4.5.1.4 Irrigation Patterns during Ultrasonic Instrumentation

Krell et al. (1988a and 1988b) studied irrigation patterns during ultrasonic canal instrumentation in an attempt to resolve differences reported in the literature concerning the efficacy of endosonics. Straight and curved canals were fabricated in clear resin blocks. The Cavi-endo ultrasonic unit was used according to the manufacturer's instructions but with a food dye placed in the irrigant reservoir. After inactivation of the ultrasonic handpiece, voids in the irrigant dye which corresponded with points of nodal activity could be seen with all file sizes. Initial obstructions inhibited the vibration of the file in the canal and shortened the distance of the first node from the Cavi-endo insert head. There was no irrigant penetration beyond the first node; only after the instruments were freed could the irrigant completely penetrate the canal. For files that bound in the canal, 1 min of activation was insufficient to allow the irrigant to penetrate to the tip of the file. The authors emphasized the need to use smaller files for longer periods of time. An unexpected finding was the reduced time required for complete irrigant penetration of curved canals. The authors speculated that because the curved canals had a 7^0 deflection the reflected energy may not have been sufficient to result in destructive interferences and would, therefore, allow the irrigant to continue to move apically more rapidly. In a subsequent study using the same experimental model, Krell et al. (1988b) found that the irrigant used with the endosonic size 35 and 45 diamond-coated files only penetrated to a depth of 1 mm beyond the tip of the file. The diamond-coated files could only penetrate to within 2 to 5 mm of the working length, with the result that portions of the canal would only be debrided with the smaller, standardized, stainless steel ultrasonic file. For this reason, the authors suggested recapitulation with the largest stainless steel file, after coronal flaring, to help increase canal taper and to minimize potential debridement inadequacies.

4.5.2 Summary

The following characteristics of ultrasound in relation to its use in the root canal were investigated: oscillatory patterns; cavitation; and, acoustic streaming.

Endodontic files oscillate in a transverse manner which sets up a pattern of nodes and anti-nodes. Damping, or physical restraint of the oscillating file, occurs when the file contacts the canal wall. The file must oscillate freely in order to produce cavitation and acoustic streaming. It was found that cavitation was difficult to induce within the root canal and, when it did occur, it played little part in debridement. Acoustic streaming, on the other hand, was more likely to occur but only under optimal conditions of a freely vibrating, small file subjected to a high power setting. Under these conditions, very clean, smear-free canal walls resulted.

CHAPTER FIVE

SUMMARY AND CONCLUSIONS - PART I

Root canal preparation is an essential step in endodontic treatment and consists of biomechanical and chemomechanical preparation followed by disinfection. The objectives of these procedures are: to remove from the root canal all organic debris which could serve as a source of infection; and, to shape the canal such that three-dimensional obturation can be achieved. The objectives can be realized with instruments of specific design (broaches, reamers, files and certain automated instruments) using irrigating solutions and following biological principles.

Clinical criteria used as an indication of cleanliness of root canals were found to be inadequate. Curved canals, in particular, were difficult to render free of pulpal and dentinal debris. Modification of instruments, step-back instrumentation and coronal flaring of canals were introduced to address this problem. Engine driven, sonic, and ultrasonic instruments were incorporated into many of the techniques.

Various irrigation regimes accompanying the instrumentation techniques have been investigated. The most widely used irrigant is NaOCl which has a unique set of antibacterial, tissue dissolving and relatively non-toxic properties making it suitable for endodontic use; its use in combination with EDTA has been shown to produce very clean, smear-free canal walls. EDTA alone as an irrigant removes the smear layer but is ineffective in the removal of organic pulpal debris from the root canal.

The use of ultrasound has been incorporated into endodontic techniques to enhance both instrumentation and irrigation of root canals. Many of the reports on the efficacy of the ultrasonic method of root canal preparation are conflicting. On closer examination, there are nearly as many different methods of canal preparation as there are reports. Factors affecting the production of ultrasonic

energy within the root canal and its subsequent ability to debride the canal include: the irrigant, the duration of ultrasonic activity, the length, width and design of the instrument, the power setting of the ultrasonic unit, and the size and shape of the canal. Understanding the biophysical properties of ultrasound can help create conditions under which the inherent advantages of ultrasound can be utilized to the maximum. Whether these conditions are applicable to fine curved canals requires further investigation.

