Relationship between the apices of the lower molars and mandibular canal—a radiographic study

M. M. Littner, D.M.D., I. Kaffe, D.M.D.,* A. Tamse, D.M.D.,** and P. Dicapua, D.M.D.,*** Tel Aviv, Israel*

SCHOOL OF DENTAL MEDICINE, TEL AVIV UNIVERSITY

The study was performed on forty-six randomly chosen dry mandibles. The molar areas of each mandible were radiographed by the paralleling technique, and an additional radiograph at −20° angulation of the same area was taken. Measurements of the distance between the upper border of the mandibular canal and the root apices of the first and second molars were taken. The location of the mandibular canal in the buccolingual plane was determined. The obtained data were statistically evaluated. Statistically significant symmetry of the relationship of the mandibular canal to the root apices was established between the right and left sides of the same mandible. In the majority of cases the mandibular canal was buccal to the apices of the second molar, and in the first molar area the canal was lingual to the root apices in almost half of the cases. Most frequently, the upper border of the mandibular canal was located 3.5 to 5.4 mm below the root apices of both first and second molars. In no case was the mandibular canal found in close proximity, both in the vertical and in the buccolingual planes, to the first and second molar apices.
(ORAL SURG. ORAL MED. ORAL PATHOL. 62:595-602, 1986)

The relation of the mandibular canal to the apices of the lower molars is of great academic and practical importance. Various surgical and endodontic procedures in the lower jaw present the possibility of complications to the mandibular canal and its components. In root canal therapy, overinstrumentation of the root canals in an area close to the mandibular canal may cause edema or hemorrhage and pressure on the mandibular nerve sheath. Endodontic materials pushed accidently beyond the root apex or into the mandibular canal itself may result in chemical or mechanical damage to the mandibular nerve, thus causing paresthesia.[1] Paresthesia may also develop when numerous surgical procedures in the mandible, such as tooth extraction or apicoectomy in one of the roots of the lower molars, are performed. The possible trauma to the mandibular canal, as a consequence of lower third molar extraction, has been described in the literature.[2-5] This is caused by the close proximity of the mandibular canal to the apices of these teeth.

*Department of Oral Pathology and Oral Medicine.
**Department of Endodontology.
***As partial fulfillment of D.M.D. degree.

According to Stockdale,[3] the distance between the apices of the permanent lower molars and the mandibular canal increases with eruption of the teeth. When the teeth come into occlusion, their apices are not in close proximity to the mandibular canal. In addition, during dental and skeletal development, the second molar remains in proximity to the mandibular canal longer than the first molar. After the second molar erupts and its apices are fully formed, there is "an appreciable distance between its apices and the canal." Generally, however, the distance between the root apices of the first and second molars and the mandibular canal is larger than that of the third molar. Nevertheless, the buccolingual and superior-inferior relationships of the mandibular canal to the roots of the third molar are of great significance. Sicher and DuBrul[6] stated that the mandibular canal is usually located lingual to the third molar roots. In contrast, Cogswell,[5] Stockdale,[3] and Waggener[2] claimed that the mandibular canal is located buccal to these roots in most cases. None of the previous studies examined the relationship of the first and second molar apices to the mandibular canal.

The purpose of the present study was to evaluate, in dry mandibles, the relationship between the root

Table I. Distance, in millimeters, between the root apices and the upper border of the mandibular canal as measured in the orthoradial and eccentric radiographs (−20°): an example of two mandibles (out of 42)

		Right				*Left*			
		First molar		*Second molar*		*First molar*		*Second molar*	
Mandible no.		*Mesial root*	*Distal root*	*Mesial root*	*Distal root*	*Mesial root*	*Distal root*	*Mesial root*	*Distal root*
I	Orthoradial radiograph	5.8	5.6	2.2	2.6	5.6	5.5	2.1	2.5
	Radiograph (−20°)	6.4	6.8	5.4	5.4	6.7	6.5	5.4	5.5
	Location of mandibular canal in relation to root apex	L	L	L	L	L	L	L	L
II	Orthoradial radiograph	5.4	5.4	5.2	5.2	5.5	5.6	6.1	6.0
	Radiograph (−20°)	8.0	8.0	4.7	4.7	7.9	8.1	5.4	5.2
	Location of mandibular canal in relation to root apex	L	L	B	B	L	L	B	B

apices of the lower first and second molars to the upper border of the mandibular canal and to establish the location in the buccolingual and vertical planes of the canal, relative to the apices of these teeth.

