Morphometric study for the localization of the mental foramen in relation to the vertical reference plane

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Abstract
Background: The mental foramen (MnF) is the anatomic landmark where the mental neurovascular bundle exists the mandible. Precisely determining the position of the MnF is necessary before all dentoalveolar therapeutic procedures performed in the mandibular premolar area.

Materials and Methods: For the study, we performed two ex vivo direct morphometric determinations on dry human dentate and edentate mandibles, and two in vivo imaging morphometric determinations through cone-beam computed tomography (CBCT) and orthopantomography (OPG) in dentate human patients. The following landmarks were used to locate the MnF: the distance between the MnF and the superior border of the mandible (MnF–SB), the distance between the MnF and the inferior border of the mandible (MnF–IB), and the position of the MnF in relation to the root apices of the posterior teeth. The results obtained from these data were processed statistically using the analysis of variance (ANOVA).

Results: By direct morphometry on dentate mandibles, the MnF was situated closer to the IB and by direct morphometry on completely edentulous mandibles, the MnF was located closer to the SB. In both direct morphometry studies, the MnF transverse diameter was larger than the vertical one, with the MnF having an oval shape. ANOVA for both direct morphometry studies showed that the distances MnF–IB and MnF–SB significantly vary statistically with interactions and depending on age (p<0.00001). The vertical diameter of the MnF significantly varies statistically depending on age, interactions and between studies, and its transverse diameter varies statistically significantly with interactions and depending on age (p=0.00001). According to OPG and CBCT imaging studies, the MnF was located closer to the IB, and the transverse diameter of the MnF was larger than the vertical diameter; such results are similar to the direct morphometry study performed on dry dentate human mandibles. Regarding the position of the MnF in relation to the root apices, it was most frequently located inferior to the root apices in 79.45% of cases, in 19.23% of cases it was located at the root apices level and in 1.31% of cases it was located superior (coronal) to the root apices. ANOVA for both imaging morphometry studies showed that the MnF–IB distance varies statistically significantly with the interactions, the study, the sex of the patients and their age, the MnF–SB distance varies statistically significantly with the interactions, the study and the patients’ age (p<0.05), and the MnF diameters vary statistically significantly with interactions and patient age (p<0.05). Conclusions: The results of this study can help dental practitioners in improving dentoalveolar surgery procedures in the posterior mandible.

Keywords: mental foramen, direct and imaging morphometry, OPG, CBCT, locoregional anesthesia.

Introduction
The mental foramen (MnF) is an important anatomical landmark of the mandible, due to its clinical relevance. It is situated in the premolar area of the mandibular body, and it represents the opening of the mental canal, lateral bifurcation of the mandibular canal (MC). The MnF and the mental canal are the passageways for the mental vessels and nerve [1, 2].

The injection of the anesthetic through the MnF in the mental canal ensures the anesthesia of the mandibular anterior teeth and premolars on the ipsilateral side. Knowledge of the topography of this mandibular anatomical landmark (MnF) is important for regional anesthesia and for dentoalveolar surgery, performed in the posterior mandible.

The topography of the MnF is variable in dentate subjects as compared to edentulous ones, has racial variations, and can be variable bilaterally even in the same individual. These topographic variations may generate the occurrence of complications during various surgical procedures, which is why a prior precise localization of the MnF is required [1–7].

Cone-beam computed tomography (CBCT) and orthopantomography (OPG) are useful imaging tools for identifying the position of the MnF [1–3].

The development and improvement of implant dentistry have led to dentists’ increased interest in the topographic location of the MnF and MC, both in dentate subjects, and in edentulous ones, especially. Accurate identification of
the MnF and MC locations is important for the success of endodontic, periodontal, dentoalveolar and implant surgeries performed on the posterior mandible [1, 4, 8–10].

The current research presents the statistically analyzed results regarding the MnF topography in vertical plane, obtained by direct morphometry on dry dentate and fully edentulous human mandibles, and by OPG and CBCT imaging morphometry on dentate human mandibles, on Romanian population.

Aim

The aim of this study was to establish reliable and clinically detectable landmarks for the localization of MnF in relation to the height line of the body of the mandible in dentate subjects compared to edentulous ones.

