrimination, and brush test, were conducted.

All individuals underwent orthognathic surgery at the Bezmialem Vakif University, and were assessed at four time points: preoperatively (T0), and postoperatively at 1 week (T1), 1 month (T2), and 3 months (T3). At each time point, the same radiological and clinical evaluations were repeated.

2.3. Orthognathic surgery protocol

Orthognathic surgeries were performed under general anesthesia following comprehensive orthodontic and radiological planning. Preoperatively, the oral cavity was disinfected, and sterile drapes were used to isolate the surgical field. For maxillary access, a horizontal vestibular incision was made, followed by Le Fort I osteotomy using a piezoelectric device. Mobilization was achieved via dissection of the piriform aperture, zygomaticomaxillary suture, and pterygomaxillary region. The repositioned maxilla was fixed using titanium plates and screws, with bone grafts applied when necessary.

Mandibular surgery involved a BSSRO. A vestibular incision provided access to the ramus, and osteotomy lines were created using a surgical bur. The anterior segment was repositioned and aligned with the posterior segment, then fixed rigidly. The inferior alveolar nerve (IAN) was classified into six categories based on position, dissection, and trauma:

IAN 1: Remained in the distal segment, not visualized.

IAN 2: Remained in the distal segment, visualized.

IAN 3: In the proximal segment, dissected without damage, repositioned distally.

IAN 4: In the proximal segment, sheath damaged, repositioned after dissection.

IAN 5: In the proximal segment, continuity preserved but injured, then repositioned.

IAN 6: Nerve continuity completely disrupted.

In this study, only IAN types 1 to 3 were observed; types 4 to 6 did not occur.

In bimaxillary procedures, the maxilla was repositioned prior to the mandible. Intraoperative splints were used when needed, and occlusion was carefully verified. Postoperative care included intravenous fluids, antibiotics, and analgesics. Patients were initially placed on a liquid diet, with intermaxillary elastics guiding occlusion. Functional chewing resumed after 4–6 weeks, and orthodontic treatment continued in the postoperative phase.

2.4. Ultrasonographic imaging and evaluation

Mental foramen diameter and vascular flow measurements were performed at the Department of Radiology, Faculty of Medicine, Bezmialem Vakif University, using a Philips PureWave ultrasound device (France). Evaluations were conducted at four time points: T0, T1, T2 and T3.

Ultrasonographic imaging was carried out extraorally using a linear probe (Philips eL18-4 MHz, France). To ensure optimal acoustic coupling, a water-based ultrasound gel (Naturel, Türkiye) was applied between the probe and skin. Patients were examined in a seated position, and both right and left mental foramen regions were evaluated separately. The probe was positioned over the mental foramen region extraorally and images were obtained in both transverse and longitudinal planes. The clearest image of the mental foramen was frozen, and vertical and horizontal diameters were measured (Fig. 1). Mental artery blood flow was assessed using color Doppler and power Doppler modes (Fig. 2).

To ensure standardization, the pulse repetition frequency (PRF) was set to 1300, and the Doppler gate was adjusted to 1.0 mm. The wall-filter was set to 28 Hz for color Doppler and 40 Hz for pulsed Doppler evaluations. The angle of insonation was maintained below 60° during all Doppler measurements to enhance signal quality and reproducibility. Blood flow in the mental artery was assessed using both color and power