MATERIALS AND METHODS

A sample of forty-six dry mandibles from the Department of Anatomy and Anthropology, Sackler Faculty of Medicine, Tel Aviv University, was selected for the study according to the following criteria:

1. All mandibles were of adults and included fully erupted molars.
2. All mandibles had a uniform plane of occlusion, that is, no overeruption or undereruption of the lower molars.

All mandibles were examined radiographically, and for this purpose the teeth in every half-mandible were divided into two groups: (1) second premolar and first molar and (2) second and third molars.

Two periapical radiographs were carried out for each of the two groups: one orthoradial in the paralleling technique in which the cone was directed in a vertical angle to the film and the long axis of the teeth; the second one was performed while the cone was angulated in −20 degrees. The position and location of the film in both radiographs were precisely identical. To fulfill this requirement, a special holder was prepared to retain the mandible in a position in which the plane of occlusion was parallel to the floor. All the films were located in exactly the same position, parallel to the long axis of the teeth. The film was held in place with a film holder and wax. The films were marked on their occlusal side for further reference.

All the films were exposed and processed under the same conditions. Kodak Ultraspeed DF-58 films (Eastman Kodak Company, Rochester, New York) were used and exposed with a Space-Marker II x-ray machine (S. S. White, Philadelphia, Pennsylvania) with a built-in long cone. The machine was operated at 70 kVp, 32 impulses, and 10 mA. All the films were processed in a Durr-Periomat automatic processing machine (Dürr-Dental GmbH & Co., KG, Bietigheim-Bissingen, West Germany) with a cycle of 8 minutes. Measurements were performed twice—once with a magnifying glass ruler and calipers and a second time with a viewer with no magnification but with the same aids as before. In four mandibles (8.7% of the sample), the mandibular canal was not demonstrated clearly on the radiographs; therefore, these mandibles were excluded from the study and only radiographs of forty-two mandibles were evaluated.

After the first (orthoradial) radiograph had been compared with the second (eccentric −20 degrees) radiograph, the buccolingual location of the canal, in relation to the root tips, was determined according to the tube shift technique described by Clark[7] and Frank.[8] Measurements of the distance between the root apices and the mandibular canal in each radiograph made possible the determinaton of whether the canal was located buccally, lingually, or in the same plane as the root apices. When the distance between the root ends and the mandibular canal increases on the radiograph made with an angulation of −20 degrees, the canal is close to the film (located lingually to the tooth). When the distance decreases, the canal lies in the buccal side of the root apices. In case there is no change in the distance, the mandibular canal is located in the same plane as the root ends. The data acquired from every mandible were tabulated in separate tables and evaluated. Table I

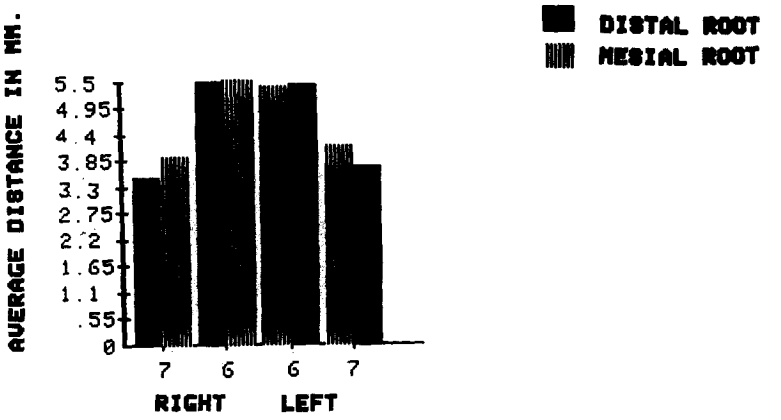

Fig. 1. Average distance, in millimeters, between the root apices of the lower molars in both sides and the upper border of the mandibular canal.

demonstrates the data obtained and evaluated in two mandibles; this procedure was repeated separately for each examined mandible.

