Research Paper

Anatomical Variationsin ChampyInterforaminal Fixation: Accessory Mental Foramina, Bone Thickness in a South African Cohort

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ABSTRACT

Introduction: The mandible represents the predominant site of fractures within the maxillofacial complex, with its body exhibiting the highest incidence. The clinical application of the champy technique, which utilizes monocortical screws and miniplates for osteosynthesis, is complicated by the presence of accessory mental foramina (AMF), posing significant risks during interforaminal fracture management. This study aimed to quantify the risk of iatrogenic injury during interforaminal fracture fixation using the Champy technique in a South African cohort by analyzing AMF prevalence, spatial relationships, and minimum buccal bone (MBB) thickness.

Methods: A morphometric analysis of 213 dry hemimandibles was conducted. AMF continuity with the mandibular canal was verified via latex injection. MBB thickness was measured at three horizontal planes (superior, foraminal, and inferior) relative to the mental foramen. Data were analyzed using IBM SPSS software, version 25. Normality was assessed via Shapiro-Wilk tests. MBB thickness comparisons across planes employed one-way analysis of variance (ANOVA) with Tukey post-hoc pairwise testing. Independent t-tests evaluated bilateral differences, while injury risks for screw lengths (4–7 mm) were calculated as a percentage of screw overlaps with vital structures relative to the total number of screw sites. G*Power software, version 3.1. was used for power analysis followed with a post hoc power analysis; mean values and standard deviations (in mm) were calculated with a 95% confidence interval (CI), while P<0.05 was considered statistically significant.

Results: AMF prevalence was 6.54% (right) and 6.60% (left), with one AMF (0.93%) near a screw site. The foraminal plane had the thickest MBB (left: 6.91±2.08 mm; right: 6.69±2.04 mm) and lowest injury risk (3.44–7.55%). The inferior plane showed higher risks (up to 33.02%).

Conclusion: The foraminal plane is the safest for miniplate placement. By tailoring the champy technique to the unique anatomical characteristics of the South African population, surgeons can enhance the safety and efficacy of interforaminal fracture fixation, ultimately reducing the risk of iatrogenic injuries.

Keywords:
Interforaminal fracture, Iatrogenic injury, Accessory mental foramen (AMF), Champy technique, Buccal bone thickness

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Introduction

The mandible, despite its biomechanical resilience, is the most frequently fractured facial bone, with interforaminal fractures presenting unique surgical challenges due to their proximity to critical neurovascular structures, such as the inferior alveolar nerve (IAN) and accessory mental foramina (AMF) [1]. The Champy technique, which utilizes monocortical screws and miniplates for fracture fixation, relies heavily on precise anatomical knowledge to minimize the risk of iatrogenic injury to these structures [2]. However, the prevalence and anatomical characteristics of AMF vary significantly across populations, with global studies reporting AMF prevalence rates ranging from 1% to 21% [3–5]. In South Africa, data on AMF remain limited, with one study [6] reporting a prevalence of 21.38% but failing to confirm the continuity of AMF with the mandibular canal. This gap in region-specific anatomical data underscores the need for detailed studies to inform safer surgical practices.

We hypothesize that the prevalence and spatial relationships of AMF, as well as the minimum buccal bone (MBB) thickness in the interforaminal region, vary significantly in the South African population, and that these variations have critical implications for the risk of iatrogenic injury during interforaminal fracture fixation using the Champy technique.

Region-specific anatomical studies are essential for optimizing surgical outcomes, as variations in neurovascular anatomy can directly influence the risk of complications such as nerve injury, hemorrhage, or implant failure [7-9]. For instance, the presence of AMF, particularly those continuous with the mandibular canal, may increase the risk of IAN injury during screw placement if not properly identified preoperatively [9]. Similarly, inadequate buccal bone thickness can compromise the stability of miniplates and screws, leading to fixation failure [10]. In South Africa, where trauma-related mandibular fractures are prevalent due to high rates of interpersonal violence and road traffic accidents [11]. Understanding these anatomical variations is crucial for improving surgical planning and reducing postoperative complications. This study investigates AMF prevalence, spatial relationships, and buccal bone thickness to predict injury risks during interforaminal fracture fixation.