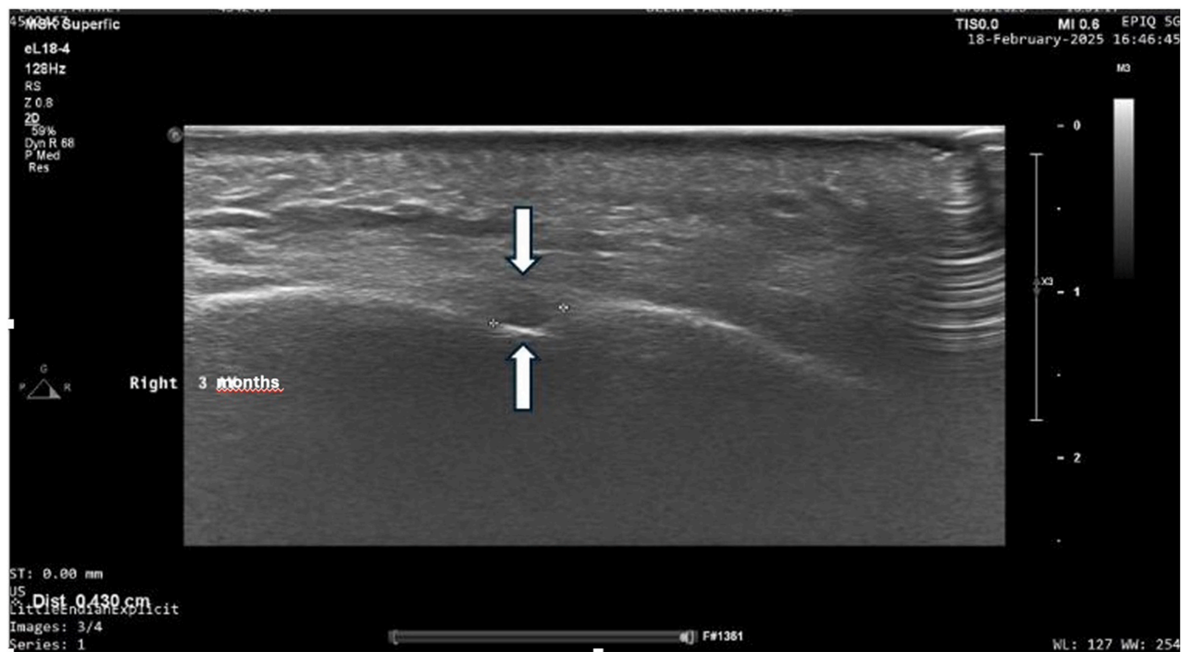


Fig. 1. Ultrasound image showing the right mental foramen (white arrow) and the measurement of its transverse diameter using a high-frequency linear transducer.

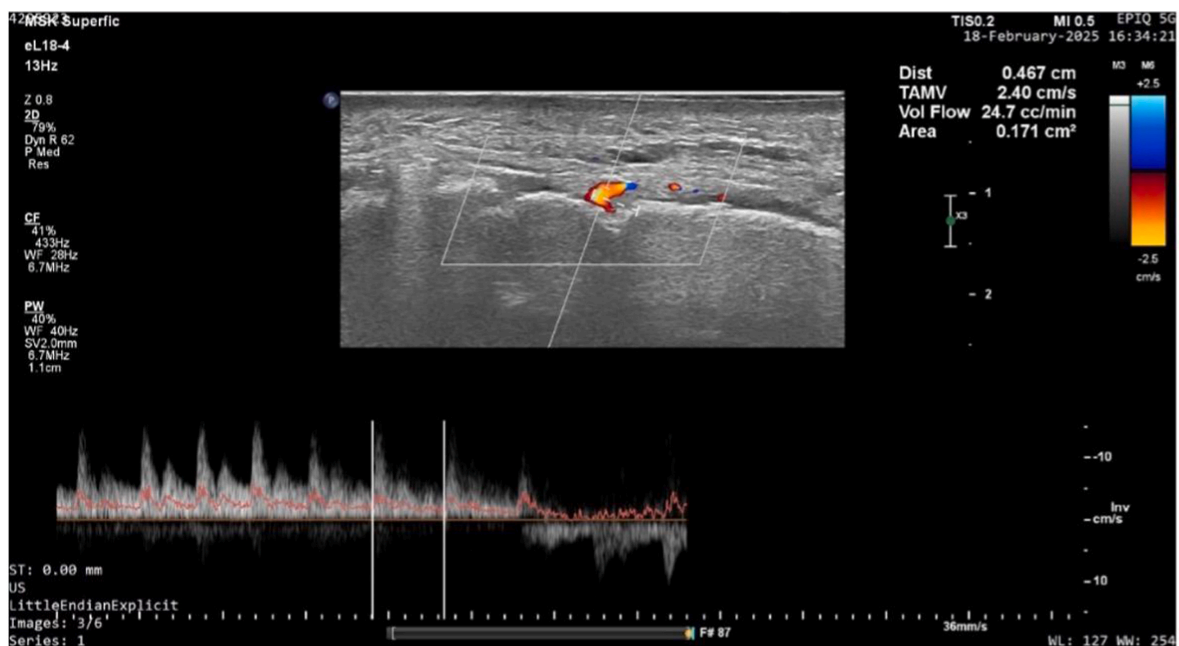


Fig. 2. Spectral and color Doppler ultrasound image showing the flow velocity within the mental foramen. Time-averaged mean velocity (TAMV) = 2.40 cm/s; volume flow = 24.7 cc/min; mental foramen diameter = .467 cm; cross-sectional area = .171 cm^2.