The results concerning the precise location of the mandibular canal in relation to the molar root apices, as attained from the radiographic examination, were verified by transverse sections in a sample of dry mandibles. In all cases, the relationship of the mandibular canal to the root apices observed in the sections was in accord with that found in the radiographic examination. All the data were tabulated and statistically evaluated.

RESULTS

The average distance in millimeters measured between the root ends of the lower molars and the upper border of the mandibular canal is shown in Table II and demonstrated graphically in Fig. 1. The shortest distance was measured from the distal root end of the second molar in both sides, and this distance increases gradually mesially.

Paired *t*-test statistical evaluation was conducted for possible symmetry of both sides of the mandible in regard to the distance of the root apices to the upper border of the mandibular canal. Symmetry was found in all cases. The most significant symmetry was found between the mesial roots of first molars (Fig. 1 and Table III). In the buccolingual plane (only 2.4% to 7.2% of the cases), the mandibular canal was located in the plane of the apex of the root (Table IV). In most cases the canal is located buccal to the roots of the lower molars, Table IV. Those results are demonstrated graphically in Fig. 2. Half of the cases showed the mandibular canal lingual to the root ends only in the distal and mesial roots of the left first molars.

The location of the mandibular canal in the vertical plane relative to the root apices is shown in Table V and demonstrated in Fig. 3. Direct relationship of the mandibular canal and root apices in the vertical plane was noted. The mandibular canal in the posterior area showed a greater tendency to be in the plane of or superior to the root apices than in the more mesial area.

Table II. Average distance, in millimeters, between the root apices of the lower molars on both sides and the upper border of the mandibular canal

Tooth	*Root*	*No. of cases*	*Average distance*	*SD*	*SE*
Second R	D	42	3.45	2.06	0.33
Second L	M	42	3.89	2.13	0.33
First R	D	42	5.44	2.31	0.38
First R	M	42	5.47	2.48	0.41
Second L	D	42	3.69	1.94	0.31
Second L	M	42	4.13	2.16	0.34
First L	D	42	5.41	1.91	0.31
First L	M	42	5.33	2.11	0.34

SD = Standard deviation; SE = standard error.

The Pearson correlation coefficient test was performed to determine the incidence of cases in which the apices of the roots of the first and second molars are located in both the vertical and buccolingual planes in close proximity to the mandibular canal. The results of the statistical evaluation indicate that in no case was the mandibular canal simultaneously in both planes close to the root apices of the first and second molars.

DISCUSSION

The mandibular canal runs from the mandibular foramen obliquely downward and forward in the

Table III. Symmetry of the distance between the root apices and the upper border of the mandibular canal in the right and left sides

Molar tooth/root	*No. of cases*	*Average distance (mm)*	*SD*	*Average difference*	*p*	*Significance of average distance*	*Symmetry*
First L M	42	5.41	1.99	0.01	0.937	No	Positive
First R M		5.42	2.36				
First L D	42	5.17	1.91	0.21	0.448	No	Positive
First R D		5.38	2.17				
Second L M	42	4.04	2.18	−0.13	0.644	No	Positive
Second R M		3.91	2.08				
Second L D	42	3.57	1.90	−0.16	0.524	No	Positive
Second R D		3.41	2.05				

SD = Standard deviation.

