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Anatomical Relationship of the Mandibular Canal to Its Surrounding Structures in Mature Mandibles

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A lack of agreement exists in the literature regarding the anatomical relationship of the mandibular canal to its surrounding structures such as the root apices. The purpose of this investigation was to study the spatial relationship of the mandibular canal to the posterior teeth in dried human mandibles. Twenty-two mature dried mandibles were sectioned through the root apices of the first and second premolars and molars. Second premolars and second molars had the closest distances to the canal with a mean of 4.7 mm and 3.7 mm, respectively. With a mean of 6.9 mm, the apices of the mesial roots of the first molars were farthest from the canal. The canal pathway in mature mandibles followed in S-shaped curve in 31% of the cases. In 41% of the cases it was located lingual (19%), buccal (17%), or directly inferior (5%) to the apices of the posterior teeth. In 28% of the cases the canal could not be identified clearly in the second premolar and first molar regions. In a typical S-shaped configuration the canal was located buccal to the distal root of the second molar, crossed to the lingual below the second molar mesial root, ran lingual to the first molar, and crossed back to the buccal apical to the apex of the second premolar. Based on our results it appears that the mandibular second premolar and second molar are the most likely teeth to be involved in accidental damage to the mandibular canal during root canal therapy.

Physical damage to the contents of the mandibular canal can occur during surgical and nonsurgical endodontic therapy. Orstavik et al. (1) in a study of 24 cases involving overfills found extruded endodontic filling materials beyond the apices of posterior teeth. They also observed that the second premolars and second molars were more likely to be involved with paresthesia of the lip than other mandibular posterior teeth. Rowe (2) reported on nine cases of paste overfills in mandibular posterior teeth. His results confirmed the findings of Orstavik et al. (1).

Olivier (3) reported the relationship of the apices of the premolars and molars to the mandibular canal. He found the canal to be lingual to the roots of the second and third molars, below the roots of the first molar, and buccal to the apices of the premolars. Stockdale (4) has reported that the mandibular canal lies close to the inferior border of the mandible as early as 8 yr of age. He primarily focused on the relationship of the third molar to the mandibular canal and reported that this relationship is determined by the vertical position of the third molars, the height of the mandible, and the length of the roots. Carter and Keen (5) described the course of the mandibular canal by gross dissections and classified them according to the location and distribution of the mandibular nerve.

DuBrul (6) reported that the most frequent relationship of the mandibular canal to the apices of posterior teeth was a close contact with the third molar, which increases in an anterior direction. In cases with high mandibular body and roots of moderate lengths, he found that the mandibular canal did not have an intimate contact with the root apices of the posterior teeth. When roots were long and the mandibular body was low in height, the canal was in close contact with all the posterior teeth (6).

Littner et al. (7) studied the relationship of the mandibular canal and the apices of mandibular teeth in 46 dried adult mandibles with the use of a radiographic technique described by Frank in 1966. They found in most cases that the canal was buccal to the second molar and lingual to the first molar. Rajchel et al. (8) studied the anatomical location of the mandibular canal in 45 dried mandibles and found the mandibular canal to be located in a single bony canal nearly uniform in diameter from the mandibular foramen to the mental foramen. In a sagittal section, the mandibular canal was located close to the buccal cortex in the area of the second premolar and close to the lingual cortex in the area of first and second molar.

Despite its importance during surgical and nonsurgical endodontic treatments, an inconsistency in the literature is noted regarding the location of the mandibular canal in relation to the apices of posterior teeth (9–11). Because of a lack of consistency in the literature we investigated the relationship of the mandibular canal to the apices of posterior teeth in mature mandibles in both vertical and horizontal planes in dried mandibles.

MATERIALS AND METHODS

Twenty-two mature dentulous dried mandibles with complete root development of the third molars were purchased

from commercial sources. The sex and exact age of the individual mandibles could not be determined. Lateral and orthoradial radiographs of the mandibles were taken using a special jig for standardization with and without stainless wire (0.016 mm) inserted into the mandibular canal prior to sectioning of the mandible.

Access cavities were prepared in the occlusal surfaces of the premolars and molars on both sides of the mandibles. Numbers 10 to 20 K files were placed in the canals of these teeth to their radiographic apices and cemented to the most apical position with cyanoacrylate adhesive. The mandibles were sectioned at the incisor mid-line and distal to the second molar with a band saw (1.2-mm thickness). To facilitate identification of the mandibular canal, a flexible plastic line was inserted as far mesially as possible from the distal of the second molar and then cemented into place with Elmer's glue (Bordon Chemical, Columbus, OH). The bone between the first and second molar was sectioned with a band saw. The second molar and adjacent bone was then ground down on the distal and mesial half in a circular grinder (Rockwell Manufacturing Co., Pittsburg, PA) until the endodontic file(s) could be identified. This allowed the accurate sectioning of the roots in the long axis and identification of the apical foramen for both remaining intact roots. The first molar was then sectioned in a similar way (Fig. 1). The first and second premolars and adjacent bone were sectioned with a band saw and then ground on the distal half until the endodontic files were identified. This left the mesial half of the crown and root intact for data measurements.