Doppler modes, and volume flow values were recorded in cc/min. Measurements were performed separately for the right and left sides, and the values were used for statistical analysis. All ultrasonographic evaluations were conducted by two expert oral and maxillofacial radiologists with 8 (E.A.) and 9 (I.S.) years of experience, respectively.

2.5. Neurosensory evaluation protocol

Before initiating neurosensory tests during the preoperative examination, each patient was thoroughly informed about the procedures at the Department of Oral and Maxillofacial Radiology, Faculty of Dentistry, Bezmialem Vakif University. During the tests, the patient's eyes were kept closed.

In the two-point discrimination test, the area between the lower lip and chin was divided in half, and each half was further subdivided into nine equal regions using a pencil. A periodontal probe was used to gently touch these points, and the patient was asked whether they could distinguish the differences, thereby identifying potential sensory loss.

In the brush test, a soft bond brush was gently stroked across the perioral region of the lower lip to evaluate the patient's ability to differentiate between the right and left sides.

In the pinprick test, the patient was asked to rate the pain intensity caused by light needle-tip pricks applied intraorally to the right and left anterior regions on a 0 to 5 Visual Analog Scale (VAS).

For pressure sensitivity testing, gentle pressure was applied to the corresponding region using the back of a dental mirror, and the patient's sensory response was rated on a VAS from 0 to 5.

All neurosensory and radiographic evaluations were performed at four time points: preoperatively (T0), postoperative 1st week (T1), 1st month (T2), and 3rd month (T3).

VAS Scoring Scale (1–5) for Pain, Pressure, and Neurosensory sensitivity.

1 No sensation at all
2 Almost no sensation
3 Decreased sensation
4 Almost normal sensation
5 Normal sensation

2.6. Statistical analysis

All statistical analyses were performed using IBM SPSS Statistics for Windows, Version 28.0 (IBM Corp., Armonk, NY, USA). Normality of data distribution was tested using the Shapiro–Wilk test, and sphericity was verified using Mauchly's test. When the assumption of sphericity was violated, the Greenhouse–Geisser correction was applied. Independent samples *t*-test was used for comparisons between two groups, and Spearman correlation analysis was applied to evaluate the relationship between continuous variables. Pearson Chi-square test was used to determine the relationship between categorical variables.

Repeated measurements over time were analyzed using repeated measures ANOVA with Greenhouse–Geisser correction. When a statistically significant main effect was found, Bonferroni-adjusted post-hoc tests were conducted, and the significance level was set at $p < 0.05$.

For non-parametric repeated measurements related to neurosensory testing (pinprick, pressure, neurosensory sensitivity, and two-point discrimination), the Friedman test was used. Pairwise comparisons between time points were performed using the Wilcoxon Signed-Rank test, and Bonferroni correction was applied only to these four comparisons, with the adjusted significance level set at $p < 0.0083$. Effect sizes were calculated for all significant time effects using partial eta squared (η^2p) for ANOVA and Cohen's dz for paired comparisons, accompanied by 95 % confidence intervals (CI). For all other analyses, $p < 0.05$ was considered statistically significant.

2.7. Power analysis

A post-hoc power analysis was performed to determine whether the study sample size was sufficient to detect temporal changes across the four follow-up periods (T0–T3). Effect sizes were derived from repeated-measures ANOVA and paired t-tests for each primary and secondary outcome variable. Within-subject effects were expressed as partial eta squared (η^2p), and paired comparisons between baseline (T0) and the late postoperative phase (T3) were further quantified using Cohen's dz with corresponding 95 % confidence intervals (95 % CI).

For the mean mental artery flow, a large effect size was observed ($\eta^2p = 0.65$; dz = 1.34; 95 % CI [.69–1.98]) with an observed power of .99 (n = 12).

For the two-point discrimination test, a similarly large effect was found ($\eta^2p = 0.61$; dz = 1.30; 95 % CI [.73–1.87]) with an observed power of 1.00 (n = 16).

For the neurosensory sensitivity test, a large within-subject time effect was also present ($\eta^2p = 0.59$; dz = 1.12; 95 % CI [.55–1.69]) with an observed power of .98 (n = 16).

For the pinprick test, the observed time effect remained large ($\eta^2p = 0.57$; dz = 1.05; 95 % CI [.51–1.59]) with an observed power of .97 (n = 16).