Table IV. Localization of the mandibular canal in the buccolingual aspect

Molar tooth	*Root*	*Buccal to root plane*		*Lingual to root plane*		*In root plane*	
		%	*Root no.*	*%*	*Root no.*	*%*	*Root no.*
Second R	D	69.0	29	23.8	10	7.2	3
Second R	M	73.8	31	23.8	10	2.4	1
First R	D	52.4	22	45.2	19	2.4	1
First R	M	50.0	21	45.2	19	4.8	2
Second L	D	66.6	28	31.0	13	2.4	1
Second L	M	71.4	30	26.2	11	2.4	1
First L	D	35.7	15	57.1	24	7.2	3
First L	M	40.4	17	52.4	22	7.2	3

Table V. Localization of the mandibular canal in the vertical plane relative to the root apices on both sides

Molar tooth	*Root*	*Inferior to root apices (positive)*		*Superior to root apices (negative)*		*In plane of root apices*	
		No.	*%*	*No.*	*%*	*No.*	*%*
Second R	D	38	90.5	3	7.1	1	2.4
Second R	M	38	90.5	3	7.1	1	2.4
First R	D	41	97.6	1	2.4	0	0
First R	M	41	97.6	1	2.4	0	0
Second L	D	39	92.8	2	4.8	1	2.4
Second L	M	39	92.8	2	4.8	1	2.4
First L	D	41	97.6	1	2.4	0	0
First L	M	41	97.6	1	2.4	0	0

ramus and then in the body of the mandible horizontally and below the sockets of the teeth. The canal contains the inferior alveolar (dental) nerve and vessels from which branches enter the roots of the teeth. Below the root of the second premolar, the mandibular canal divides into mental and incisive canals. According to Worth,[9] there are wide variations in the radiographic appearance of the canal. Most commonly, the mandibular canal appears as a radiolucent shadow with radiopaque lines at the margins. In some cases, the mandibular canal is seen as two faint white lines without alteration in the bone density between them. Usually the upper line is predominant in density. In other cases, the borders of the canal are poorly defined and observed as discontinuous gray lines (Figs. 4 to 6).

Usually, the canal is seen in the radiograph immediately below the roots of the molars.[9-14] In

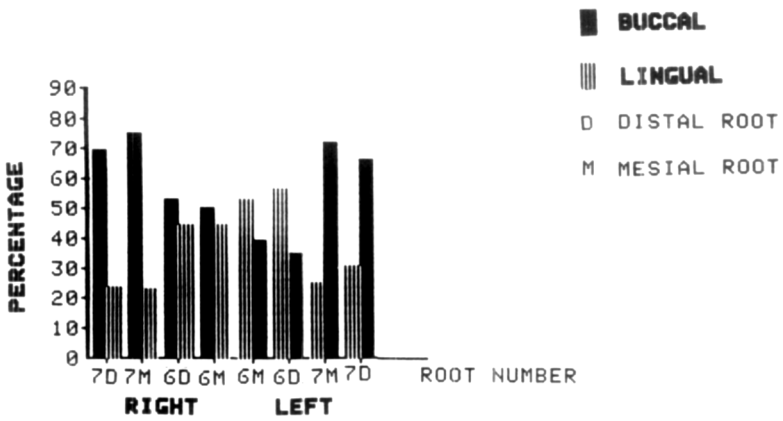

Fig. 2. Localization of the mandibular canal in the buccolingual plane.

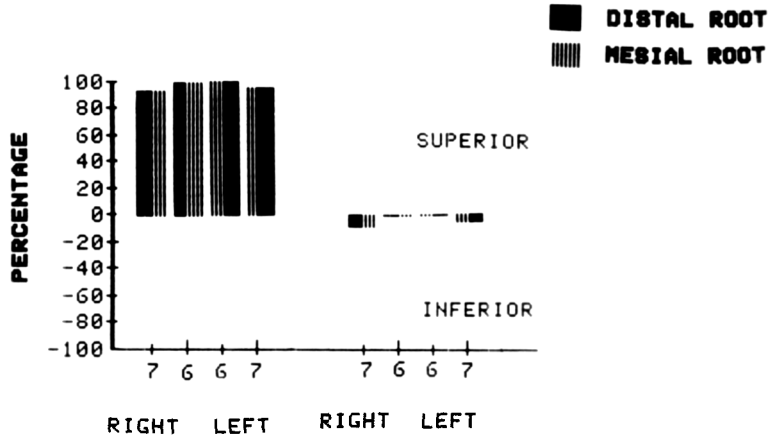

Fig. 3. Localization of the root apices in the vertical plane relative to the mandibular canal.

some cases, it may be related more closely to the inferior border of the mandible than to the tooth apices. In rare cases, the mandibular canal is seen above the level of the molar apices. Sometimes the apices of the molar teeth appear to be superimposed over the canal.