The location of the apical foramen (apical line—A), the mandibular canal (canal line—B), the intersection of the canal line and long axis of the tooth (intersection point—C) were identified and drawn with a permanent fine felt pen on each section (Fig. 2).

Each section containing both tooth and surrounding bone was photographed at an exact double-sized enlargement on a duplicator stand. Seven distances to the nearest tenth of a

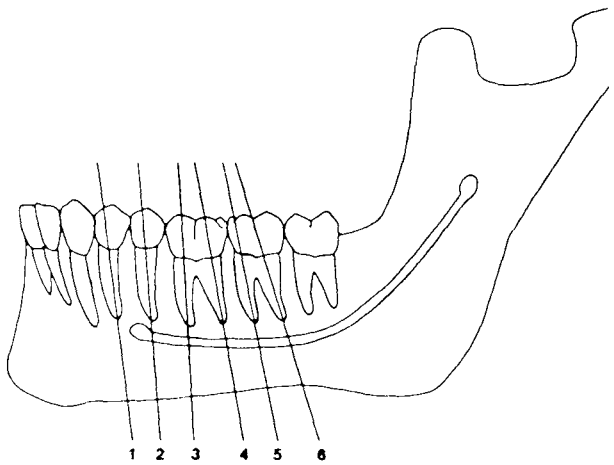

FIG 1. Vertical sectioning of the mandible from the first premolar to the second molar. The first and second molars were removed as a block specimen and then ground down from the mesial and distal to expose file(s) located in the canals. This left half of the mesial and distal root intact. The first and second premolars were removed as a block specimen and then ground down from the distal leaving the mesial half intact.

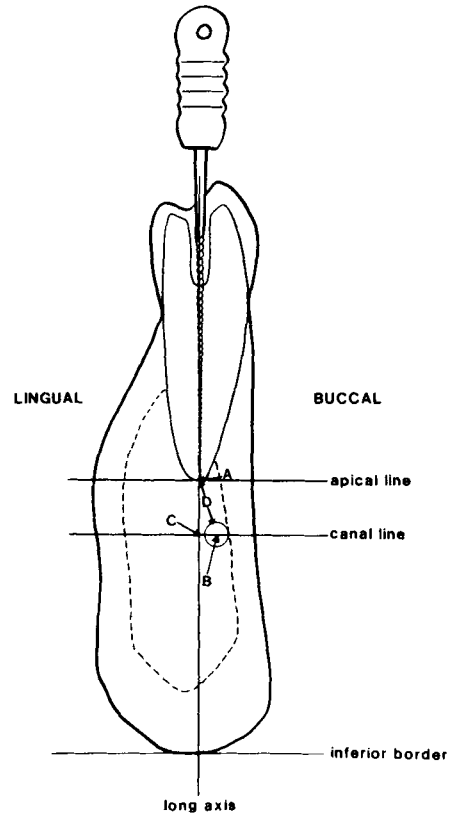

FIG 2. Mandibular reference points. *A*, apical foramen; *B*, center point of mandibular canal; and *C*, intersection of canal line and long axis of tooth.

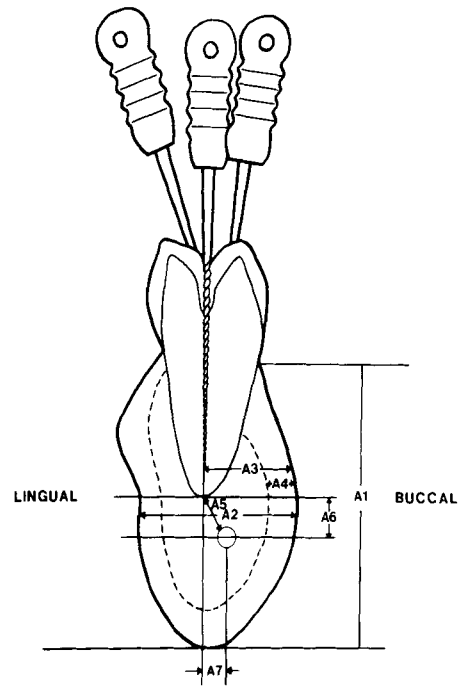

FIG 3. Graphic illustration of a cross-section of the mandible showing measurements A1 to A7. See text for definitions of A1 through A7.