PART II

ORIGINAL RESEARCH

A Comparison of Different Techniques For Cleaning Curved Root Canals: A Scanning Electron Microscope Investigation.

CHAPTER SIX

AIM OF THE INVESTIGATION

The primary aim of the investigation reported here was to compare by means of a SEM evaluation of the canal wall, the effectiveness of four different instrumentation techniques for cleaning curved root canals. In particular, the study was designed to compare:

i) step-back hand instrumentation;

ii) a variation of step-back hand instrumentation, which includes the use of Gates-Glidden drills to provide early access;

iii) step-back hand instrumentation with early access and ultrasonic irrigation; and,

iv) an ultrasonic technique, resembling that recommended by the manufacturers of the Enac Ultrasonic Unit, which incorporates the use of hand and ultrasonic instruments.

Secondary objectives of this SEM evaluation of the canal wall were: to determine if one region, more or less than any other region of the canal (apical, middle or coronal) was more effectively cleaned during root canal preparation; and, to determine if the canal type (mesiobuccal and distobuccal canals of maxillary molars and mesial canals of mandibular molars) influenced the effectiveness of root canal preparation techniques.

CHAPTER SEVEN

MATERIALS AND METHODS

7.1 MATERIALS

Freshly extracted, human first and second maxillary and mandibular molar teeth were collected from the Department of Oral Surgery, Westmead Hospital Dental Clinical School. The age and sex of the patient and the pulpal status or reason for extraction of the teeth were not recorded by the Department at the time of collection. The teeth were stored in a freezer at -12°C until required. While the roots of all teeth selected were intact, some of the crowns were heavily restored or partially missing. Only the mesial roots of mandibular molars and the buccal roots of maxillary molars were used in the study.

7.1.1 Tooth Selection

Root curvature was determined using Schneider's method (Schneider, 1971) (Fig. 7.1). The teeth were radiographed from the buccal direction using a Siemens Heliodent[38] x-ray machine at 70 kV with a current of 7 mA. Kodak Ultraspeed[39] film was exposed for 0.2 s. The radiographs were projected onto tracing paper on a screen 75 cm from a projector (Kodak Carousel S-AV 2050[40]) at 10x magnification. After the outlines of the roots were traced onto the paper, a line was scribed parallel to the long axis of the canal. A second line was drawn from the apical foramen to intersect with the first at the point where the canal began to leave the long axis of the tooth. The acute angle thus formed was measured by means of a protractor. When roots exhibited a secondary curvature in the apical region, the second line drawn was from the end of the principal curve rather than from the apex. In order to standardize canal curvature, only those roots exhibiting 15° to 35° of curvature were used in this study.

