Review

The Mental Foramen and Nerve: Clinical and Anatomical Factors Related to Dental Implant Placement: A Literature Review

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Background: The mental foramen is a strategically important landmark during osteotomy procedures. Its location and the possibility that an anterior loop of the mental nerve may be present mesial to the mental foramen needs to be considered before implant surgery to avoid mental nerve injury.

Methods: Articles that addressed the position, number, and size of the mental foramen, mental nerve anatomy, and consequences of nerve damage were evaluated for information pertinent to clinicians performing implant dentistry.

Results: The mental foramen may be oval or round and is usually located apical to the second mandibular premolar or between apices of the premolars. However, its location can vary from the mandibular canine to the first molar. The foramen may not appear on conventional radiographs, and linear measurements need to be adjusted to account for radiographic distortion. Computerized tomography (CT) scans are more accurate for detecting the mental foramen than conventional radiographs. There are discrepancies between studies regarding the prevalence and length of the loop of the mental nerve mesial to the mental foramen. Furthermore, investigations that compared radiographic and cadaveric dissection data with respect to identifying the anterior loop reported that radiographic assessments result in a high percentage of false-positive and -negatives findings. Sensory dysfunction due to nerve damage in the foraminal area can occur if the inferior alveolar or mental nerve is damaged during preparation of an osteotomy.

Conclusions: To avoid nerve injury during surgery in the foraminal area, guidelines were developed based on the literature with respect to verifying the position of the mental foramen and validating the presence of an anterior loop of the mental nerve. These guidelines included leaving a 2 mm zone of safety between an implant and the coronal aspect of the nerve; observation of the inferior alveolar nerve and mental foramen on panoramic and periapical films prior to implant placement; use of CT scans when these techniques do not provide clarity with respect to the position of the nerve; surgical corroboration of the mental foramen’s position when an anterior loop of the mental foramen is suspected of being present or if it is unclear how much bone is present coronal to the foramen to establish a zone of safety (in millimeters) for implant placement; once a safety zone is identified, implants can be placed anterior to, posterior to, or above the mental foramen; and prior to placing an implant anterior to the mental foramen that is deeper than the safety zone, the foramen must be probed to exclude the possibility that an anterior loop is present. In general, altered lip sensations are preventable if the mental foramen is located and this knowledge is employed when performing surgical procedures in the foraminal area. J Periodontol 2006;77:1933-1943.

KEY WORDS
Dental implants; foramen; sensation.

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The mental foramen is an important landmark when considering placing implants in the foraminial region of the mandibular arch. Differences in its location, the number of foramina, and the possibility that an anterior loop of the mental nerve may be present mesial to the mental foramen need to be considered prior to preparing an osteotomy in this region. This article reviews the literature with respect to the mental foramen and makes clinical suggestions to reduce inadvertent damage to the mental nerve during osteotomy development.

**INFERIOR ALVEOLAR NERVE AND ITS BRANCHES**

The mandibular division of the trigeminal nerve (V3) enters the mandibular foramen. As the inferior alveolar nerve proceeds anteriorly in the mandibular canal, it traverses the mandible from the lingual to the buccal side. The nerve is midway between the buccal and lingual cortical plates in the first molar vicinity. In the molar region, the inferior alveolar nerve usually divides into the mental and incisal nerves. In the mental canal, the mental nerve continues upward and emerges from the mental foramen in conjunction with blood vessels. Normally, three nerve branches come out of the mental foramen. One innervates the skin of the mental area, and the other two proceed to the skin of the lower lip, mucous membranes, and the gingiva as far posteriorly as the second premolar. The mental nerve may provide innervation to tissues adjacent to the canine and incisor areas. Medial to the mental foramen, studies confirmed the existence of a true incisive canal, which is a continuation of the mandibular canal. The incise canal may also appear to be ill-defined, and neurovascular bundles may run through a labyrinth of intertrabecular spaces.

In about 1% of patients, the mandibular canal bifurcates in the inferior superior or medial lateral plane. Thus, a bifurcated mandibular canal will manifest more than one mental foramen. This may or may not be seen on panoramic or periapical films. Accordingly, Dario suggested that clinicians should consider obtaining a preoperative tomo gram to avoid nerve injury prior to implant placement above the inferior alveolar canal.

**MENTAL FORAMEN**

**Shape**

Mbajjorgu et al. found different shapes of the mental foramen in the mandibles of Zimbabwean subjects: round in 14 of 32 (43.8%) mandibles and oval in 18 of 32 (56.3%) jaws. Others reported it was round in 34.5% of mandibles and oval in 65.5% (N = 575).