Björk[12] stated that the shape and position of the mandibular canal do not change during mandibular growth. Most of the bone remodeling occurs in the outer part of the mandible and not so much around the canal itself. Sicher and DuBrul[6] and Worth[9] wrote that the vertical relationship between the mandibular canal and the apices of the lower molars is stable. As a result of the canal's pathway downward from the ramus to the body of the mandible, the upper border of the canal is close to the apices of the third molar, but this distance increases toward the first molar.

Traumatic dental procedures in the lower jaw, such as overextension of instruments or materials in root canal therapy or surgical procedures, may result in damage to the neurovascular bundle (for example, paresthesia as a result of the close proximity of the root apices to the upper border of the mandibular canal). Waggener,[2] Stockdale,[3] and Westesson and Carlsson[4] wrote articles with regard to third molar extractions, describing the possible damage to the mandibular canal. Root canal therapy is performed mostly in the first and second molars, and the majority of cases of paresthesia reported were in these two teeth. Ørstavik and colleagues[1] stated that out of twenty-four endodontically treated teeth that were reported to have caused paresthesia, eleven were in the first and second molars, four in the third molar, and nine in the second premolar.

The numerous root canal procedures performed in the lower molars in everyday practice do not correlate with the few reported cases of paresthesia in the lower jaw. The only explanation of the low incidence of damage to the mandibular neurovascular bundle

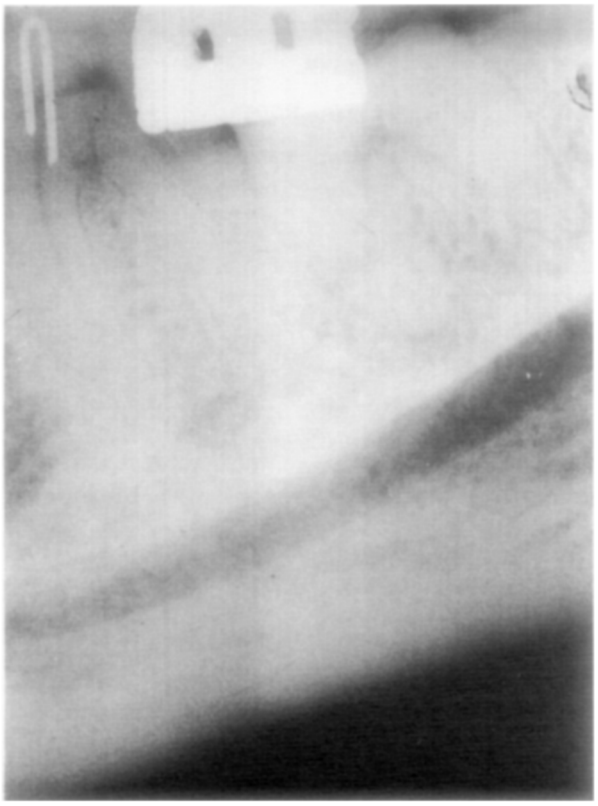

Fig. 4. Periapical radiograph showing the mandibular canal as a radiolucent shadow with clear radiopaque boundaries.