Materials and Methods

Ethical approval

This study was conducted in accordance with ethical standards for research involving human cadaveric specimens.

Sample preparation

A total of 120 macerated adult mandibles (240 hemimandibles) were procured from the Division of Clinical Anatomy, Stellenbosch University. Maceration involved immersion in a heated enzymatic solution (40 ˚C) for 72 hours to remove soft tissues, followed by manual cleaning and air-drying. Each mandible was bisected along the midsagittal plane using a hand drill equipped with a 0.75×38 mm metal cutting disc (Dremel, USA). Specimens were excluded if they exhibited perimortem fractures (identified by irregular edges and lack of healing signs) or pathological conditions (e.g. osteomyelitis, tumors) via visual and tactile inspection.

AMF identification

Canal Continuity Test: To confirm anatomical continuity between AMF and the mandibular canal, a 23-gauge needle was inserted into the mandibular foramen. A mixture of rubber latex (60%), 25% aqueous ammonia (20%), and food dye (20%) was injected under gentle pressure until the latex emerged from the mental foramen (MF). Extravasation of the colored latex through accessory foramina confirmed their continuity with the mandibular canal (Figure 1A). The latex was allowed to cure for 24 hours at room temperature (22 ˚C).

Spatial Mapping: The midpoint of the MF was established as the reference point (origin). Using a digital Vernier caliper (Mitutoyo, Japan; precision: ±0.01 mm), the x (mesiodistal) and y (superoinferior) coordinates of each AMF relative to the MF midpoint were recorded. Measurements were repeated thrice to ensure accuracy.

Horizontal planes and screw site localization

The selection and the use of the foraminal plane as a reference is grounded in anatomical studies and surgical guidelines, while the 3 mm inferior offset is based on empirical evidence and recommendations from the literature to ensure patient safety and surgical efficacy. The planes have been validated in both cadaveric studies and clinical practice, demonstrating their utility in reducing complications and improving outcomes in mandibular fracture fixation [2, 7].

Three transverse reference planes were demarcated perpendicular to the mandibular inferior border (Figure 1B):

1. Superior plane (S): 3 mm superior to the MF midpoint. 2. Foraminal plane (F): At the level of the MF midpoint. 3. Inferior plane (I): 3 mm inferior to the MF midpoint.

On each plane, four screw insertion sites were marked using a surgical pencil:

1) Mesial sites: 4.5 mm and 9 mm mesial to the MF midpoint. 2) Lateral sites: 4.5 mm and 9 mm lateral to the MF midpoint (Figure 1C).

Bone thickness measurement

MBB: At each screw site, buccal bone thickness was measured anterior to vital structures (e.g. tooth roots, neurovascular bundles) using digital calipers (Mitutoyo, Japan; precision: ± 0.01 mm). Measurements were taken perpendicular to the bone surface, from the outer buccal cortex to the nearest vital structure or the lingual cortex if no structures were present (Figure 1D). The thinnest measurement per hemimandible and plane was recorded as the MBB.

Intra-rater reliability was evaluated by the primary investigator, while interobserver reliability was assessed by two independent observers, using two sets of 24 randomly selected hemimandibles. These reliability indices quantify agreement beyond chance, with values ranging from 0 to 1, where higher values indicate greater agreement.

Statistical analysis

A two-way mixed-effects intraclass correlation coefficient and Cohen's Kappa statistics were employed to assess agreement for measurements and observations of AMF presence. Data were analyzed using IBM SPSS software, version 25 (IBM Corp., USA). Normality was assessed via Shapiro-Wilk tests. MBB thickness was compared across planes using one-way analysis of variance (ANOVA), with post-hoc Tukey tests for pairwise comparisons. Independent t-tests evaluated bilateral differences; an a priori power analysis using G*Power software, version 3.1 [12]. with a further post hoc power analysis were conducted. The results were expressed as Mean±SD, P<0.05 was considered statistical significant. Predictive injury risk (%) was calculated as (Equation 1):

$$1.\text{Risk} = \frac{\text{Number of screw overlaps with vital structures}}{\text{Total screw sites}} \times 100$$

Screw overlap was defined as screw length (4–7 mm) exceeding MBB+1 mm (miniplate thickness).