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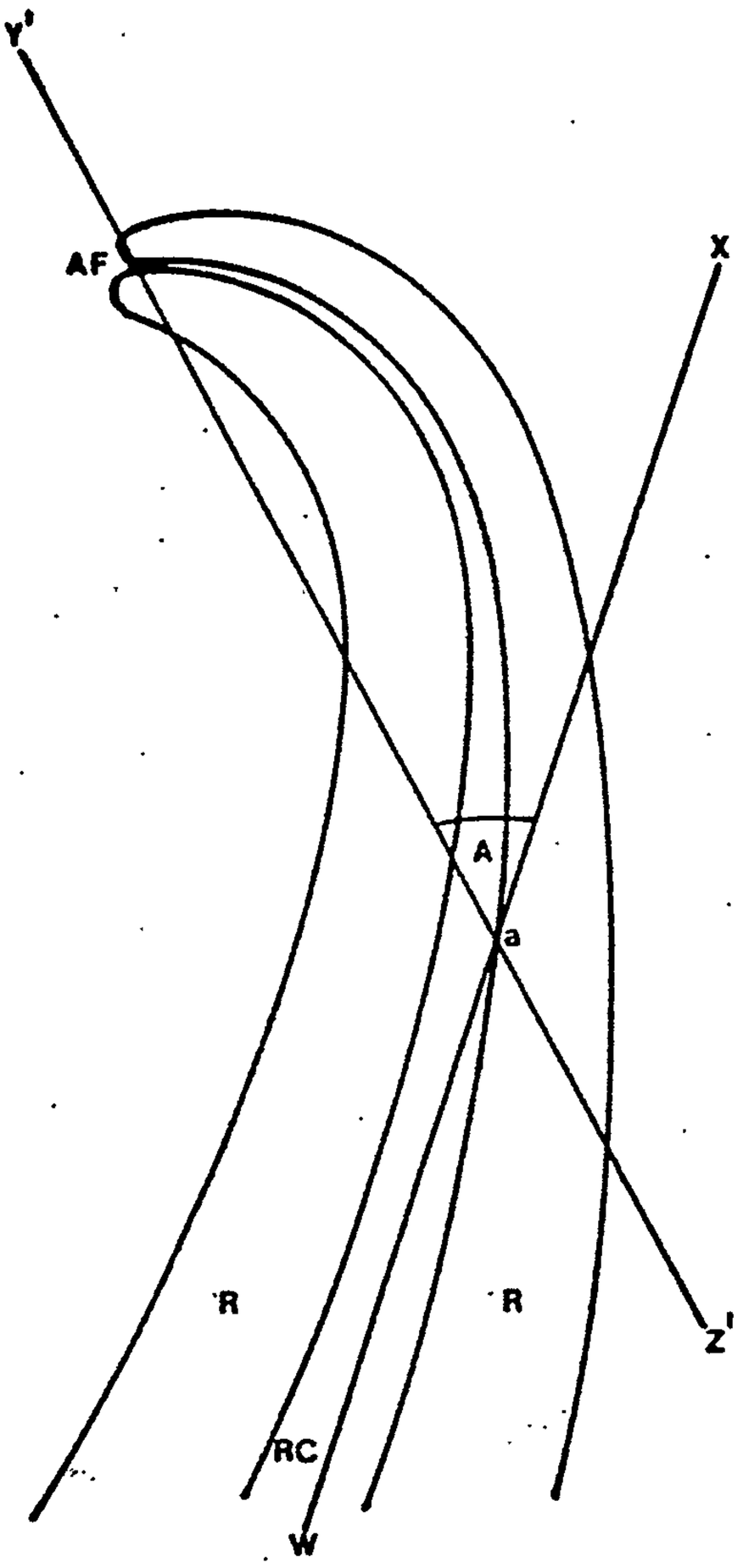
[38] Siemens Aktiengesellschaft, Bensheim, Germany.

[39] Eastman Kodak Co., Rochester, New York, U.S.A.

[40] Eastman Kodak Co., Rochester, New York, U.S.A.

FIGURE 7.1

Interpretation of Schneider's (1971) Technique for Determining Root Curvature *in vitro*



WX - Long access of root canal

Y^1Z^1 - Line from apical foramen to point of departure of root canal from its long axis

Y^1aX - Angle of curvature

AF - Apical foramen

R - Root

RC - Root canal space

a - Point of intersection of lines WX and Y^1Z^1

Of the 80 teeth selected, 32 were maxillary molars and 48 were mandibular molars. These teeth were randomly divided into 4 groups of 20; the teeth within each group were prepared using a different instrumentation technique.

7.1.2 **Instruments**

7.1.2.1 Hand Instruments

Hand instruments used were Beutelrock/CC cord K-files[41] and Hedstroem files[42]. To determine working length, a size 10 K-file was placed in the canal until the file tip was just visible at the apical foramen. The working length was recorded as 1 mm less than the length measured. The fine hand instruments, sizes 10, 15 and 20, were discarded during instrumentation after each tooth; the larger hand instruments were discarded either after showing signs of damage or after the third or fourth tooth. All K-files were precurved before placement in the canal.

7.1.2.2 Ultrasonic Instruments

A preliminary study, designed to familiarize the author with the ultrasonic unit, was carried out using 20 extracted molar teeth of which all canals were instrumented. Approximately half the teeth were instrumented by hand using the step-back technique and then irrigated for 2 mins with the ultrasonic file placed at working length. The remaining teeth were instrumented using the ultrasonic technique recommended by the manufacturers of the Enac ultrasonic unit. The above techniques were modified for the purpose of the subsequent investigation as a result of the difficulties encountered in the preliminary study.

The Enac ultrasonic system was used as the source of ultrasound. It was operated at an automatically adjusted frequency of 30,000 Hz. The directions of the manufacturer suggested the Enac be operated at the power setting 3,

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[41] Vereinigte Dentalwerke, Munchen, W. Germany.