All observed power values exceeded the conventional .80 threshold, confirming that the study was adequately powered to detect clinically meaningful changes across time. Therefore, the sample size was considered statistically sufficient to support the validity and reproducibility of the reported findings within this prospective controlled design.

3. Results

A total of 16 participants (11 females, 5 males) aged 18–55 years (mean age: 25.19 ± 9.15) were included. Of the 32 hemimandibles evaluated, 3 (9.4 %) exhibited accessory mental foramen (AMF). Skeletal Class II malocclusion was present in 5 individuals (31.3 %) and Class III in 11 (68.8 %). The mean diameter of the mental artery was 3.80 ± .59 mm (range: 2.50–5.00 mm).

The mental foramen diameter was significantly larger in males (4.15 ± .59 mm) than in females (3.64 ± .53 mm) ($p = 0.025$). No statistically significant sex-related differences were observed in mean blood flow values or any sensory test parameters ($p > 0.05$). Spearman correlation showed no significant relationship between age and variation (r = .082, $p = 0.657$). A significant association was identified between sex and intraoperative IAN status ($\chi^2 (2) = 6.49$, $p = 0.039$), with the nerve more frequently dissected and repositioned in females (Table 1).

No significant differences were found between malocclusion type and mental foramen flow values at any time point (T0–T3), although a moderate, non-significant effect size was seen at T3 (Cohen's d = −.53, $p = 0.134$). Repeated-measures ANOVA (Greenhouse–Geisser correction) revealed a significant decrease in mean blood flow over time ($F (1.38, 13.79) = 7.13$, $p = 0.013$). Post-hoc Bonferroni tests indicated that T3 flow was significantly lower than at T0, T1, and T2 ($p < 0.05$), while no differences were found among T0–T2 (Table 2).

For neurosensory parameters, the Friedman test indicated significant time-dependent changes in all measures. Pinprick test: $\chi^2 (3) = 54.55$, $p < 0.001$, with the lowest scores at T1 and partial recovery by T3. Pressure VAS: $\chi^2 (3) = 60.76$, $p < 0.001$, lowest at T1; recovery observed at T3 but not fully reaching baseline. Neurosensory sensitivity: $\chi^2 (3) = 56.24$, $p < 0.001$, improving at T3 but remaining below T0. Two-point discrimination: $\chi^2 (4) = 50.46$, $p < 0.001$, highest thresholds at T1, approaching baseline by T3 ($p = 0.199$). (Table 3).

4. Discussion

This prospective study demonstrated that postoperative vascular and sensory changes in the mental foramen region are dynamic. A statistically significant reduction in blood flow was detected at postoperative month 3, suggesting underlying neurovascular remodeling or transient vascular dysregulation that may delay neurosensory recovery. Doppler ultrasonography proved valuable not only for anatomical localization of the mental foramen but also for dynamic perfusion assessment. Its non-invasive and real-time application supports individualized follow-up and informed decision-making for secondary interventions such as implant placement.

AMF is an anatomically significant variation with clinical

Table 1
Association between gender and the status of the mandibular nerve during surgery.

		IAN 1	IAN 2	IAN 3	Total
Gender	Female	4	3	15	22
	Male	4	4	2	10
Total		8	7	17	32

	Value	df	Asymptotic Significance (2-sided)
Pearson Chi-Square	6.498[a]	2	.039*
Likelihood Ratio	6.783	2	.034
Linear-by-Linear Association	4.648	1	.031
N of Valid Cases	32		

Pearson Chi-Square a. 3 cells (50.0 %) have expected count less than 5. The minimum expected count is 2.19.

Table 2
Inter-timepoint comparison of changes in mental foramen blood flow.

(I) Time mean ± SD(I)	(J) Time	Mean Difference (I-J)	Std. Error	Sig.[b]	95 % Confidence Interval for Difference[b]	
					Lower Bound	Upper Bound
T0 .06 ± .04	T1	−.025	.027	1.000	−.112	.062
	T2	−.010	.019	1.000	−.071	.050
	T3	.051[a]	.014	.033[a]	.004	.097
T1 .09 ± .05	T0	.025	.027	1.000	−.062	.112
	T2	.015	.010	.879	−.016	.046
	T3	.076[a]	.018	.012[a]	.016	.136
T2 .07 ± .03	T0	.010	.019	1.000	−.050	.071
	T1	−.015	.010	.879	−.046	.016
	T3	.061[a]	.012	.003[a]	.022	.099
T3 .01 ± .01	T0	−.051[a]	.014	.033[a]	−.097	−.004
	T1	−.076[a]	.018	.012[a]	−.136	−.016
	T2	−.061[a]	.012	.003[a]	−.099	−.022