Reproducibility notes:

1) Mandible bisection was performed by a single operator to minimize variability. 2) All measurements were conducted in a climate-controlled laboratory (22 °C, 50% humidity). 3) Calipers were calibrated daily using certified reference blocks. 4) Raw datasets and analysis scripts are available upon request.

Results

Twenty-seven hemi-mandibles were excluded due to perimortem fractures or and pathological conditions via visual and tactile inspection, resulting in a final cohort of 213 hemimandibles. An a priori power analysis was conducted using G*Power software, version 3.1. to ensure that the retained sample was sufficiently powered to detect meaningful differences, assuming a significance level of P=0.05, power (1–β) of 0.80, and a medium effect size (Cohen's f=0.25), a minimum total sample size of 180 was required for a one-way ANOVA. The final sample of 213 exceeds this requirement, confirming that the analysis is adequately powered to detect moderate group differences in mandibular measurements.

AMF

Figure 2 shows a small proportion of hemimandibles exhibited single AMF, with no significant difference observed between the right and left sides. Double AMF were rare and only present in right hemimandibles, with no bilateral cases identified. Spatial mapping indicated that half of the AMF were located mesial and superior to the MF midpoint, predominantly in the premolar region. Importantly, only one AMF was found within a 1 mm radius of a predefined screw insertion site, indicating a low likelihood of direct iatrogenic injury to accessory neurovasculature during surgical fixation.

MBB thickness

Buccal bone thickness varied significantly across the three horizontal planes (P<0.05), one-way ANOVA. The foraminal plane (F), positioned at the MF midpoint, demonstrated the greatest MBB thickness bilaterally:

1) Left hemimandibles: 6.91±2.08 mm. 2) Right hemimandibles: 6.69±2.04 mm.