**Size**

Morphometric skull analyses revealed the mean height of the mental foramen was 3.47 mm (range: 2.5 to 5.5 mm) and the average width was 3.59 mm (range: 2 to 5.5 mm). Other investigators noted that the mean diameter of the foramen was 3.5 and 5 mm wide. Further studies indicated the foramen is usually found more coronal than the mandibular canal. Agthong et al. indicated the foramen was 28 mm from the midline of the mandible and 14 to 15 mm from the inferior border of the mandible. Similarly, Neiva et al. reported the foramen was 27.6 mm (range: 22 to 31 mm) from the midline and 12 mm (range: 9 to 15 mm) from the most apical portion of the lower cortex of the mandible. Other authors commented the foramen was usually found halfway between the crest of bone and the inferior border of the mandible. However, this finding could be influenced by the amount of crestal bone loss.

Table 1 lists studies that addressed the mental foramen’s location in the horizontal plane. It is usually located by the apex of the second mandibular premolar or between the apices of the premolars. Minor variations may be race related. For instance, among Chinese subjects, the mental foramen is usually located apical to the second premolar, whereas in Caucasian subjects, it is usually found between the premolars. Atypically, it can be found anteriorly by the canine or posteriorly by the first molar (Table 1).

Fishel et al. (N = 936 full-mouth series) reported the mental foramen’s location in the vertical plane (occluso-apically) for the first and second premolars. They recorded the percentage of times it was present: first premolars – 38.6% coronal to the apex, 15.4% at the apex, and 46.0% apical to the apex; second bicuspid – 24.5% coronal to the apex, 13.9% at the apex, and 61.6% apical to the apex. It can be concluded that the foramen’s location is not constant in the horizontal or vertical planes. Furthermore, the finding that it may be coronal to the apex of the root needs to be considered when performing immediate placement of dental implants in sockets.

After extraction of teeth and resorption of alveolar bone, the mental foramen is closer to the alveolar crest. In extreme situations, the mental foramen and mandibular canal can be adjacent to the crest of the alveolar ridge. Radiographs indicating close proximity of the foramen to the alveolar crest dictate that the foramen should be surgically located to avoid nerve damage prior to osteotomy development. Furthermore, if there is insufficient room to place implants, the nerve can be transposed to create adequate space. Some investigators found this procedure to be...
very successful. However, other researchers\textsuperscript{30-32} noted a high rate of sensory dysfunction post operatively.

**Number of Foramina**

More than one mental foramen may be present.\textsuperscript{17,18} Sawyer et al.\textsuperscript{18} assessed the frequency of accessory mental foramina in skulls in four population groups. The prevalence of additional foramina was as follows: American Whites = 1.4%; Asian Indians = 1.5%; African Americans = 5.7%; and pre-Columbian Nazca Indians = 9.0%. In other studies, two mental foramina were noted in 1.8% (N = 110) of examined Asian skulls\textsuperscript{21} and in 10% (N = 50) of examined cadavers.\textsuperscript{4} In contrast, de Freitas et al.\textsuperscript{33} found no mental foramina in some skulls (among 1,435 dry human mandibles, the foramen was absent twice on the right side [0.06%] and once on the left side [0.03%]). It can be surmised that a variety of patterns occurs, and it should not be assumed that there is only one mental foramen on each side.

**Emerging Direction of the Mental Canal and Foramen**

In cadaveric specimens, Kieser et al.\textsuperscript{34} determined the most common emergence pattern of the mental foramen was directed posteriorly (80.7% of males and 86.6% of females; N = 341). The finding of a posterior inclination is in agreement with others.\textsuperscript{35} However, among black Zimbabwean subjects, a right-angled exit path was frequently detected (45.8% males and 45.0% females; N = 32).\textsuperscript{12} With respect to the mental canal, Solar et al.\textsuperscript{16} observed that the mental nerve within the mental canal traverses cranially at an angle of inclination ranging from 11° to 77°. They noted that the average gradient in 37 specimens (22 had an anterior loop) was 50°. They also reported there was no correlation between residual ridge type (e.g., reduced) and the gradient.

### DETECTION OF THE MENTAL FORAMEN ON RADIOGRAPHS

**Panoramic Films**

Radiographic assessment of the mental foramen must be interpreted cautiously. Jacobs et al.\textsuperscript{36} reported the foramen was detected on 94% (N = 545) of panoramic radiographs, but clear visibility was only attained 49% of the time. Similarly, Yosue and Brooks\textsuperscript{15} noticed the foramen on 87.5% (N = 297) of panoramic radiographs, and it was distinct 64% of the time. In another investigation in which four skulls were radiographed,
Yosue and Brooks\textsuperscript{37} concluded that panoramic and periapical films reflected the actual position of the foramen in the skulls <50\% the time. They also classified the foramen’s appearance on panoramic radiographs into four categories (separated from the mandibular canal, continuous with the mandibular canal, diffuse with indistinct borders, and unidentified) and recorded the occurrence of each type (Table 2).\textsuperscript{37}