Based on estimated marginal means.
[a] The mean difference is significant at the .05 level.
[b] Adjustment for multiple comparisons: Bonferroni.

implications, particularly during procedures involving the mandibular neurovascular bundle such as implant placement and orthognathic surgery. Studies have reported considerable variability in AMF prevalence and location. In a Turkish cohort, Çoban et al. (Coban et al., 2025) reported a prevalence of 13 %, with most AMFs located posteroinferior to the mental foramen. Our study identified AMF in 9.4 % of patients, without significant associations with age or sex. Although precise localization was not subclassified, the observed frequency aligns with previous reports. Variations in prevalence may reflect differences in sample size, imaging technique, or inclusion criteria. These findings reinforce the importance of detailed preoperative radiographic assessment to identify AMF and minimize the risk of iatrogenic complications.

Accurate evaluation of the IAN is essential for reducing complications in orthognathic surgery. The proximity of the IAN to mandibular cortical structures can influence nerve injury risk, as demonstrated by Wittwer et al., (2012), who found a 60 % injury likelihood when the nerve was near the buccal cortex during BSSRO. Similarly, Shaik et al., (2017) confirmed the predictive value of CT imaging in correlating with intraoperative nerve findings. In our study, we used a six-type intraoperative classification across 32 mental foramen regions. Most cases were classified as type 3, with the nerve remaining in the proximal segment and being transferred safely. No significant associations were found between IAN position and either volume flow or malocclusion. However, a significant sex-related difference emerged: female patients more frequently required nerve dissection and repositioning ($p = 0.039$). This contrasts with previous literature, which focused on imaging-based geometric assessments. Our intraoperative approach offers direct insight into nerve behavior during surgery and suggests that sex may influence nerve positioning. These findings highlight the importance of both preoperative radiographic imaging and intraoperative classification systems to optimize surgical planning, minimize iatrogenic injury, and enhance procedural safety.

The evaluation of vascular dynamics in the mental foramen region holds clinical importance, particularly for neural regeneration, postoperative healing, and implant-related surgical planning. However, existing studies are limited and largely qualitative, often categorizing blood flow as “strong” or “weak,” which restricts detailed understanding of perfusion changes over time. Caglayan et al. (Çağlayan et al., 2019) assessed 60 mental foramina and reported 52 with strong and 8 with weak flow; Baladi et al., (2015) found 18 strong and 12 weak patterns in patients over 60; Eiseman et al., (2005) reported strong flow in 11 of 12 patients under 65 and in 9 of 19 over 65. Artas et al. (Artas and Yalcin, 2023) observed strong flow in only 25.8 % of 120 foramina. These studies, however, lacked temporal assessment and objective quantification. In contrast, our study performed quantitative Doppler ultrasonographic evaluations at four time points—preoperatively (T0), and at postoperative week 1 (T1), month 1 (T2), and month 3 (T3) —in 32 mental foramina of 16 orthognathic surgery patients. A slight increase in blood flow volume was observed at T1 compared to T0, followed by a minor decline at T2, although still higher than baseline. These changes were not statistically significant ($p > 0.05$). However, a significant reduction in vascular flow was recorded at T3 compared to all prior time points ($p < 0.05$). The observed decrease in perfusion at T3 may be explained by mechanisms such as transient sympathetic hyperactivity, which impairs microcirculation and promotes tissue edema, or by structural changes including microvascular remodeling and perivascular fibrosis (Li et al., 2017; Wang et al., 2025). This suggests a potential decline in regional perfusion during the late postoperative period, which may have clinical implications not only for neural regeneration but also for implant planning and pre-prosthetic soft-tissue grafting, as reduced flow may compromise graft take and tissue healing. Unlike previous studies, which generally provided single-time-point and qualitative assessments, our study offers a time-dependent quantitative analysis, addressing a notable gap in the literature. The key distinction lies in our objective documentation of dynamic flow changes over time. Differences between our findings and previous research may stem from the surgical patient population included, the longitudinal design, and the use of quantitative Doppler parameters. Taken together, our results provide novel insight into the temporal vascular response of the mental foramen region following orthognathic procedures.