Materials and Methods

For this study, we performed direct morphometric assessments of the position of the MnF in the vertical plane on 27 dentate and 22 fully edentulous dry human mandibles. All the specimens we used belonged to Francisc I. Rainer Institute of Anthropology, Bucharest, Romania, and the measurements were performed with a digital caliper (WESTport Corp., USA).

We also performed imaging morphometric investigations on the vertical position of the MnF in dentate patients, whose informed consent had been obtained for using their radiographic data in research. Determinations were performed by OPG (21 patients) with a PLANMECA Pro Max 2D device, and the data thus gathered were analyzed with ROMEXIS 4.6 software, and CBCT (19 patients) via a NewTom VGi Evo 3D imaging device, with the data analyzed on a computer using the NNT software application version 11.

The obtained data were statistically processed using the Stata/MP13 software, by the two-way analysis of variance (ANOVA), with a p-value ≤0.05 being statistically significant. The analyzed landmarks were the distances between the MnF and the superior (alveolar) border of the body of the mandible (MnF–SB distance) and inferior border of the body of the mandible (MnF–IB distance). The MnF diameters were also analyzed (Figures 1–3).

By imaging morphometry, we also determined the vertical position of the MnF in relation to the dental root apices (Figure 4).

Results

The first study: the position of the MnF in the vertical plane by direct morphometry in the dentate samples

The study was performed on 27 specimens of dry dentate human mandibles, of which 18 (66.7%) were from women, and nine (33.3%) were from men. The average age for all subjects was 29.5 years, with the minimum age 20, and the maximum age 39. The results of the measurements on MnF topography in vertical plane obtained by direct morphometry of dry dentate human mandibles are shown in Table 1.

According to the data in Table 1, the MnF is not located in the center of the height line of the body of the mandible,
being closer to its inferior border, an aspect also encountered separately in male and female specimens. The transverse diameter of the MnF is larger than the vertical one, thus conveying an oval shape to the MnF.

The multifactorial ANOVA for the morphological landmarks concerning the MnF topography in vertical plane, bilaterally compared in relation to the age and sex of the subjects, on the 27 dentate dry human mandibles is presented in Table 2.

According to our findings, the analyzed morphological landmarks, the MnF–IB distance, the MnF–SB distance and the vertical diameter of the MnF show statistically significant values for all variables analyzed as a whole (interactions) and in relation to the subjects’ age (p<0.05). The exception was the transverse diameter of the MnF for which the values obtained were not statistically significant (p>0.05). As regards the sex of the subjects and the investigated side (left/right), none of the analyzed morphological landmarks showed statistical significance, the obtained average values being similar.

The second study: the MnF position in the vertical plane in totally edentulous samples, by direct morphometry

The study was performed on 22 completely edentulous dry human mandible specimens, of which 13 (59.09%) were from women, and nine (40.91%) were from men. The average age of all the subjects was 71.4 years, with the minimum age 60, and the maximum age 81.

The measurement results regarding the position of the MnF in the vertical plane from all the specimens, obtained by direct morphometry on fully edentulous human mandibles are shown in Table 3. According to these data, the position of the MnF is closer to the superior border of the mandibular body, a similar aspect found in both male and female specimens. The transverse diameter of the MnF was larger than the vertical one, the MnF being oval in shape for all the analyzed specimens, a result similar to the one obtained for the dentate specimens (Table 3).

The multifactorial ANOVA for the morphological landmarks concerning the MnF topography in vertical plane, bilaterally investigated and compared, in relation to the age and sex of the subjects, on the 22 dry, totally edentulous mandibles is presented in Table 4.

The results show that the analyzed morphological landmarks, the MnF–IB distance and the MnF–SB distance, present statistically significant values for all the variables analyzed as a whole (interactions), and in relation to the age of the subjects. In addition, the MnF–SB distance shows statistically significant values also depending on the sex of the subjects (p<0.05). The values of the MnF diameters have no statistical significance, either for interactions, or for side, or according to the sex and age of the subjects, the values being quite close, (p>0.05), with one exception: the values of the MnF transverse diameter were statistically significant depending on the sex of the subjects (p<0.05).