TABLE 1. Means and standard deviations of various anatomical parts in the mandibles

	Mean (mm)		(mm)			
			First Molar		Second Molar	
	First Premolar	Second Premolar	Mesial Root	Distal Root	Mesial Root	Distal Root
A-1	28.6 ± 3.5	29.4 ± 2.9	28.2 ± 2.7	27.1 ± 2.7	25.7 ± 2.5	24.5 ± 3.9
A-2	11.1 ± 1.6	11.2 ± 1.2	12.8 ± 1.4	13.6 ± 1.2	13.9 ± 2.0	13.5 ± 2.2
A-3	3.9 ± 1.2	4.0 ± 1.0	5.4 ± 0.8	6.4 ± 1.5	8.7 ± 2.0	8.6 ± 1.7
A-4	1.8 ± 0.3	2.0 ± 3.1	2.4 ± 0.4	2.7 ± 0.5	3.0 ± 0.7	3.2 ± 0.7
A-5	NA*	4.8 ± 3.1	7.3 ± 3.4	7.2 ± 4.3	5.3 ± 2.0	5.2 ± 2.3
A-6	NA	5.8 ± 3.1	8.6 ± 3.0	7.8 ± 3.4	6.7 ± 2.5	6.5 ± 2.3
A-7	NA	0.07 ± 2.0	−1.3 ± 2.6	−1.9 ± 2.7	1.4 ± 0.8	0.5 ± 1.9

* Mandibular canal not present at this location.

millimeter were measured twice and then averaged by the same examiner using a Boley gauge on each photograph (Fig. 3). These measurement included:

A1—The farthest distance between the buccal alveolar bone at the cervical margin of each tooth and the outside margin of the mandibular body.

A2—The width of the mandible as measured on the apical line.

A3—The distance from the buccal border of the mandible to the long axis of the tooth along the apical line.

A4—The width of the solid cortical bone without trabecular pattern on the buccal aspect.

A5—The closest distance from the apical foramen to the inside edge of bone within the mandibular canal to determine the distance between the apical foramen and the mandibular canal.

A6—The distance between the apical line and the canal line.

A7—The distance from the center of the mandibular canal to the root long axis. The root long axis was determined by using the most apical extent of the root as one reference point. The coronal reference point was determined by a point equidistant to the buccal and lingual cementoenamal junction from the apical point to obtain two points. The intersection of these coronal points using a compass determined the most coronal point. The intersection of the most apical point and the coronal point determined the root long axis. If the center of the canal was located to the lingual of the long axis, the value was indicated as negative and if located to the buccal, this value was indicated as positive.

RESULTS

A total of 264 sections were taken from the left and right sides of the 22 dried mandibles used in the study. A total of 88 sections containing the first and second premolars were collected. One hundred seventy-six sections were obtained containing the mesial and distal root of the first and second molars. Due to extensive damage during sectioning and grinding, 17 sections were discarded (four first premolars, two second premolars, eight first molars, and three second molars). The means and the standard deviations of measurements determined in the study are shown in Table 1.

The mandibular canal was visible to some extent in all lateral radiographs. The most frequent visible portion was the initial segment of the canal beginning at the mandibular foramen and extending apical to the third molar. The inferior border of the canal was easier to identify than the superior border. The most frequently missing portion of the canal was the superior border apical to the first molar and second premolar.

The periphery of the mandibular canal was not a solid body channel throughout its entire course. Instead it was more like a coalescence of trabecular bone, which in some cases ranged from quite dense to very delicate structure (Fig. 4). The canal wall was less identifiable in the region of the second premolar and first molar.

The mandibular canal was often found buccal to the long axis of the distal root of the second molar and apical to the long axis of the mesial root of the second molar. In the area of the first molar, the canal was usually located lingual to the long axis of this tooth. The canal changed its direction and was always found inferior or buccal to the long axis of the second premolar. This anatomical pattern known as the "S-shaped canal pathway" was the highest (31%) configuration found in the mandibles. In 12 (28%) hemi-mandibles the exact location of the canal could not be clearly determined. In the other cases, the mandibular canal was located lingual (19%), buccal (17%), or directly inferior (5%) to the apices of the posterior teeth.

By using the Pearson correlation test a significant correlation was found between A1 (mandibular height) and A5 (closest distance between the apices and canal wall), $p < 0.01$. However, there was no significant correlation between A2 (width of mandible) and A5. This suggests that as the mandibular height increases, the distance between the canal and root apices also increases and vice versa.