**Periapical Films**

With respect to periapical films, the mental foramen was found on 75\% (N = 75) in one investigation\textsuperscript{38} and on 46.8\% (N = 1,000) in another study.\textsuperscript{29} To enhance foramen detection, it was suggested that a vertical bitewing and a panoramic film be taken in conjunction with a horizontal periapical film.\textsuperscript{39}

There are several explanations as to why the mental foramen does not appear on all radiographs. Yosue and Brooks\textsuperscript{15,37} hypothesized that the inability to see it may be due to the difficulty in differentiating the foramen from the trabecular pattern, thin mandibular bone which provided no radiographic contrast, overly dark radiographs, or because the lingual cortical plate of bone was very thick and the foramen did not decrease the density of the bone enough to be detected. Image distortion can occur due to positioning the head on panoramic films\textsuperscript{23} or angulation of periapical films,\textsuperscript{37} and this also may account for failure to detect the foramen. In addition, the mental foramen will be missed on periapical films if it is located below the edge of the film.

Measurement discrepancies when using different radiographic methods must be considered when computing the amount of bone coronal to the mental foramen. In this regard, Sonick et al.\textsuperscript{40} determined the following average linear errors occurred during routine bone assessments (N = 12): panoramic films = 24\% (mean: 3 mm; range: 0.5 to 7.5 mm); periapical films = 14\% (mean: 1.9 mm; range: 0.0 to 5.0 mm); and computerized tomography (CT) scans = 1.8\% (mean: 0.2 mm; range: 0.0 to 0.5 mm).\textsuperscript{40} It can be concluded that neither periapical nor panoramic films precisely portray the amount of bone coronal to the mental foramen.

**CT Scans**

CT scans are more accurate than conventional radiographs.\textsuperscript{36,40-43} Nevertheless, conventional radiographs can usually be used if potential radiographic distortions are taken into account. However, if it is difficult to locate the inferior alveolar canal or the mental foramen, consideration should be given to obtaining a CT scan.

**Improving Radiographic Interpretation**

To improve visualization of the mandibular canal when taking a panoramic radiograph, Dharmar\textsuperscript{44} suggested that the patient’s head should be tilted \(\sim 5^\circ\) downward with reference to the Frankfort horizontal reference bar of the orthopantomogram machine. Changing the angulation improved seeing structures because it reduced the chance of superimposition of the contralateral side. In addition, to compensate for radiographic distortions caused by the panoramic method, it is prudent during film taking to include a 5-mm ball bearing (held in position with wax), which can be used to calculate the percentage of radiographic error.\textsuperscript{45} If the ball bearing is 5 mm on the radiograph, then the height of bone can be measured directly on the film. If it is not 5 mm, then the following formula can be used to compute radiographic corrections: \(\text{rs/5} = \text{rm/rx} (\text{size of radiographic sphere in millimeters/5-mm sphere}) = \text{radiographic measurement of bone/corrected bone measurement.}\)

### ANTerior LOOP OF THE Inferior Alveolar/Mental Nerve

**Definition and Location**

The anterior loop refers to “an extension of the inferior alveolar nerve, anterior to the mental foramen, prior to exiting the canal.”\textsuperscript{46} It has also been referred to as the anterior loop of the mental nerve.\textsuperscript{47} Other authors\textsuperscript{19,48} described the anterior loop as the mental neurovascular bundle traversing inferiorly and anteriorly to the mental foramen, which then doubles or loops back to exit the mental foramen.

**Prevalence and Length**

Detection and measurement of the anterior loop was attempted using a variety of diagnostic methods: panoramic films of patients, panoramic films of markers in dried skulls and cadaver mandibles, periapical films of cadaver jaws, and CT scans of patients and surgical cadaver dissections. Data in Table 3 underscore that different diagnostic methods provide divergent results and studies using the same analytical techniques attain dissimilar outcomes.\textsuperscript{7,14,16,19,34,36,47-53} Varied results may be
attributed to different criteria used to define the anterior loop, dissimilar diagnostic techniques, and diverse findings in patients.

**Detection of Anterior Loop With Different Diagnostic Methods**

**Panoramic films.** Jacobs et al. found an anterior loop on 11% of patient panoramic radiographs (N = 545); they did not record the size of the anterior loops. Misch and Crawford noted an anterior loop whose average length was 5 mm in 12% of patient panoramic radiographs (N = 324). They did not provide a range of findings or incidence data with regard to specific sizes of detected loops. Arzouman et al. used two different panoramic methods (methods A and B) on the same dried skulls (N = 25) to detect the anterior loop. Methods A and B detected the anterior loop, respectively, in 56% and 76% of evaluated skulls. They evaluated loop size in dried skulls with and without radiopaque markers. Without bone markers the average loop size ranged from 2.69 mm (of skulls) to 4.17 mm (method A) and 2.75 mm (4.64 mm) (method B).