Comparison of the data obtained in the first two studies

The multifactorial ANOVA for the studied landmarks regarding the MnF topography in vertical plane, investigated in relation to the side, age and sex of the subjects, as compared between the two studies above, dentate versus totally edentulous specimens, is presented in Table 5.

Table 1 – Results of the measurements on the dry dentate human mandibles

Table 2 – The results of multifactorial ANOVA regarding the topography of the MnF on dentate mandibles

Table 3 – Measurement results on completely edentulous dry human mandibles

Table 4 – Results of multifactorial ANOVA regarding the topography of the MnF in completely edentulous mandibles

Table 5 – Results of multifactorial ANOVA regarding the topography of the MnF in totally edentulous mandibles

ANOVA: Analysis of variance; IB: Inferior border of the mandible; MnF: Mental foramen; N: No. of specimens; N2: No. of findings; R2: Coefficient of determination; SB: Superior border of the mandible.
The multifactorial ANOVA shows that the distances MnF–IB and MnF–SB vary statistically significantly with the interactions and according to age (p<0.00001). The vertical diameter of the MnF varies statistically significantly depending on age, interactions and between studies, and the transverse diameter of the MnF varies statistically significantly with interactions and according to age (p<0.00001).

**The third study: position of the MnF in the vertical plane in dentate specimens – imaging morphometry by OPG**

The study was performed on 21 OPGs from 10 (47.62%) female patients and 11 (52.38%) male patients. The patients’ average age was 41.3 years, the minimum age 20, and the maximum age 81. In addition to the morphological landmarks investigated by direct morphometry, in this study we also analyzed the position of the MnF in relation to the dental root apices (Table 7).

As the results presented in Table 6 reveal, the MnF was located inferior to the root apices in most cases, 90.48%, and in 9.52% of cases it was located at the root apex level. We did not find any MnF located superior (coronal) to the root apices. Morphological landmarks, measured in millimeters, showed similar results for male and female patients, respectively, so the MnF–IB distance was shorter than the MNF–SB distance, indicating that the MnF is located closer to the IB. The transverse diameter of the MnF was slightly larger than the vertical diameter, by 0.5 mm, which makes us say that the MnF shape is almost round. We also found right/left morphological symmetry on the vertical MnF topography in the whole group of patients.

**The fourth study: the MnF position in the vertical plane in dentate specimens – imaging morphometry by CBCT**

The study was performed on 19 CBCTs from eight (42.2%) females and 11 (57.8%) males. The average age of the patients was 56.3 years, with the minimum age 34, and the maximum age 81. In addition to the morphological landmarks investigated by direct morphometry, in this study we also analyzed the position of the MnF in relation to the dental root apices (Table 7).

In the overall study on the MnF topography analyzed by CBCT imaging morphometry, the results presented in Table 7 show that, in relation to root apices, the MnF was located most frequently inferior in 68.42% of cases, at the root apex level in 28.94% of cases, and superior (coronal) in 2.63% of cases.

### Table 4 – The results of multifactorial ANOVA regarding the topography of the MnF on completely edentulous mandibles

| Analyzed landmarks | N1  | N2  | R²   | Model/Interactions | Side | Gender | Age |
|--------------------|-----|-----|------|---------------------|------|--------|-----|
| MnF–IB distance    | 22  | 44  | 0.5841 | 0.0384              | 0.9244 | 0.1407 | 0.00649 |
| MnF–SB distance    | 22  | 44  | 0.8704 | <0.00001            | 0.5457 | <0.00001 | <0.00001 |
| Vertical diameter of MnF | 22  | 44  | 0.3628 | 0.6093              | 0.1886 | 0.2867 | 0.6430 |
| Transverse diameter of MnF | 22  | 44  | 0.5646 | 0.0562              | 0.1793 | 0.0081 | 0.0502 |

ANOVA: Analysis of variance; IB: Inferior border of the mandible; MnF: Mental foramen; N1: No. of specimens; N2: No. of findings; R²: Coefficient of determination; SB: Superior border of the mandible.