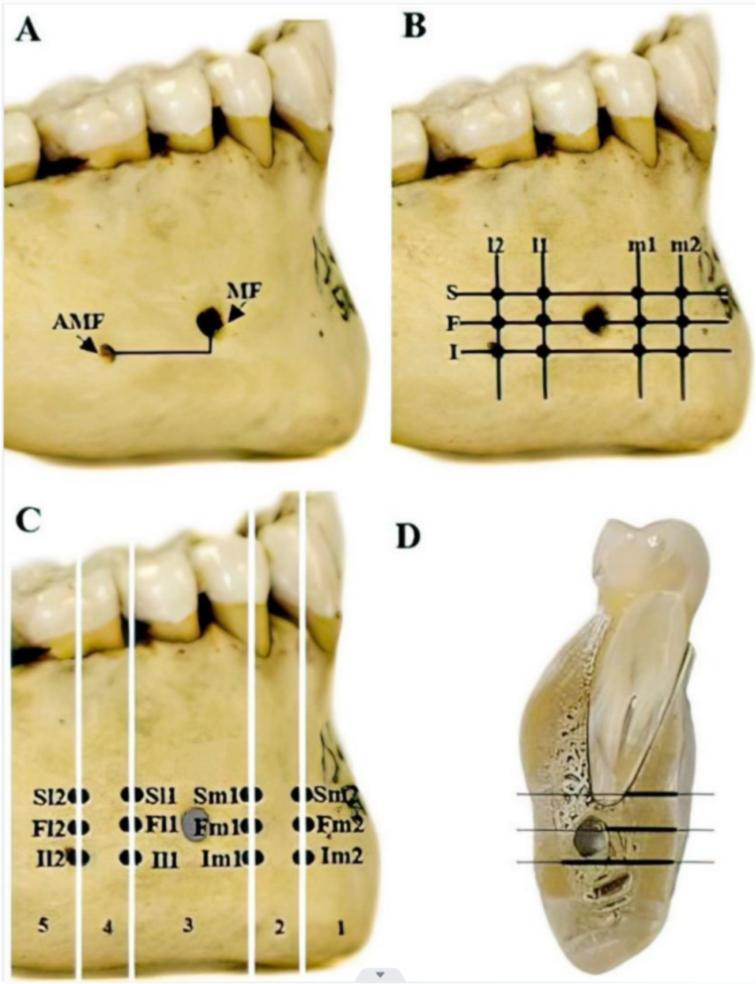

Figure 1. Views of the mandible presenting: A) AMF continuity assessment, B) Horizontal planes, C) Screw sites, D) MBB measurement Legends S) : Plane 3 mm superior to the foraminal plane, F) : Plane through the foraminal midpoint, I) : Plane 3 mm inferior to the foraminal plane, m1): 4.5 mm mesial to the foraminal midpoint, m2): 9 mm mesial to the foraminal midpoint, l1): 4.5 mm lateral to the foraminal midpoint, l2): 9 mm lateral to the foraminal midpoint

This thickness was statistically greater than measurements at the superior (S) and inferior (I) planes. The superior plane, located 3 mm above the MF, showed intermediate values:

1) Left: 6.23±2.58 mm; 2) Right: 5.97±2.76 mm.

The thinnest MBB was observed at the inferior plane (3 mm below the MF):

1) Left: 5.83±1.90 mm; 2) Right: 5.84±1.90 mm.

Observers reliability

The bone cortical plate showed substantial to perfect ($0.800<r<1$; $P<0.050$) inter-rater agreement at 23 of 24 assessment points, while almost perfect agreement was achieved ($0.900<r<1$; $P< 0.001$) in 23 of 24 assessment points during intra-rater reliability testing.

Predictive risk of iatrogenic injury

The risk of screw overlap with vital structures, such as the mandibular canal and tooth roots, was evaluated for standard mono-cortical screw lengths. The foraminal plane (F) demonstrated the lowest cumulative risk bilaterally, highlighting its relative safety for screw placement. In contrast, the inferior plane (I) exhibited a significantly higher risk profile, with a notable escalation in risk as screw length increased. The superior plane (S) presented intermediate risks, with right hemimandibles consistently showing higher risk compared to left hemimandibles. These variations in risk were inversely correlated with MBB thickness, emphasizing the protective effect of