**Table 3.**

<table>
<thead>
<tr>
<th>Author</th>
<th>Technique</th>
<th>%</th>
<th>N</th>
<th>Length of the Loop</th>
</tr>
</thead>
<tbody>
<tr>
<td>Jacobs et al.</td>
<td>CT scan</td>
<td>7</td>
<td>230</td>
<td>–</td>
</tr>
<tr>
<td>Rothman</td>
<td>CT scan</td>
<td>–</td>
<td>–</td>
<td>10 mm (single scan; not a study)</td>
</tr>
<tr>
<td>Misch</td>
<td>Panoramic radiographs</td>
<td>12</td>
<td>–</td>
<td>Distance up to 3 mm</td>
</tr>
<tr>
<td>Misch and Crawford</td>
<td>Panoramic radiographs</td>
<td>12</td>
<td>324</td>
<td>Mean: 5 mm</td>
</tr>
<tr>
<td>Jacobs et al.</td>
<td>Panoramic radiographs</td>
<td>11</td>
<td>545</td>
<td>–</td>
</tr>
<tr>
<td>Arzouman et al.</td>
<td>Panoramic radiographs</td>
<td>56*</td>
<td>25</td>
<td>Mean lengths without (and with) bone markers were 2.69 mm (of skulls)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>(4.17 mm) (method A) and 2.75 mm (4.64 mm) (method B)</td>
</tr>
<tr>
<td>Bavitz et al.</td>
<td>Dissected cadavers</td>
<td>11</td>
<td>35†</td>
<td>1 mm was the largest anterior loop</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Mean: 0.2 mm in the dentate group; range: 0.0 to 1.0 mm</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Mean: 0.0 mm in the edentulous group; range: 0.0 to 0.0 mm</td>
</tr>
<tr>
<td></td>
<td>Periapical radiographs</td>
<td>54</td>
<td>35</td>
<td>Mean: 2.5 mm in the dentate group; range: 0.0 to 7.5 mm</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Mean: 0.6 mm in the edentulous group; range: 0.0 to 2.0 mm</td>
</tr>
<tr>
<td>Rosenquist</td>
<td>Dissected cadavers</td>
<td>26</td>
<td>58</td>
<td>For 13 cases, the loop was 0.5 mm; for two cases, it was 1 mm; mean: 0.15 mm</td>
</tr>
<tr>
<td>Kieser et al.</td>
<td>Dissected cadavers</td>
<td>0</td>
<td>56</td>
<td>No additional data</td>
</tr>
<tr>
<td>Kuzmanovic et al.</td>
<td>Dissected cadavers</td>
<td>37</td>
<td>22</td>
<td>Range: 0.11 to 3.31 mm</td>
</tr>
<tr>
<td></td>
<td>Panoramic radiographs</td>
<td>27</td>
<td>22</td>
<td>Range: 0.5 to 3.0 mm</td>
</tr>
<tr>
<td>Mardinger et al.</td>
<td>Dissected cadavers</td>
<td>28</td>
<td>46</td>
<td>Range: 0.40 to 2.19 mm, 12/13 ≤2 mm, 1/13 ≥2.1 mm</td>
</tr>
<tr>
<td></td>
<td>Periapical radiographs</td>
<td>19</td>
<td>46</td>
<td>Range: 0.5 to 2.95 mm, 8/9 ≤2 mm, 1/9 &gt;2.1 mm</td>
</tr>
<tr>
<td>Neiva et al.</td>
<td>Dissected cadavers</td>
<td>88</td>
<td>22</td>
<td>Mean: 4.13 mm; range: 1 to 11 mm</td>
</tr>
<tr>
<td>Solar et al.</td>
<td>Dissected cadavers</td>
<td>59</td>
<td>37</td>
<td>Mean: 1 mm; range: 0.5 to 5.0 mm</td>
</tr>
</tbody>
</table>

= no data.
* Panelipse.
† Orthoralix.
‡ Cadaver dissections corresponding to 35 of 47 mandibles where periapical films were taken.