### Table 5 – Results of the multifactorial ANOVA on the MnF topography in vertical plane, dentate versus fully edentulous specimens

| Analyzed landmarks | N1  | N2  | R²   | Model/Interactions | Side | Gender | Age |
|--------------------|-----|-----|------|---------------------|------|--------|-----|
| MnF–IB distance    | 49  | 98  | 0.7239 | <0.00001            | 0.1281 | 0.2836 | 0.6526 |
| MnF–SB distance    | 49  | 98  | 0.7260 | <0.00001            | 0.8819 | 0.2507 | 0.7185 |
| Vertical diameter of MnF | 49  | 98  | 0.8159 | <0.00001            | <0.00001 | 0.0725 | 0.7863 |
| Transverse diameter of MnF | 49  | 98  | 0.6643 | <0.00001            | 0.0526 | 0.1223 | 0.5619 |

ANOVA: Analysis of variance; IB: Inferior border of the mandible; MnF: Mental foramen; N1: No. of specimens; N2: No. of findings; R²: Coefficient of determination; SB: Superior border of the mandible.

### Table 6 – The MnF position results obtained by imaging morphometry (OPG) in dentate patients

#### Imaging morphometry by OPG

| Analyzed landmarks | N | Mean | SD | Median | Min. | Max. |
|--------------------|---|------|----|--------|------|------|
| Right side         | 0 |      |    |        |      |      |
| Superior to the root apex | 1 | 3.54 | 0.99 | 3.8 | 2.63 | 6.3 |
| At the level of the root apex | 1 | 20.37 | 4.06 | 20.2 | 13.1 | 27 |
| Inferior to the root apex | 1 | 3.07 | 1.01 | 2.8 | 1.8 | 5.2 |
| MnF–IB distance    | 21 | 13.9 | 2.98 | 13.7 | 9.2 | 21.5 |
| MnF–SB distance    | 21 | 20.42 | 3.95 | 20.6 | 13.8 | 26.3 |
| Vertical diameter of MnF | 21 | 3.11 | 0.78 | 3.1 | 1.7 | 4.9 |
| Transverse diameter of MnF | 21 | 3.62 | 0.98 | 3.9 | 2.2 | 6.5 |

| Left side          | 0 |      |    |        |      |      |
|--------------------|---|------|----|--------|------|------|
| Superior to the root apex | 3 | 3.11 | 0.78 | 3.1 | 1.7 | 4.9 |
| At the level of the root apex | 18 | 20.42 | 3.95 | 20.6 | 13.8 | 26.3 |
| Inferior to the root apex | 1 | 13.98 | 2.8 | 13.9 | 8 | 18.6 |
| MnF–IB distance    | 21 | 3.62 | 0.98 | 3.9 | 2.2 | 6.5 |
| MnF–SB distance    | 21 | 20.42 | 3.95 | 20.6 | 13.8 | 26.3 |
| Vertical diameter of MnF | 21 | 3.11 | 0.78 | 3.1 | 1.7 | 4.9 |
| Transverse diameter of MnF | 21 | 3.62 | 0.98 | 3.9 | 2.2 | 6.5 |

IB: Inferior border of the mandible; Max.: Maximum; Min.: Minimum; MnF: Mental foramen; N: No. of MnF in relation to the root apex / No. of patients; OPG: Orthopantomography; SB: Superior border of the mandible; SD: Standard deviation.
The analyzed morphological landmarks were measured in millimeters. The MnF–IB distance was shorter than the MnF–SB distance, indicating that the MnF was located closer to the inferior border of the body of the mandible. The transverse diameter of the MnF was slightly larger than the vertical diameter, by 0.37 mm. Comparing the values obtained bilaterally, it can be seen that there is a right/left morphological symmetry because the values are close.

### Comparison of the data obtained in the two imaging studies

The multifactorial ANOVA for the morphological landmarks concerning the MnF topography in vertical plane, investigated in relation to the side, age and sex of the subjects, comparatively between the two imaging morphometry studies, is presented in Table 8.