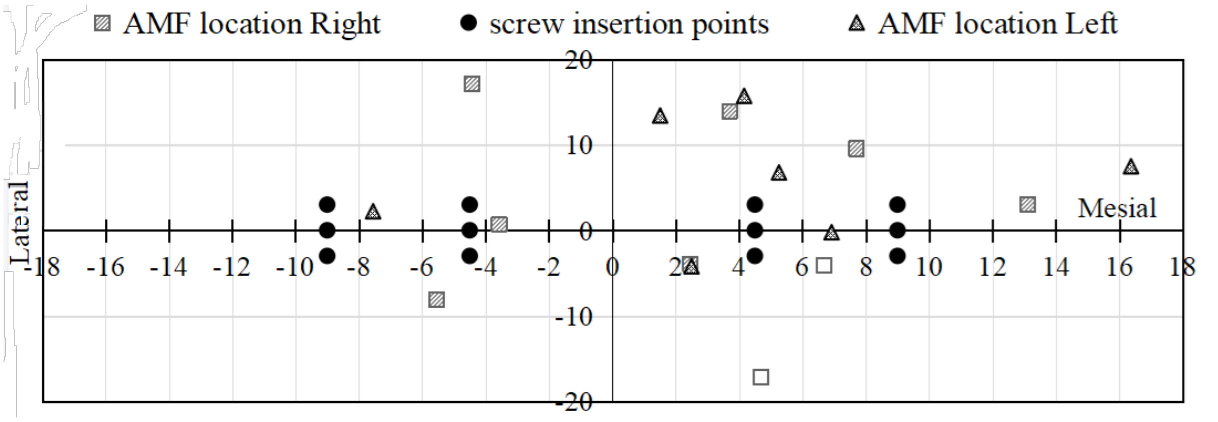

Figure 2. AMF Spatial distribution relative to screw insertion points

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Legend: 1) Graph origin: MF midpoint, 2) Black dots: screw insertion points, 3) Shaded triangle and square: left and right AMF location, respectively, 4) Empty square: presence of double AMF.

thicker buccal bone at the foraminal plane. These findings underscore the importance of preoperative planning and anatomical assessment to minimize iatrogenic injury during interforaminal fracture fixation (Figure 3).

Interpretation

1) The foraminal plane's anatomical advantage—thicker buccal bone and fewer vital structures—makes it the safest zone for miniplate anchorage. 2) surgeons should exercise caution when placing screws >5 mm in the inferior plane due to proximity to the mandibular canal.

Discussion

This study provides critical anatomical insights into interforaminal fracture fixation, emphasizing the interplay between anatomical variability and surgical risk. The prevalence of AMF in our cohort (6.57%) aligns with global studies using cone-beam computed tomography (CBCT) [7], but contrasts sharply with prior South African studies reporting a 21.38% prevalence [6]. This discrepancy stems from our stricter classification, requiring anatomical continuity between AMF and the mandibular canal, verified via latex injection [11]. This approach enhances clinical relevance, as only AMF with confirmed neurovascular continuity pose significant surgical risks.

The superior and mesial predominance of AMF relative to the MF mirrors findings in other populations [13], suggesting potential ethnic or population-specific variations in neurovascular patterning. Such variability underscores the need for region-specific anatomical data to guide surgical planning, particularly in ethnically diverse populations, such as South Africa, where trauma-related mandibular fractures are prevalent [11].

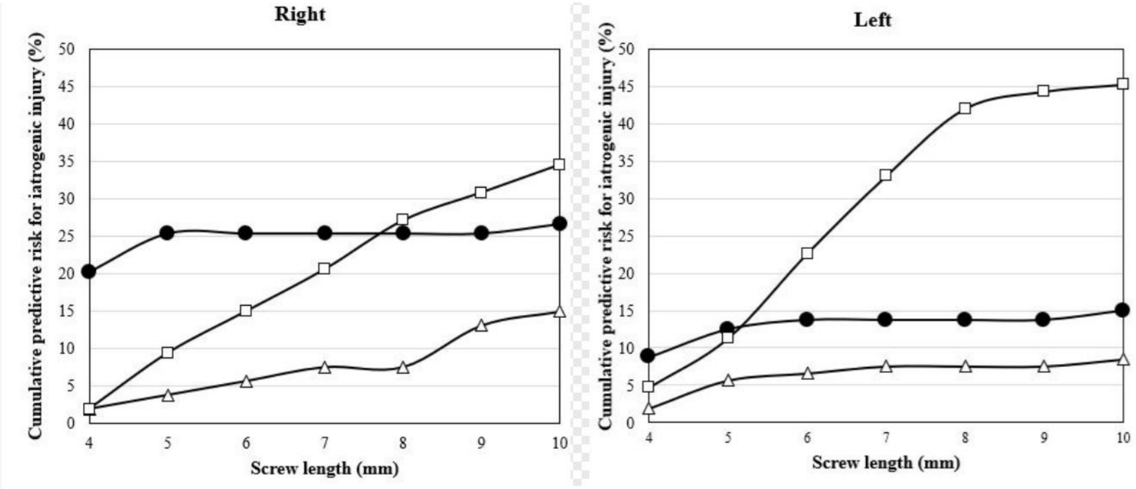

Figure 3. Predictive injury risk by screw length and plane

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Legend: Circle, triangle and square: Superior, foraminal, and inferior planes, respectively.