‡ Panelipse, General Electric, Milwaukee, WI.
§ Orthoralix, Philips Sistemi Medical, Monza, Italy.
Arzouman et al.\textsuperscript{51} also assessed the extent of the anterior loop by inserting a 2-mm polyethylene tube into the mesial aspect of the skulls’ mental foramen; the mean length of the anterior loops was 6.95 mm.\textsuperscript{51} It was assumed that the 2-mm tubing width was larger than the incisal canal and, therefore, the distance the tubing penetrated into the bone reflected anterior loop length. However, after evaluating 230 CT human scans of mandibles, Jacobs et al.\textsuperscript{7} noted the average incisal canal had a 4.7-mm vertical and a 3.7-mm bucco-lingual diameter. Other investigators reported the incisal canal width measured as much as 1.8,\textsuperscript{4,2,19} 2.09,\textsuperscript{53} and 2.53 mm.\textsuperscript{47} Accordingly, Rosenquist\textsuperscript{52} and Kuzmanovic et al.\textsuperscript{47} suggested that the detection of large anterior loops in skulls reported by Arzouman et al.\textsuperscript{51} may be attributed to the manner in which bone markers were placed into the mental canals because they may have inadvertently penetrated into the incisal canal.

Periapical films. The ability of periapical films to detect the anterior loop of the mental nerve is discussed in “Dissection studies with comparison to radiographs,” which compares results between dissection studies and radiographs.

Computerized scans (CT scans). Jacobs et al.\textsuperscript{7} found an anterior loop of the mental nerve in 7% of CT scans of patients (N = 230). They did not provide data concerning the length of the anterior loop. As an observation, Rothman\textsuperscript{49} noted that the anterior loop could be 10 mm long. He described the radiographic appearance of the loop as a figure eight because there appears to be two cross-sections of the mandibular canal in the bone (the lower one coursing forward and the upper one coursing backward).

Surgical dissection of cadaveric specimens. Surgical dissection provides the highest level of evidence for validating the presence of the anterior loop of the mental foramen (Table 3). In addition, a comparison of radiographic and dissection results on the same patients provided insight as to the reliability of radiographs to identify the anterior loop.

Dissection studies without comparison to radiographs. Solar et al.\textsuperscript{16} detected an anterior loop in 60% (22 of 37) of dissected cadaver mandibles, ranging in length from 0.5 to 5 mm (mean: 1 mm). However, the mean length was not provided for the 22 mandibles with an anterior loop; it was presented for the 37 patients. Therefore, the actual mean length of present loops was underestimated. In addition, a frequency distribution concerning the length of the loops was not provided. Thus, it is unclear how often a 5-mm loop was present. Accordingly, the recommendation by Solar et al.\textsuperscript{16} that implants should be placed 6 mm anterior to the mental foramen to avoid possible injury to the mental foramen needs corroboration.

Neiva et al.\textsuperscript{14} identified the loop by probing the mesial cortical wall of the mental canal in 22 cadavers. They reported the loop was present 88% of the time and its length ranged from 1 to 11 mm (mean length: 4.13 mm). A frequency distribution of anterior loop lengths was not provided. It should be noted that Neiva et al.\textsuperscript{14} identified the loop by probing the mesial cortical wall of the mental canal, and it is possible that the reported large incidence and loop size actually reflected penetration into the incisal canal. In this regard, Misch\textsuperscript{48} cautioned that the opening on the mesial aspect of the mental foramen leading to the incisal canal often feels the same as the anterior loop.

In contrast to the previous dissection studies,\textsuperscript{14,16} other cadaveric studies noted dramatically different results. Rosenquist\textsuperscript{52} detected anterior loops in 24% (15 of 58) of cadaveric mandibles. He reported the loop length varied from 0 to 1 mm. In 13 cadavers, the loop was 0.5 mm long, and two patients had a 1-mm loop (mean study length: 0.15 mm). Similarly, Keiser\textsuperscript{34} found that there was no measurable anterior loop after exposing 1 cm of the nerve on both sides of the mental foramen in 56 cadaveric mandibles.

Dissection studies with comparison to radiographs. Bravitz et al.\textsuperscript{19} reported the anterior loop was present in 54% (17 of 35) of periapical radiographs taken of hemimandibles. However, this finding was only confirmed by dissection in 11% (four of 35) of the corresponding cadaver specimens. Loop sizes ranged from 0.0 to 7.5 mm on periapical radiographs and from 0 to 1.0 mm among cadaver specimens. It was suggested that radiographs overestimated the size of the anterior loop, and implants should be placed 1 mm mesial to the foramen.\textsuperscript{19} Likewise, Mardinger et al.\textsuperscript{53} reported a weak correlation between mental nerve detection on periapical films (19%; 9 of 46 hemimandibles) and surgical exposure (28%; 13 of 46 hemimandibles). They noted that 70% percent of anatomically detected loops did not appear on periapical films, and radiographs provided a 40% false-positive finding compared to their corresponding cadaver dissections. Loop length ranged from 0.5 to 2.95 mm on periapical films and 0.4 to 2.19 mm in cadavers. Anatomically, eight of the 13 anterior loops were 0.4 to 1 mm long, four of 13 anterior loops were 1.1 to 2 mm, and one anterior loop was 2.19 mm. Thus, 11% (5 of 46) of anterior loops were >1 mm. Mardinger et al.\textsuperscript{53} suggested that the large percentage of false-positive findings was due to misinterpreting the wide orifice of the incisal canal as part of the anterior loop.