[42] Vereinigte Dentalwerke, Munchen, W. Germany.

however, a trial run at this setting using 31 mm K-files with handles removed resulted in instrument fracture at the apical tip in several cases. For this reason, a power setting of 2.5 was used. The rate of continuous water flow was adjusted, by the control knob located on the front of the unit, until a stream of water encircled the file. The files were discarded after use in one canal. All ultrasonic files were precurved before placement in the canal.

7.1.3 Irrigation

Milton solution[43] (1% NaOCl), delivered into the canal using a 27 gauge needle, was the irrigant in all cases, except during operation of the Enac Ultrasonic system when water flowed continuously. R-C prep was used as a lubricant on fine hand instruments. All canals were flushed with 5 ml of Milton solution on completion of instrumentation and thoroughly dried using paper points[44].

7.1.4 Experimental Set-up

All procedures except working length determination were performed with the teeth secured into the plastic lid of a vial which was seated in a teflon™ block (Figs 7.2 & 7.3). The teflon block was attached to a slightly inclined perspex tray. A slow speed evacuator was attached to the lowest point of the perspex tray, which was itself secured to the bench. This avoided the operator having to hold the teeth, leaving two hands free for simultaneous irrigation and high speed evacuation during experimentation.

During canal preparation, the following information was recorded on the instrumentation record sheet (Fig. 7.4): type of tooth; length of canals; size of apical preparation; and, occurrence of ledgings, apical perforations and fracture of instruments.

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[43] Milton Pharmaceutical Co., Villawood, N.S.W., Australia

[44] Sure Products Ltd., Gurodanjil, Korea.

FIGURE 7.2

Enac Ultrasonic Unit and apparatus for holding teeth during instrumentation.