DISCUSSION

The mandibular canals observed in this study did appear in some cases as distinct bony-walled channels within porous lined trabecular bone. However, in many cases the canals had no definite borders apical to the first molars and second premolars. Olivier (3), as well as Carter and Keen (5), found that 60% of mandible specimens contained canals while 40% of the dissections had no distinct canals. They found that branches of the nerve occupied a space in the bone rather than being present in distinct tunnels. The present study confirmed the finding of Olivier (3) who reported that the

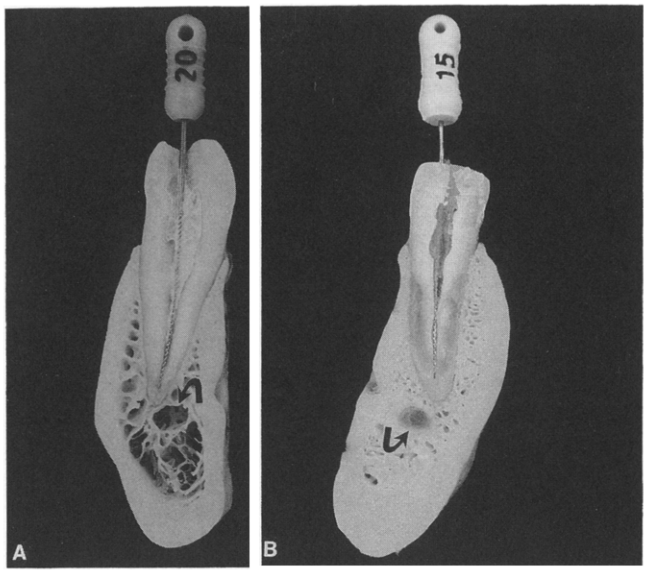

FIG 4. *A*, Visible mandibular canal wall with porous trabecular bone surrounding the canal (*arrow*). *B*, Dense mandibular canal wall (*arrow*) with thick cortical bone and compact trabecular bone.

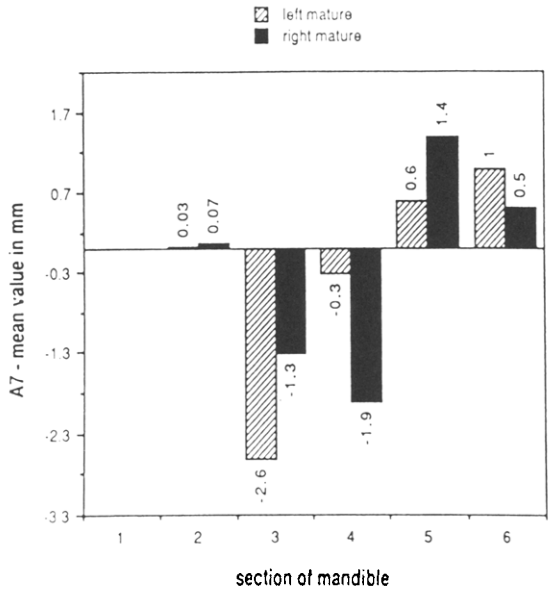

FIG 5. Comparison of mean values in horizontal distance between the canal and the root long axis (A7) in the mature mandibles. If located to the lingual of the long axis, the value was noted as negative and if located to the buccal, the value was indicated as positive.

canal wall becomes progessively thinner as the canal moves in an anterior direction. This was also seen radiographically in this study. The borders of the mandibular canals were more difficult to distinguish radiographically in the anterior portion of the mandible when compared with those observed in the posterior segments.

The pathway of the mandibular canal was found to travel in an S-shaped pattern in almost a third of the specimens. The canal was located buccal to the second molar, lingual to the first molar and directly inferior to the second premolar (Fig. 5). This corroborates the findings of Littner et al. (7) who investigated the relationship of root apices in first and