The dimensional evaluation of the mental foramen is clinically important for procedures such as implant placement, surgical planning, and endodontics. Multiple studies have compared mental foramen dimensions across imaging modalities, including CBCT, panoramic radiography, and USG(Artas and Yalcin, 2023; Çağlayan et al., 2019; Kalender et al., 2012, Kökten et al., 2012). Artaş et al. (Artas and Yalcin, 2023) reported horizontal diameters of 4.14 ± .86 mm (USG) and 4.62 ± .78 mm (CBCT), indicating a slight underestimation by USG. Kalender et al., (2012) found mean diameters of 3.4 ± .8 mm (transverse) and 3.7 ± .7 mm (vertical) via CBCT, while Kökten et al. (Kökten et al., 2012) reported values of 3.39 mm on dry mandibles and 4.06 mm on radiographs. In contrast, Caglayan et al. (Çağlayan et al., 2019) observed no

Table 3
Evaluation of pinprick test, pressure VAS, neurosensory sensitivity VAS, and two-point discrimination results over time.

	Mean Rank		Mean Rank		Mean Rank		Mean Rank
T0 Pinprick	3,53	T0 Pressure Test	3,55	T0 Neurosensory sensitivity	3,66	T0/Two point discrimination	1,69
T1 Pinprick	1,63	T1 Pressure Test	1,55	T1 Neurosensory sensitivity	1,84	T1/Two point discrimination	3,59
T2 Pinprick	2,08	T2 Pressure Test	2,06	T2 Neurosensory sensitivity	1,77	T2/Two point discrimination	2,94
T3 Pinprick	2,77	T3 Pressure Test	2,84	T3 Neurosensory sensitivity	2,73	T3/Two point discrimination	1,78
N	32	N	32	N	32	N	16
Chi-Square	54,551	Chi-Square	60,756	Chi-Square	56,244	Chi-Square	50,463
Df	3	Df	3	Df	3	Df	4
Asymp. Sig. Pinprick	<,001*	Asymp. Sig. Pressure	<,001*	Asymp. Sig. Neurosensory sensitivity	<,001*	Asymp. Sig. Two point discrimination	<,001*

Friedman Test *$p < 0.05$.

significant difference between USG and CBCT, supporting USG's diagnostic reliability. In our study, USG was used to measure only transverse diameters, revealing significantly larger values in males (4.15 ± .59 mm) than females (3.64 ± .53 mm; p = 0.025). These findings align with prior data from Artaş et al. (Artas and Yalcin, 2023) for male patients. Variations in female measurements may reflect demographic differences or technical factors. Comparisons with dry bone studies suggest that tissue absence may reduce apparent diameter. Collectively, our results support USG as a reliable modality and reveal gender-related anatomical differences.

The evaluation of neurosensory disturbances after orthognathic surgery is essential for assessing both surgical success and postoperative prognosis. Accordingly, there has been an increasing focus in the literature on longitudinal studies assessing temporal changes in sensory function. In a 2024 study by Baydan et al. (Baydan and Soylu, 2024) the effectiveness of two types of laser therapy and vitamin B complex supplementation was compared in the treatment of lower lip paresthesia. Several neurosensory tests—including two-point discrimination, pinprick, and brush tests—were administered at frequent intervals in the early postoperative period (days 3, 5, 7, and 9). While statistically significant differences were found between treatment groups at some points (e.g., at point C in the pinprick test), these results had limited generalizability due to the short follow-up duration. In contrast, our study employed a broader range of neurosensory tests—pinprick, pressure sensitivity, general neurosensory sensitivity, and two-point discrimination—at extended intervals (preoperative, 1 week, 1 month, and 3 months postoperatively) to assess the natural course of sensory recovery. Significant temporal changes were observed across all sensory parameters, providing a comprehensive view of how neurosensory sensitivity evolves during the healing process. Notably, the most pronounced sensory deficits were recorded at T1, suggesting that the early postoperative phase is critical for neurosensory impairment. The use of multiple complementary tests allowed for a multidimensional evaluation of sensory recovery. Although our study and the study by Baydan et al. (Baydan and Soylu, 2024) share similar testing methodologies, the primary distinction lies in their focus: while the former assessed the response to therapeutic interventions, our investigation monitored spontaneous recovery without any targeted treatment. Differences in follow-up intervals and the presence or absence of interventions likely account for the discrepancies in outcomes. Taken together, our findings contribute valuable insight to the literature by offering a long-term evaluation of postoperative neurosensory changes following orthognathic surgery.