Kuzmanovic et al.\textsuperscript{47} detected the anterior loop on 27% (six of 22) of panoramic films and 35% (eight of 22) of the dissected specimens. The size of the anterior loop in panoramic radiographs ranged from 0.5 to 3.0 mm, and dissected specimens revealed an anterior loop that varied from 0.11 to 3.31 mm (one
patient had a loop >3 mm, three had a loop 1 to 2 mm, and four patients had a loop <1 mm). Nevertheless, the authors stated that 50% of the radiographs were misinterpreted, and a loop was not corroborated by cadaver dissection. In addition, 62% of the anatomically identified loops were not observed radiographically. Overall, it can be surmised that a high percentage of false-positive and -negative findings occur when diagnosing the anterior loop with radiographs.19,47,53 Among the patients, 2% had a loop >3 mm, 10% had a loop 1 to 2 mm, and 3% had a loop <1 mm, and four patients had a loop <1 mm. Nevertheless, the authors stated that 50% of the radiographs were misinterpreted, and a loop was not corroborated by cadaver dissection. In addition, 62% of the anatomically identified loops were not observed radiographically. Overall, it can be surmised that a high percentage of false-positive and -negative findings occur when diagnosing the anterior loop with radiographs.19,47,53

SENSORY DYSFUNCTION DUE TO NERVE DAMAGE IN THE FORAMINAL AREA

Sensory disturbance can be caused by diverse factors such as pressure on the mental nerve from a denture or partial denture, an implant impinging on the nerve, pressure caused by an edema, hematomas, scars, or dental injections.54,55 Nerve damage can result from the nerve being stretched, compressed, and partially or totally transected.55 Violation of the mandibular canal or mental foramen during surgery can result in injury of the inferior alveolar nerve, mental nerve, or adjacent blood vessels. This may cause one of the following conditions: parasthesia (numb feeling), hyposthesia (reduced feeling), hyperesthesia (increased sensitivity), dysesthesia (painful sensation), or anesthesia (complete loss of feeling) of the teeth, the lower lip, or surrounding skin and mucosa.55 It may also result in venous or arterial bleeding. Other terms used to describe nerve injuries are:46

Neurapraxia: there is no loss of continuity of the nerve; it has been stretched or undergone blunt trauma; the parasthesia will subside, and feeling will return in days to weeks.

Axonotmesis: nerve damaged but not severed; feeling returns within 2 to 6 months.

Neurotmesis: severed nerve; poor prognosis for resolution of parasthesia.

The prevalence of sensory alterations varies due to multiple reasons: osteotomy locations, manner of surgery, study design, sensitivity of assessment techniques, selection of outcome variables, and terminology employed to explain sensory disturbances.56 After implant placement in the anterior mandible, the incidence of transient altered lip sensations was noted by several investigators: 8.5% (N = 94),57 11% (N = 110),58 and 24% (N = 75) of patients.59 Walton59 reported that 1% of the patients manifested symptoms 1 year after therapy, whereas Bartling et al.57 noted no permanent alterations of sensation 4 months posttherapy (N = 94). In another study, 7% (N = 110) of the patients reported sensory disturbance 16 months after treatment that was not present before therapy.58 This occurred despite exposing the mental foramen as part of the surgical procedure and placement of implants at least 3 mm in front of the mental foramen. Because altered sensation of the lower lip and surrounding tissue is possible, the authors58 cautioned that patients must be forewarned of this possible complication prior to implant placement.

Delayed onset of altered sensation of the mental nerve after surgery was reported by Flanagan.60 He suggested the transient altered sensation his patient experienced was due to remote bone compression and not direct injury induced by the twist drill. Flanagan60 believed that cancellous bone may be compressed by an implant which presses on a nerve, resulting in nerve dysfunction. Usually, an implant is 0.5 mm wider than the osteotomy; therefore, bone compression does occur, and force may be transferred to the nerve. In this regard, Dahlin et al.61 reported that nerves in rat tibia compressed at 200 to 400 mm Hg for 2 hours showed demyelination and axonal degeneration 3 weeks after compression.

DISCUSSION: CLINICAL APPLICATION OF DATA IN THE LITERATURE

The most distal aspect of an implant anterior to the mental foramen is dictated by the location of the foramen and the possibility that there may be an anterior loop of the mental nerve. In this respect, it has been suggested that the most distal aspect of an implant should be at least 1,19 2,48 3,53,58 4,47 and 6 mm16 anterior to the foramen to avoid injuring the inferior alveolar and/or mental nerves during an osteotomy. These diverse recommendations reflect controversies associated with the prevalence and extent of the anterior loop of the mental nerve. Therefore, it was decided to reassess all the data and try to establish clinical realities regarding the anterior loop of the mental nerve.