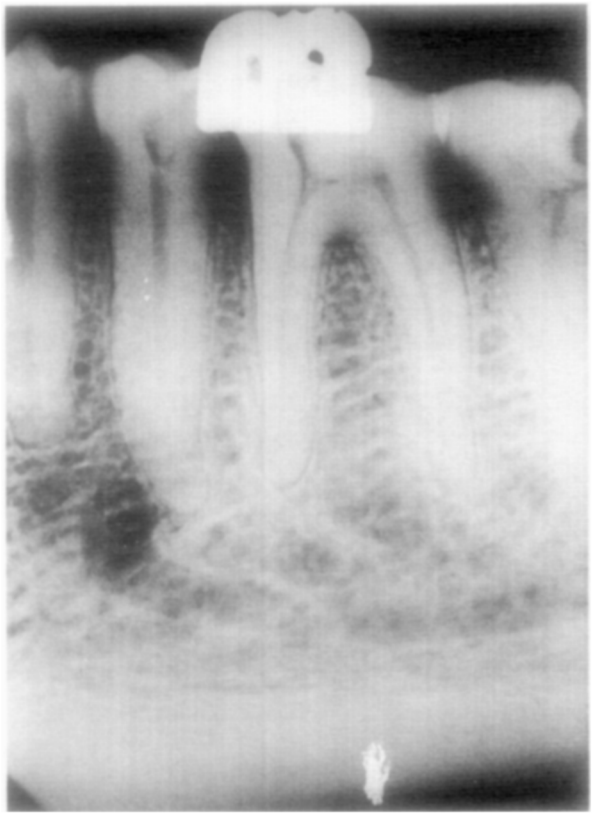

Fig. 5. Periapical radiograph showing the mandibular canal. Boundaries of the canal are faint, and no distinct alteration between the density of bone of the mandible and the canal area is present.

during endodontic therapy is that the proximity of the molar root apices to the mandibular canal, as seen in periapical radiographs, is a result of the radiographic technique and not necessarily the real anatomic relationship.

According to Harris,[13] there are many references in the literature regarding periapical surgery in mandibular molar teeth, most of which are negative in nature. The potential damage to the inferior alveolar neurovascular bundle is often cited as a contraindication to this procedure. Ioannides and Borstlap[14] also conducted a review of the literature and concluded that apicoectomy on molars is not a routine procedure. In their opinion, possible damage to the neurovascular bundle discouraged many dentists from performing apicoectomies in this region. Diminished interest of the patients in retaining their molars because of minimal contribution to their esthetic appearance was another reason to avoid the procedure. There is also hesitation on the part of several (inexperienced) surgeons to resect molar roots because of adjacent structures. Harris[13] and Ioannides and Borstlap[14] are in agreement that anatomic considerations are not a contraindication to surgery in mandibular first and second molars. Their conclusion is based only on their excellent experience. Harris[13] performed retrograde fillings on 322 mandibular first molars, 66 mandibular second molars, and 4 mandibular third molars, and there was only one incidence of nerve damage with a very short duration. Ioannides and Borstlap[14] reported that, out of 397 apicoectomies performed on lower molars, there was only one case of paresthesia. In our review of the current literature, we found no explanation for the low incidence of paresthesia as a result of root canal therapy and apicoectomies performed on lower first and second molars. Furthermore, not one study concerning the relations between the measured distance of the root apices of the lower first and second molars and the upper border of the mandibular canal, in periapical radiographs, could be found.

The present study investigated the relation of the apices of the lower first and second molars to the upper border of the mandibular canal. Our results strongly correlate with Worth's[9] description of radio-

graphic appearance and position of the mandibular canal in the periapical radiographs.

The upper border of the mandibular canal in the region of the first molar was almost always below the apices of this molar (Fig. 3), and in only in two cases was the upper border of the mandibular canal seen above the plane of the apices of the distal roots of the first molar. In the region of the second molar, most frequently, the upper border of the mandibular canal was inferior to the apices, but in 4.8% to 7.1% of the cases, the upper border of the mandibular canal was superior to the apices of the second molars. The average distance between the molar apices and the upper border of the mandibular canal increases toward the first molar. The largest distance was found in the mesial root of the first molar on the right side (5.47 mm) and in the distal root of the first molar on the left side (5.41 mm). According to the Pearson correlation coefficient test, a positive clear correlation was found in the distance between all the distal and all the mesial roots and the upper border of the mandibular canal in the same mandible. When the distance increases or decreases in one root, it will have the same pattern in the corresponding roots of the other teeth. The close proximity between the root apices and the canal can be found in very few persons.[6] Such close proximity can be seen in mandibles with a short vertical dimension and in children before there is bone apposition in the alveolar process.[6] Our results confirm this statement. The data concerning the distance between the root apices and the upper border of the mandibular canal were evaluated by paired *t* test for symmetry between the right and left sides of the same mandible (Table III). The results prove that, statistically, symmetry between both sides of the same mandible exists.