This study has several limitations. The relatively small sample size and unequal sex distribution may limit generalizability, although the post-hoc power analysis confirmed adequate sensitivity for detecting clinically meaningful temporal effects. Doppler USG is inherently operator-dependent, and small variations in probe angulation could influence measurements. Additionally, follow-up was limited to 3 months; longer observation may reveal further vascular stabilization or neural recovery. Future studies incorporating neurophysiological methods (e.g., electromyography or nerve conduction testing) and multicenter designs are recommended to validate and expand upon the present findings.

This study provides one of the first quantitative, time-dependent evaluations of vascular and sensory changes in the mental foramen region after orthognathic surgery. Doppler USG revealed a significant decline in flow at 3 months, while sensory tests showed partial but incomplete recovery. These results underscore the complementary value of Doppler USG and clinical neurosensory testing for postoperative neurovascular monitoring. Integrating these modalities may improve risk assessment and guide individualized rehabilitation and surgical planning.

Trial registration

This study is registered in the ClinicalTrials.gov database (NCT06661798).

Funding sources

This research did not receive any specific grant from funding agencies in the public, commercial, or not-for-profit sectors.

Conflict of interest

None.

Acknowledgements

None.

References

Artas, A., Yalcin, E.D., 2023. Evaluation of the validity of mental foramen USG measurements by comparison with CBCT and determination of blood flow. Oral Radiol. 39, 699–707.

Baladi, M.G., Tucunduva Neto, R.R., Cortes, A.R., Aoki, E.M., Arita, E.S., Freitas, C.F., 2015. Ultrasound analysis of mental artery flow in elderly patients: a case-control study. Dentomaxillofacial Radiol. 44, 20150097.

Baydan, E., Soylu, E., 2024. Investigation of the efficacy of two different laser types in the treatment of lower lip paresthesia after sagittal split ramus osteotomy. Laser Med. Sci. 39, 23.

Chhikara, D., Singh, V., Bhagol, A., Dahiya, A., 2023. Mental nerve shielding from possible injury during mandibular surgical procedures. Int. J. Oral Maxillofac. Surg. 52, 1071–1073.

Coban, D., Unal Erzurumlu, Z., Sadik, E., Yasa, Y., 2025. Evaluation of mental foramen and accessory mental foramen using cone beam computed tomography in a Turkish population. BMC Med. Imag. 25, 140.

Çağlayan, F., Sümbüllü, M.A., Akgül, H.M., 2019. Is ultrasonography sufficient for evaluation of mental foramen? Dentomaxillofacial Radiol. 48, 20180252.

Eiseman, B., Johnson, L.R., Coll, J.R., 2005. Ultrasound measurement of mandibular arterial blood supply: techniques for defining ischemia in the pathogenesis of alveolar ridge atrophy and tooth loss in the elderly? J. Oral Maxillofac. Surg. 63, 28–35.

Friedrich, C., Graw, C., Kröplin, J., 2024. A narrative review of present knowledge and digital approaches in orthognathic surgery. Innov. Surg. Sci. 9, 175–179.

Kalender, A., Orhan, K., Aksoy, U., 2012. Evaluation of the mental foramen and accessory mental foramen in Turkish patients using cone-beam computed tomography images reconstructed from a volumetric rendering program. Clin. Anat. 25, 584–592.

Kim J, Yang H, Chung JH. Orthognathic surgery of Goldenhar syndrome patient with absent bilateral mental foramina. J. Craniofac. Surg.:10.1097.

Kökten, G., Büyükertan, M., ve Balcıoğlu, H., 2012. Foramen mentale'nin çap Ve lokalizasyonunun kuru kemik Ve panoramik radyografide Karşılaştırılması/kuru Mandibulalarda Ve panoramikte mental foramenin çapı Ve Konumunun karşılaştırılması. İstanbul Üniversitesi Diş Hekimliği Fakültesi Dergisi 38 (3–4), 57–63.

Krishnan, D.T., Joylin, K., Deepak, J.H., Ilango, S., Al Hamad, K., Shanab, H., Salama, M. H., Jayakumar, S., Murugan, K., 2024. Assessment of the anterior loop and pattern of entry of mental nerve into the mental foramen: a radiographic study of panoramic images. Cureus 16.

Kumar, D., Brar, R., Ahmad, T., Narad, C., Sodhi, S., Kaur, A., 2021. Assessment of the anterior and caudal extent of inferior alveolar nerve canal, location of inferior alveolar canal and mental foramen, and the depth of submandibular fossa using computed tomography. Natl. J. Maxillofac. Surg. 12, 380–386.