According to the multifactorial ANOVA, the MnF–IB distance varies statistically significantly with the interactions, the study, the sex of the patients and their age, and the MnF–SB distance varies statistically significantly with the interactions, the study, and the age of the patients ($p<0.05$). The MnF diameters vary statistically significantly with interactions and in relation to patients’ age ($p<0.05$).

### Discussions

In the accessed references, we did not find any other study in which there would be an analysis of the MnF topography in vertical plane by combined, direct and imaging morphometry.

The results presented in this study on the MnF topography in vertical plane were obtained by direct and imaging morphometry performed on 67 dentate human mandibles and 22 fully edentulous human mandibles, the measurements being expressed in millimeters.

The vertical diameter of the MnF, on all the four studies performed, had an average of 3.43 mm; these dimensions were close left/right, between studies and between sexes, an aspect that shows the morphological symmetry.

The results regarding the position of the MnF in relation to the dental root apices were obtained by imaging morphometry studies based on OPG and CBCT. In most cases, on all imaging studies, the MnF was located below the dental root apices (79.45%), followed by a position at the root apices level (19.23%), and a location above the root apices (1.31%). The values were close left/right and between the sexes, but they were slightly different between the two imaging studies, which brings into question the fact that OPGs could have been oversized.

The MnF–IB distance had an average value of 12.08 mm, globally, on the three morphometric studies performed in dentate subjects. The close values among the three studies, between left and right sides, demonstrate the morphological symmetry. Statistically significant differences according to sex were not found either. Comparing the mean value of the MnF–IB distance in dentate subjects with the distance in completely edentulous ones, for which the mean value was 11.50 mm, we can say that this landmark does not undergo significant dimensional changes after the loss of occlusal support. The fact that the MnF–IB distance had a close average value in both dentate and completely edentulous subjects demonstrates that the position of the MnF in
relation to the IB remains almost identical (±0.6 mm) even after tooth loss. Therefore, we consider that this distance is the most important anatomical landmark for the localization of the MnF in relation to the vertical reference plane in the dentate specimens, but especially in the completely edentulous ones.

Globally, in the morphometric studies performed in dentate subjects, the average value of the MnF–SB distance was 16.18 mm, the values being close left/right, between sexes and between the direct morphometry study and the imaging morphometry study by CBCT. The values obtained in the OPG imaging morphometry study were higher, which suggests that the OPGs could have been oversized. By dimensionally comparing the MnF–SB distance in dentate and completely edentulous specimens, an average value of 5.85 mm was obtained, hence we can say that the position of the MnF is closer to the IB in dentate samples and closer to the SB in fully edentulous ones. The MnF–SB distance shows important changes in dimension after the loss of the occlusal support, being very variable, 0–14.7 mm.

The results obtained in this study show similarities, but also many differences, as compared to other studies on the same issue, as we will show below.

The same groups of patients and the same specimens had been used in other previous studies [11, 12]. Oguz & Bozkir (2002) [13], studying the position of the MnF on Turkish population, on dentate dry mandibles, showed that it was located almost in the center of the mandibular body in relation to the vertical plane, a different result from the one we demonstrated.

A study of dry dentate human mandibles, on Indian population, showed that, in the vertical plane, the MnF was situated 10.18 mm away from the superior margin of the mandible and 12.62 mm away from the inferior margin of the mandible [14], which is also a different result from the one presented in this study.

In their studies, other authors presented results similar to those shown previously on the vertical topography of the MnF, according to which it was situated closer to the superior margin of the mandible [15, 16]; such results contradict the results of our study.

In a study on the MnF topography in vertical plane, on Greek population, on dentate and edentulous mandibles, Charalampakis et al. (2017) [17] showed that, in the edentulous samples, it was situated closer to the superior margin of the mandible, at an average value of 6.4 mm; the MnF was located at an average distance of 12.6 mm from the IB. These results were very close to our results. According to the same authors, on the dentate mandibles, the MnF was located 13.6 mm away from the superior margin of the mandible and 15.2 mm away from the inferior margin of the mandible; such results are different from those obtained by us.

Another study showed that the MnF was located almost in the center of the height line of the body of the mandible. Thus, the MnF was found above the IB at a mean distance of 13.34±1.79 mm on the right side and 12.89±1.56 mm on the left side and below the alveolar border at a mean distance of 13.23±2.69 mm on the right side and 13.47±3.06 mm on the left side [18].