Biomechanical and clinical implications

The foraminal plane, positioned at the MF midpoint, demonstrated the thickest MBB and the lowest risk of iatrogenic injury (3.44–7.55% for 4–7 mm screws). These findings validate Champy's principles of osteosynthesis, prioritizing tension-band fixation along biomechanically favorable regions of the mandible [2]. The thicker buccal bone at this plane likely enhances screw stability and reduces the risk of damaging the mandibular canal or tooth roots. In contrast, the inferior plane exhibited elevated risks (up to 33.02% for 7 mm screws), attributable to its proximity to the mandibular canal and thinner buccal bone. These results align with another study [10], reinforcing the need for caution and the knowledge of anatomical relationship when using longer screws in this region. Surgeons should prioritize screw placement in the foraminal plane, where thicker bone provides greater safety, and avoid the inferior plane, especially when longer screws (>5) are required.

Clinical relevance in South Africa

The findings of this study are particularly relevant in South Africa, where high rates of trauma-related mandibular fractures demand efficient and safe surgical interventions [11]. By providing region-specific data on AMF prevalence, spatial relationships, and buccal bone thickness, this study equips surgeons with the anatomical insights needed to minimize iatrogenic injury and optimize outcomes. Preoperative imaging, particularly CBCT, should be utilized to assess individual anatomical variations and guide screw placement.

Clinical recommendations

1. Preoperative CBCT imaging: To mitigate risks, CBCT is recommended to map AMF, quantify buccal bone thickness, and identify anterior loops or incisive canals. This is particularly critical in populations with high anatomical variability.

2. Screw length selection: On the foraminal plane, 4 mm screws optimize the balance between stability and safety, minimizing overlap with vital structures.

Conclusion

The findings of this study demonstrate that mini-plate placement across the MF in the interforaminal region offers enhanced functional fixation while significantly reducing the risk of injury to nervous tissue. This further underscores the importance of integrating region-specific anatomical data into surgical planning. By tailoring the Champy technique to the unique anatomical characteristics of the South African population, surgeons can enhance the safety and efficacy of interforaminal fracture fixation, ultimately improving patient care in a high-trauma setting.

Limitations

1. Measurement variability: Manual sectioning of mandibles using handheld tools introduced minor discrepancies in plane localization. Future studies should employ CBCT or standardized cutting guides to improve precision. 2. Anterior loop misclassification: Some structures assumed to be anterior loops may represent incisive canals. Histological or radiological confirmation is needed to resolve this ambiguity. 3. Screw diameter exclusion: The study did not account for screw diameter, potentially underestimating injury risks. Future work should incorporate three-dimensional risk modeling. 4. Impact of anatomical features: There was a sparsely distribution of cancellous bone which would increase the risk for screw loosening following mini-plate placement. 5. Exclusion of a smaller number of hemimandibles: Post hoc power analysis revealed that the excluded hemimandibles would require substantially larger samples (e.g. ≥104 for medium effects) to achieve comparable power. Although their inclusion risked underpowered comparisons, their exclusion reduces generalizability to the differences detected in the populations. Future studies should prioritize larger samples to enable comprehensive analyses.

Future directions

Prospective clinical trials are warranted to correlate these anatomical findings with postoperative outcomes. Additionally, biomechanical testing of 4 mm screws on the foraminal plane could validate their sufficiency for fracture stabilization in vivo.

Ethical Considerations

Compliance with ethical guidelines

This study was approved by the Ethics Committee of Stellenbosch University, Stellenbosch, South Africa (Code: SU-1810). All mandibles were obtained through the university's body donation program, with informed consent secured prior to donation.

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Authors' contributions

Conceptualization: C. McKay and Venant Tchokonte-Nana; Methodology: C. McKay and Amanda Alblas; Data curation and writing the original draft: C. McKay; Review, editing and Funding acquisition: Venant Tchokonte-Nana; Supervision: Amanda Alblas; Final approval: All authors.

Conflict of interest

The authors declared no conflicts of interest.

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