Anterior Loop of the Mental Nerve Debate

It is clear from the above data that radiographic determinations regarding the presence or length of the anterior loop of the mental foramen are suspect because there is a poor correlation with cadaver dissection assessments.19,47,53 This is further complicated by the finding that distance bone markers or tubing that penetrates the mental foramen (on dry skulls) cannot reliably be used to indicate the length of the anterior loop because these devices may penetrate into the incisal canal.47,52 Furthermore, limited data exist using CT scans to determine the incidence of the anterior loop, and no studies were found that correlated CT scans with surgical dissections.

With regard to cadaver dissection data, there are conflicting and incomplete data in the literature. Several studies documented and corroborated the presence of the anterior loop and others have refuted its importance as a treatment planning consideration.
For example, Solar et al.\textsuperscript{16} found an anterior loop in 60% of dissected mandibles. Kuzmanovic et al.\textsuperscript{47} and Mardinger et al.\textsuperscript{53} confirmed that the anterior loop of the foramen is not a radiographic artifact. However, the incidence and sizes detected were smaller than reported by Solar et al.\textsuperscript{16} (Table 3). Recently, Neiva et al. found a high occurrence of anterior loops; however, as previously mentioned, mesial penetration of the canal by a probe is not an accurate method to determine anterior loop length.\textsuperscript{14}

In contrast to the above findings, three dissection studies\textsuperscript{19,34,52} determined that detection of an anterior loop is a relatively rare occurrence, and its size is usually very small. Rosenquist\textsuperscript{52} did not find a loop in 43 of 58 cadavers. In 13 jaws, the loop was 0.5 mm long, and in two cases, it was 1 mm long. Similarly, Bravitz et al.\textsuperscript{19} assessed hemimandibles and found a loop in four of 35 mandibles that were also x-rayed (the cadaver length of the loop was 0.0 to 1.0 mm). Kieser et al.\textsuperscript{34} also examined 56 cadaveric mandibles and reported there were no distinctive anterior loops.

Based on the preponderance of evidence in the literature, the following statements can be deduced with regard to the anterior loop of the mental nerve: Evidence indicates that an anterior loop may be present. It has been detected radiographically and, more importantly, by cadaver dissection; however, its size or how often it occurs is debatable.

In general, radiographic studies indicated that the anterior loop varied in size between 0 and 7.5 mm (Table 3).\textsuperscript{19,48,51} However, these measurements may be inaccurate. Radiographs may underestimate\textsuperscript{47,51} or overestimate\textsuperscript{19,47} anterior loop length.

The correlation between the detection of an anterior loop on cadaveric specimens and conventional radiographs (periapical of panoramic films) is weak.\textsuperscript{19,47,53} Radiographs provide false-negative and -positive findings.

Clinicians in doubt concerning the position of the mental foramen or who are considering placing an implant in the foraminial region at a depth where there is unease about not having a 2-mm clearance coronal to a location where an anterior loop may exist should obtain a CT scan prior to implant placement to avoid injury of the inferior alveolar or mental nerve. Alternately, the mental foramen’s location can be surgically verified (Figs. 1 through 3).

\textbf{Methods to Avoid Inducing Nerve Damage During Osteotomies}

\textbf{Radiographs.} Misch\textsuperscript{48} and Misch and Crawford\textsuperscript{50} used panoramic radiographs (\(N = 854\)) to identify a “zone of safety” where implants could be placed and not impinge on the inferior alveolar or mental nerves. The zone of safety reflects the measurement taken from the most coronal aspect of the mental foramen to the crest of the alveolar ridge. It was determined that the vertical height of bone coronal to the mental foramen would also be present between the mental foramen and the first molar 100\% of the time, and this height of bone is maintained to the middle of the first molar 97.5\% of the time. In addition, if a radiograph revealed that the level of the mandibular canal on the distal and mesial sides of the first molar were the same, then the safety zone could be extended to the distal half of the first molar.\textsuperscript{48} The mesial half of the second molar usually has less bone coronal to the mandibular canal compared to the first molar, and bone height corresponding to the safety zone measurement is present 43\% of the time.\textsuperscript{48} The “safety zone” also takes into account that the coronal aspect of the mental foramen is \(\sim 2\) mm above the inferior alveolar/mental nerve.\textsuperscript{50} However, when there has been a great deal of bone resorption, these relationships may not be present. Furthermore, it should
be noted that the data from these studies did not account for distortion of panoramic radiographs.