Li, P., Huang, P.-P., Yang, Y., Liu, C., Lu, Y., Wang, F., Sun, W., Kong, X.-Q., 2017. Renal sympathetic denervation attenuates hypertension and vascular remodeling in renovascular hypertensive rats. J. Appl. Physiol. 122, 121–129.

Lin, C., Zhang, J., Zheng, M., Li, M., Zhu, C., Wan, Q., 2025. Factors influencing the quality of life among orthognathic patients: a systematic review and meta-analysis. EJO (Eur. J. Orthod.) 47, cjaf034.

Ngan, P., Moon, W., 2015. Evolution of Class III treatment in orthodontics. Am. J. Orthod. Dentofacial Orthop. 148, 22–36.

Pelé, A., Berry, P.A., Evanno, C., Jordana, F., 2021. Evaluation of mental foramen with cone beam computed tomography: a systematic review of literature. Radiol. Res. Pract. 2021, 8897275.

Peleg, O., Mahmoud, R., Shuster, A., Arbel, S., Manor, Y., Ianculovici, C., Kleinman, S., 2021. Orthognathic surgery complications: the 10-year experience of a single center. J. Cranio-Maxillofacial Surg. 49, 891–897.

Rahpeyma, A., Khajehahmadi, S., 2018. Accessory mental foramen and maxillofacial surgery. J. Craniofac. Surg. 29, e216–e217.

Rios, O., Lerhe, B., Chamorey, E., Savoldelli, C., 2022. Accuracy of segmented le fort I osteotomy with virtual planning in orthognathic surgery using patient-specific implants: a case series. J. Clin. Med. 11, 5495.
Shaik, K.V., Mohan, A.P., Kumar, J., Chari, H., 2017. Pre-operative assessment of anatomical position of inferior alveolar nerve and its significance in bilateral sagittal split osteotomy. J. Maxillofac. Oral Surg. 16, 453–464.
Verweij, J.P., Mensink, G., Fiocco, M., van Merkesteyn, J.R., 2015. Morphological features of the mandible as predictors for neurosensory disturbances after bilateral sagittal split osteotomy. J. Cranio-Maxillofacial Surg. 43, 1710–1715.
Vilanova, I.D., Almeida, S.B., de Araujo, V.S., Santos, R.S., Schroder, A.G.D., Zeigelboim, B.S., Correa, CdC., Taveira, K.V.M., de Araujo, C.M., 2023. Impact of orthognathic surgery on voice and speech: a systematic review and meta-analysis. EJO (Eur. J. Orthod.) 45, 747–763.
Wang, J.-X., Xu, X.-Y., Wang, Y.-M., Chen, A.-D., Li, Y.-H., Zhu, G.-Q., Xiong, X.-Q., 2025. Superior cervical ganglionectomy attenuates vascular remodeling in spontaneously hypertensive rats. J. Hypertens. 43, 236–245.
Wittwer, G., Adeyemo, W.L., Beinemann, J., Juergens, P., 2012. Evaluation of risk of injury to the inferior alveolar nerve with classical sagittal split osteotomy technique and proposed alternative surgical techniques using computer-assisted surgery. Int. J. Oral Maxillofac. Surg. 41, 79–86.
Xianwen, L., Weijian, A., Huixi, Z., Yunfeng, L., Shuguang, L., 2017. Evaluation for vertical stability after various orthognathic surgical treatment plans for skeletal class III malocclusion with anterior open-bite. Hua xi kou Qiang yi xue za zhi= Huaxi Kouqiang Yixue Zazhi= W. China J. Stomatol. 35, 484–488.
Yoshimoto, M., Marques, G.B., Andrade, M., Shinohara, E.H., 2022. Inferior alveolar nerve lateralization surgery for implant installation in atrophic posterior mandible with accessory mental foramen: a challenge for the usual technique. J. Craniofac. Surg. 33, e255–e257.
Zamboni, R., de Moura, F.R.R., Brew, M.C., Rivaldo, E.G., Braz, M.A., Grossmann, E., Bavaresco, C.S., 2019. Impacts of orthognathic surgery on patient satisfaction, overall quality of life, and oral health-related quality of life: a systematic literature review. Int. J. Dent. 2019, 2864216.
Zawiślak, E., Przywitowski, S., Olejnik, A., Gerber, H., Golusiński, P., Nowak, R., 2021. Current trends in orthognathic surgery in Poland—A retrospective analysis of 124 cases. Appl. Sci. 11, 6439.