Afkhami et al. (2013) [7] studied the vertical topography of the MnF on Iranian population, through imaging morphometry on OPG, and demonstrated that the MnF was situated closer to the inferior border than to the SB, a result that we obtained as well.

Sing & Srivastav (2010) [19] analyzed the topography of the MnF on dry mandibles on Indian population and found that the mean distance from the MnF to the alveolar margin of the mandible was 17.8 mm and to the lower border it was 15.5 mm (average values of the bilaterally measured distances), thus showing the location of the MnF to be closer to the IB, just as we showed.

Souaga et al. (2004) [20] investigated the topography of the MnF on dry mandibles, on Africans, and determined that the distance between the MnF and the superior margin of the mandible was 16.16 mm in men and 15.66 mm in women, and as compared to the IB, it was of 14.89 mm in men and of 14.21 mm in women; such results are close to those presented in this study.

There were other authors who showed in their studies on the MnF topography in the vertical plane that it was positioned closer to the IB [21, 22], as we also highlighted by the results we hereby presented.

However, there were studies on the topography of the MnF in the vertical plane in which only the distance between the MnF and the IB or the distance to the SB were highlighted: such observations did not enable an assessment of the MnF position relative to the mandibular body height [23–25].

Regarding the MnF topography in relation to the root apices, the results obtained in our study are comparable to those reported by other authors, but they also show differences, as can be seen below.

Parmami et al. (2015) [6] studied MnF topography on the vertical plane on Indian population and showed that the MnF was situated below the root apices in most cases, 72.2%, a result which is very close to the one in our study.

Al-Khateeb et al. (2007), in their study on Jordanians, found that the most frequent location of the MnF in the vertical plane was inferior to the roots of the mandibular premolars [1, 26], a result close to the one presented in this study.

Kabak et al. (2017), by assessment on CBCT images on population in Belarus, showed that, in the vertical plane, in 65% of cases, the MnF was situated inferior to the dental roots, at a distance of 3.2±1.3 mm, in 29.5% of cases it was situated at the level of the line drawn through the dental apices and in 5.6% of cases it was located coronal to the root apices [1, 27]. These results are close to those presented in our CBCT imaging morphometry study.

In his retrospective review, Jasim (2020) [28] showed that the MnF was located below the root apices in most cases, a result similar to what we obtained in our study.

In their study on Brazilian population, Fontenele et al. (2021) [29] found that the MnF was more frequently located below the root apices.

In his study on Tanzanian population, Fabian (2007) [30] illustrated that the MnF was located below the root apices, similar to our findings.

Sheikhi et al. (2015) [31] analyzed the MnF topography through CBCT images on Iranians and showed that vertically, the most common location of the MnF was below the root apices.

Ndiaye et al. (2018) evaluated the MnF topography in
the vertical plane by OPG on Senegalese subjects and demonstrated that it was more frequently situated below the dental apex, followed by the position at the root apex level [1, 5]. This result was similar to the one presented in our study.

Race and population variations seen in the MnF topography may exist due to anatomical variations and craniofacial development, but they may also come from the evaluation methodologies [1].

The presence of the MnF, the MC and the accessory MCs in the posterior mandible requires special attention during all surgical procedures performed at this level [12, 32–34].

Conclusions

Failed outcomes following various therapeutic procedures in dentistry can be the consequences of the variations in the position of the MnF. Therefore, accurately locating the MnF becomes essential for the success of conservative and surgical treatments performed in the mandibular premolar area. The morphometric study of the vertical topography of the MnF on 89 human mandibles is a complex study, which showcases uniqueness and authenticity among all the other studies of this type available in the specialized literature. The MnF–IB distance is the most important vertical reference point of the mandibular foramen for the localization of the mandibular foramen (MF) in dentate and edentulous human subjects. Rom J Morphol Embryol, 2021, 62(2):517–523. PMID: 37024740 PMCID: PMC8589227

Conflict of interests

The authors declare that they have no conflict of interests.

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