If the anterior loop is present, it means that the mental nerve traversed inferiorly past the mental foramen and then looped superiorly and distally to emerge from the foramen. Thus, the amount of bone measured coronal to the mental foramen will also normally be available mesial to the mental foramen for implant placement. However, a problem can arise when it is desirable to place an implant mesial to the mental foramen that is longer than the length calculated for the safety zone. This should not be done until it is verified either by surgical exposure of the mental foramen or with a CT scan that the anterior loop of the inferior alveolar nerve is not present.

**Surgically exposing the mental foramen.** If there is uncertainty as to the location of the mental foramen, the amount of bone coronal to it, or the presence of an anterior loop of the mental nerve, it is prudent to surgically expose the foramen to assess the situation prior to developing an osteotomy in this area. Based on this evaluation, the length of planned implants or their locations may need to be modified. Full-thickness mucoperiosteal flaps are elevated to expose the mental foramen (Figs. 1 and 2). A distal mid-crestal ridge incision is used to extend the flap as far posteriorly as needed to place the planned implants (assuming that the radiographs did not reveal the mental foramen was close to the alveolar bone crest because then the incision needs to be modified and performed further lingually to ensure the nerve is not injured). A periosteal elevator is used to raise the periosteum and soft tissue just past the mucogingival junction. Then, wet sterile gauze is used to gently push the mucosa off of the bone slightly past the coronal aspect of the mental foramen. The gauze protects the nerve from being injured, and the periosteal elevator can be used to gently push the gauze. When the coronal margin of the foramen is exposed, it is possible to establish if there is an anterior loop. First, a small bur should be used to mark the crest to denote the position of the mental foramen. Second, a blunt curved probe (e.g., Naber’s 2N probe) is gently inserted into the foramen to determine whether the distal aspect is patent (Fig. 3). If it is not patent, then the nerve entered on the mesial side, and this is pathognomonic that an anterior loop is present (Fig. 3B). The mesial side is always patent because either the anterior loop emerges from the bone or the incisal nerve continues anteriorly. However, as previously indicated, the opening on the mesial aspect of the foramen leading to the incisal region and an anterior loop feel similar, and it is not possible to differentiate between these two structures.

During surgical procedures, nerve damage also can occur due to stretching or crushing of the mental nerve by the retractor. This may happen due to direct contact with the nerve or if the retractor presses on the flap containing the mental nerve. To avoid this problem or retractor slippage, which can damage the nerve, Moiseiwitsch suggested that, if the teeth are present, a groove be created with a bur in the bone at the apex of a premolar, coronal to the mental foramen, thereby providing a positive seat for the retractor. It probably is safer to create a groove lateral to the foramen to avoid nerve injury due to retractor slippage.

**Guidelines to Avoid Nerve Injuries in the Mental Foraminal Region**

Observe the position of the inferior alveolar nerve and mental foramen on a panoramic radiograph and periapical films. It is desired to place an implant leaving a 2-mm safety zone above the nerve.

If the nerve canal, after adjusting for radiographic distortion, is close to the anticipated osteotomy depth, a CT scan would be helpful in determining the exact position of the neurovascular structures.

If an anterior loop is detected radiographically (panoramic or periapical film), corroborate its presence surgically. If there are doubts regarding the amount of bone available for an implant in the foraminal region, surgically locate the mental foramen and establish the safety zone in millimeters. As previously described, verify the presence of the anterior loop.

![Figure 3](image-url)
using a curved probe. The proximity of the nerve to the alveolar crest needs to be considered when designing initial incisions.

Implants can be placed over the mental foramen, anterior to it, and posterior to the foramen up to the mesial half of the first molar using the length of the safety-zone measurement which was defined radiographically (adjust for radiographic distortions and severe crestal bone loss) or with surgical exposure of the mental foramen.

Before placing an implant anterior to the mental foramen, which is longer than the safety-zone measurement, probe the mental foramen to determine whether there is an anterior loop. If the loop is present, place implants no longer than the safety-zone measurement which was defined radiographically (adjust for radiographic distortions and severe crestal bone loss) or with surgical exposure of the mental foramen.

If there is no loop, clinicians can place an implant anterior to the foramen beyond the length of the safety zone. However, for safety, place an implant so that its distal aspect is ≥2 mm mesial to the mental foramen to allow for surgical error.48

CONCLUSIONS

The mental foramen is an important landmark, and its location needs to be considered prior to implant placement in the foraminar region. The foramen's position can vary, and radiographs may be misleading with regard to its precise location and the presence of an anterior loop of the mental nerve. Nevertheless, injuries to this nerve during implant placement can be avoided if the mental foramen is located and evaluated with regard to its precise location and the presence of an anterior loop of the mental nerve. Nevertheless, injuries to this nerve during implant placement can be avoided if the mental foramen is located and evaluated, and this information is used to help guide surgical procedures.

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