The vertical dimension concerning the proximity of the canal to the root apices and the horizontal dimension in the buccolingual plane are of equal importance. Our study included examination of the relationship between the mandibular canal and the root apices in the buccolingual plane.

Several authors[2, 3, 5] claim that the mandibular canal is located buccal to the roots of the third molar, whereas Sicher and DuBrul[6] state that it lies lingually. The relationship between the mandibular canal and the apices of the first and second molars in the buccolingual plane was not investigated previously, and no data concerning this subject could be found in the current literature. In the present study, the mandibular canal was interpreted to be, in most instances, in the buccal side of the root apices of the second molar. The canal was interpreted radiographically to be lingual to the root apices in almost half of the cases in the first molar area. In only between 2.4% and 7.2% of the cases was the mandibular canal in the radiographs in the same plane as the root apices, that is, in continuation with the long axis of the roots. Statistical evaluation of the data collected in both horizontal and vertical planes proved that in no case in the examined sample did there occur the combination of close proximity of the mandibular canal to the root apices of the examined teeth in both planes. This may explain the rare reported cases of damage to the neurovascular bundles resulting from trauma in endodontic and surgical treatment in the area. It may well be that because clinically most of the dentists still perform periapical radiographs in the bisecting angle technique, in which the radiograph is taken at an angulation of $-10°$ or $-5°$, often the canal can be seen as being closer to the root apices than it is in reality. It is suggested that in those situations in which the operator sees the root apices to be in close contact with the upper border of the mandibular canal, two radiographs should be taken with a difference of $-20°$. This may help to diagnose more accurately the relationship between

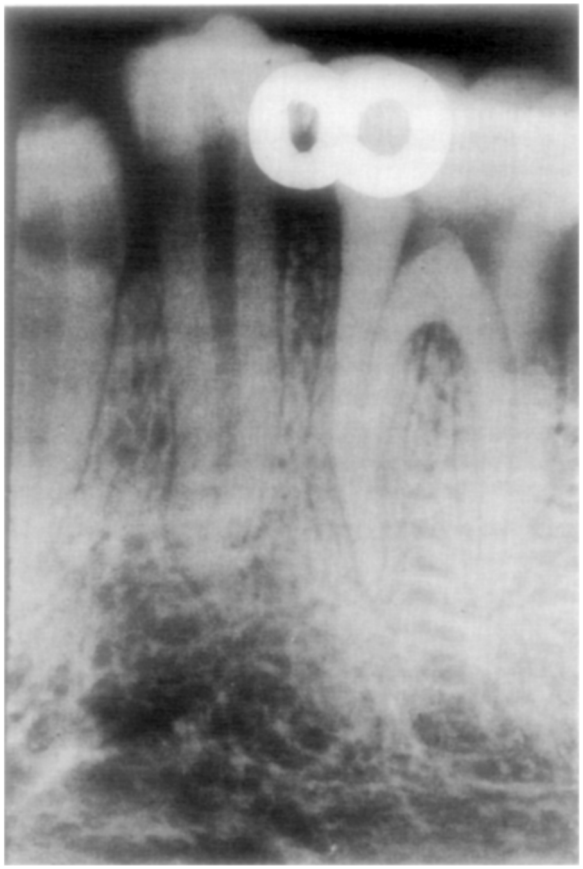

Fig. 6. Periapical film demonstrating radiographically poorly defined borders of the mandibular canal.

the root apices and the upper border of the mandibular canal.

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Reprint requests to:
Dr. M. M. Littner
Department of Oral Pathology and Oral Medicine
School of Dental Medicine
Tel Aviv University
69978 Tel Aviv, Israel