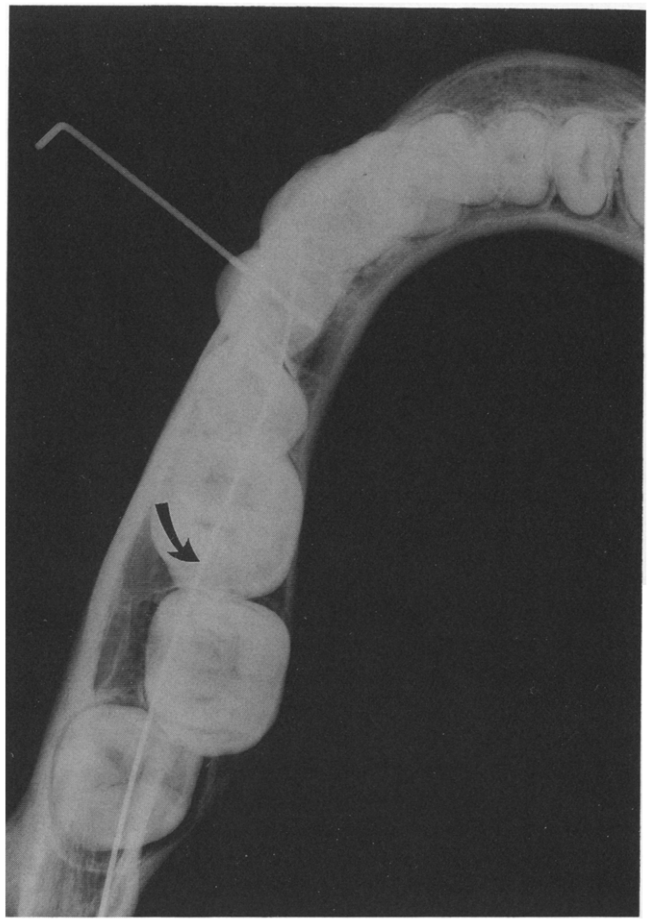

FIG 6. Radiograph showing a typical S-shaped pathway of the mandibular canal as demonstrated by the insertion of a wire (*arrow*) into the mandibular foramen.

second molars to the mandibular canal in dried mandibles and found the canal to be located to the buccal of the second molar and lingual to the first molar. They found the closest approximation was with the distal root of the second molar and most distant relationship was with the mesial root of the first molar. The relationship of the mandibular canal to the second premolar was not examined in their study (7).

As shown in Fig. 6 the apices of the premolars are located to the buccal of the cortical plate whereas the apices of the molars are located to the lingual when moving in a posterior direction. This radiograph was taken parallel to the root long axis of the posterior teeth. The root apices would be located approximately in the center of the crowns. The increased distance of the apices to the buccal border is not due to an increased thickness of mandible, but a result of the lingual positioning of the posterior teeth (Table 1, A2). There is a slight increase of approximately 1 to 2 mm in the thickness of buccal cortical bone from anterior to posterior direction (Table 1, A4). This increase contributes a minimal amount to the distance of the apices from the buccal surface (A3).

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References

1. Orstavik D, Brodin P, Aas E. Paresthesia following endodontic treatment: survey of the literature and report of a case. Int Endod J 1983;16:167–72.
2. Rowe AHR. Damage to the inferior dental nerve during or following endodontic treatment. Br Dent J 1983;153:306–7.
3. Olivier E. The inferior dental canal and its nerve in the adult. Br Dent J 1927;49:356–8.
4. Stockdale CR. The relationship of the roots of mandibular third molars to the inferior dental canal. Oral Surg 1959;12:1061–72.
5. Carter RB, Keen EN. The intramandibular course of the inferior alveolar nerve. J Anat 1971;108:433–40.
6. DuBrul EL. Structure and relations of the alveolar process. 7th ed. Sicher's oral anatomy. 7th ed. St. Louis: CV Mosby, 1980:444–50.
7. Littner MM, Kaffe I, Tamse A, Dicapua P. Relationship between the apices of the lower molars and mandibular canals—a radiographic study. Oral Surg 1986;62:595–602.
8. Rajchel J, Ellis E, Fonseca RJ. The anatomical location of the mandibular canal: its relationship to the sagittal ramus osteotomy. Int J Adult Orthodont Orthognathic Surg 1986;1:37–47.
9. Cogswell WW. Surgical problems involving the mandibular nerve. J Am Dent Assoc 1942;29:964–9.
10. Harris MH. Apicoectomy and retrograde amalgam in mandibular molar teeth. Oral Surg 1979;48:405–7.
11. Lin L, Skribner J, Shovlin F, Langeland K. Periapical surgery of mandibular posterior teeth: anatomical and surgical considerations. J Endodon 1983;11:496–501.

The Way it Was

In his farewell address at Harvard Medical School in 1882, Oliver Wendell Holmes observed fondly, "I can hardly believe my own memory when I recall the old practitioners and professors" who were my teachers when I "mingled with the train of students that attended the morning visits." But, "old theories, and old men who cling to them, must take themselves out of the way as the new generation with fresh thoughts and altered habits of mind comes forward. . . ."

And that "new generation" were, in their turn, old men long ago. . . .

Zachariah Yeoman