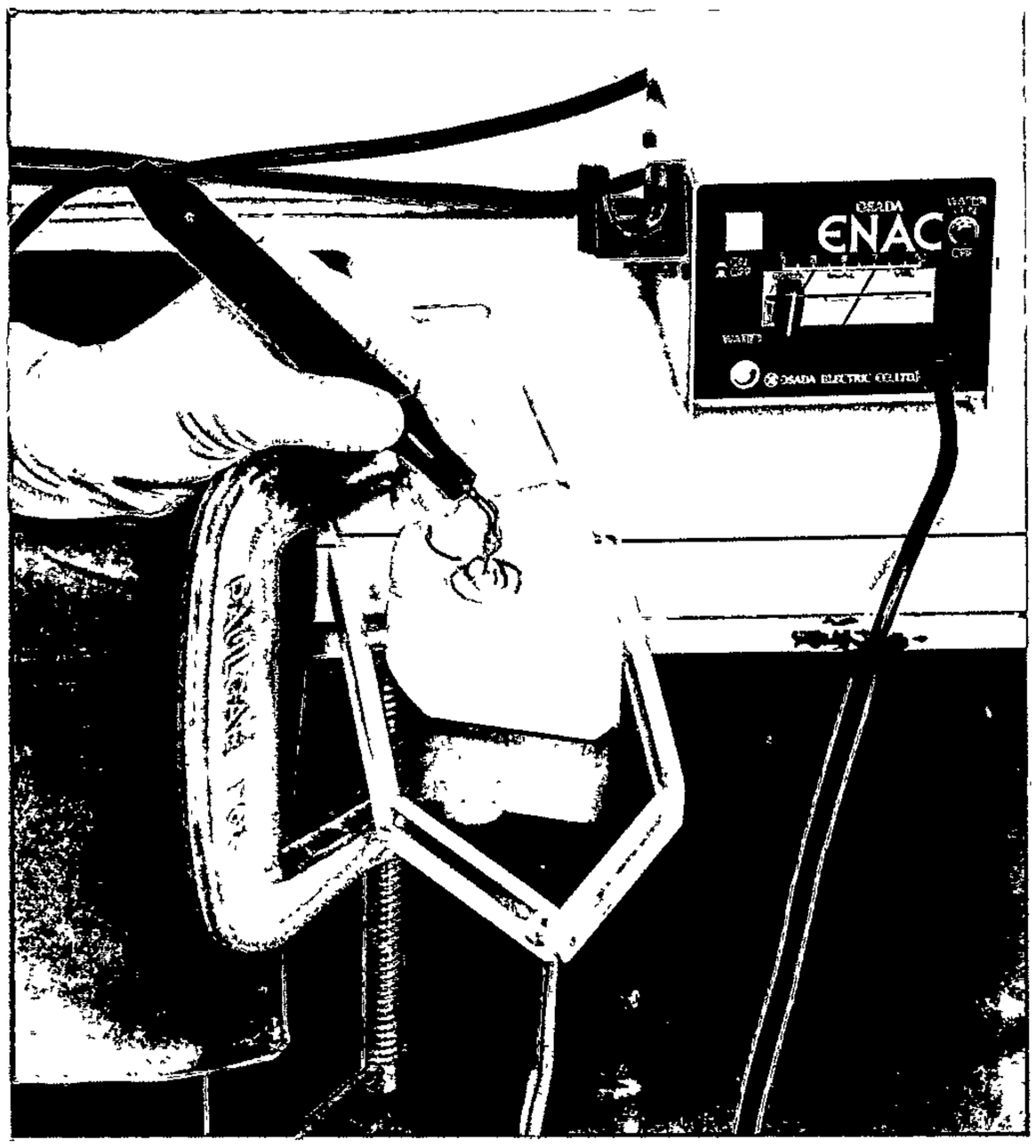

FIGURE 7.3

Apparatus for holding teeth during instrumentation.

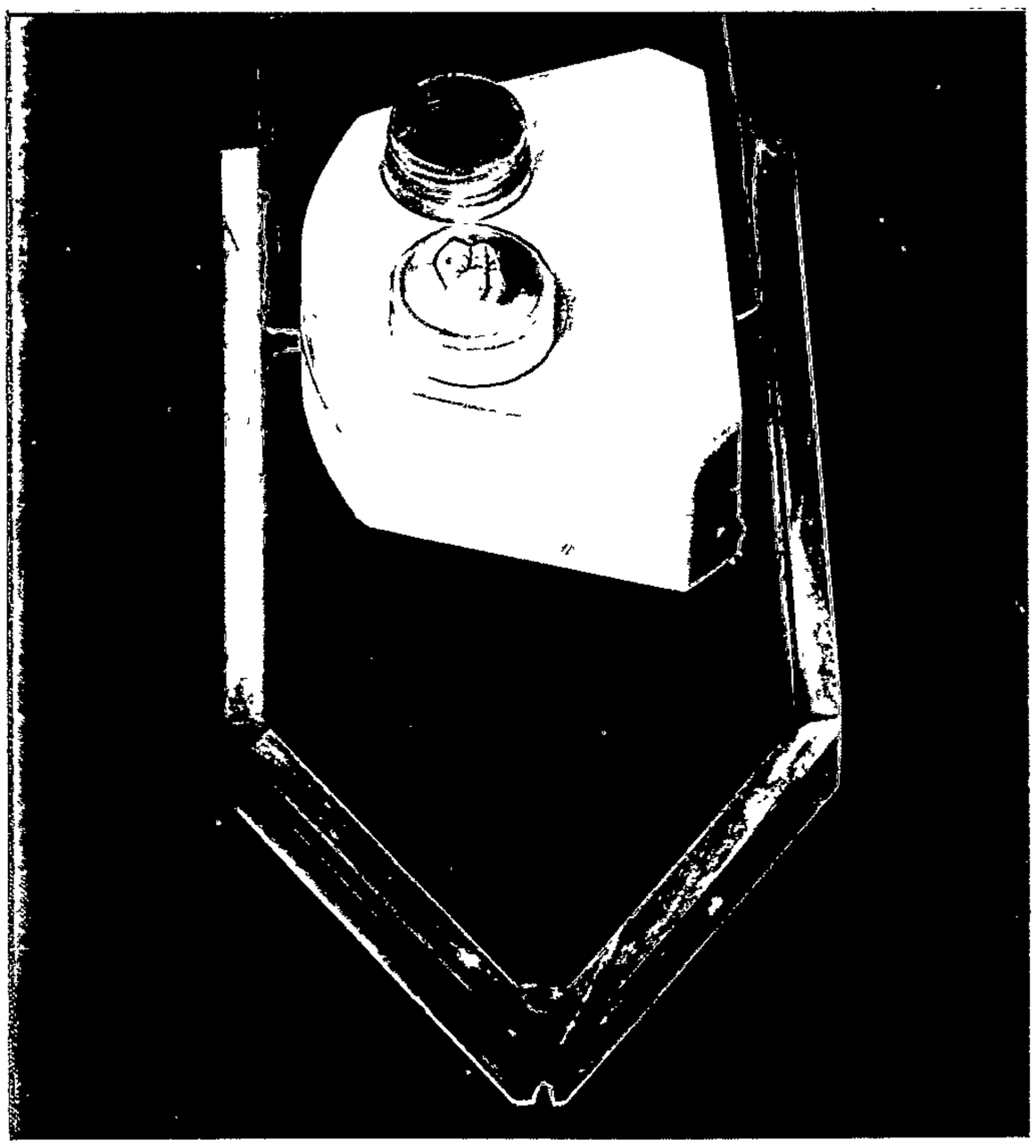

FIGURE 7.4

Instrumentation Record Sheet

Instrumentation

Details of tooth	Number	Type	Number of roots
	Comments		
Radiographic Assessment			
Length Determination	Canals:		
Instrumentation Technique: _____ Files: _____	Apical		
	Coronal		
Irrigant			

Comments: _____

7.2 DESCRIPTION OF INSTRUMENTATION TECHNIQUES

7.2.1 Technique 1: Step-back Hand Instrumentation

Step-back hand instrumentation is well recognized for use in curved canals (see Literature Review, Section 2.2.5) and served primarily as a control. The canals were filed apically with K-files to a size 3 times larger than the file which first bound at working length. In all cases except one, this was either size 30 or 35. One maxillary molar had both distobuccal and mesiobuccal canals filed apically to size 40. Between each instrument use, 2 ml of Milton solution were used to irrigate the canals. Approximately 40 ml of irrigant were used per canal. After instrumenting to size 25 apically, instruments were stepped back in 1 mm increments for 3-4 sizes. Recapitulation with the size 25 at working length was carried out between each instrument. The apex was then enlarged to the appropriate size - 30, 35 or 40. Hedstroem files were used to flare the coronal two thirds of the canal, after which, final recapitulation was performed with the last file used at working length.

Nine maxillary molars and eleven mandibular molars were instrumented using this technique.

7.2.2 Technique 2: Hand Instrumentation with Early Access

All canals were prepared apically to a size three times greater than the first instrument which bound at working length. This was generally size 30 or 35. On two occasions, canals were enlarged apically to a size 40. After instrumentation with a size 20 at working length, the canal orifice was enlarged with a size 2 Gates-Glidden drill to approximately the mid-root region. A size 25 K-file was then used at working length, after which, the canal orifice was further enlarged with a size 3 Gates-Glidden drill. Hand instruments were stepped back, as in Technique 1, prior to final preparation of the apical seat. Hedstroem files were used for flaring in the coronal two thirds of the canal. Between the use of each hand instrument, and after the use of the Gates-Glidden drills, 2 ml of Milton

solution was used to irrigate the canals. Approximately 50 ml of irrigant were used per canal.

Eight maxillary molars and twelve mandibular molars were instrumented with this technique.

7.2.3 Technique 3: Hand Instrumentation with Early Access and Ultrasound

The canals were instrumented as for Technique 2. All canals except two were apically prepared to size 30 or 35. The mesial canals of one mandibular molar were prepared to size 40. A size 15 precurved file in the Enac ultrasonic unit was positioned loosely in each canal approximately 2-3 mm short of the working length, and activated for 1 min. During the preliminary study, the author noted that frequent binding of the ultrasonic file occurred when it was placed at working length. A continuous flow of water along the file from the ultrasonic unit accompanied activation. After 1 min, the canal was irrigated with 2 ml of Milton solution before the file was replaced in the canal for a further minute of activation. Approximately 55 ml of Milton solution were used per canal. The volume of water accompanying the ultrasonic activity was not recorded.

Seven maxillary molars and thirteen mandibular molars were instrumented with this technique.

7.2.4 Technique 4: Ultrasonic Instrumentation

The canals were prepared apically, by hand and to a size 20, with 2 ml of Milton solution as the irrigant between each instrument use. During the preliminary study, it was noted that hand preparation to size 15, as recommended by the manufacturers, resulted in binding of the ultrasonic file at the apex. A precurved size 15 file in the Enac Unit was placed in each canal at working length and activated for 30 secs. At each 30 sec interval, the canal was checked until the appropriate size 30, 35 or 40 K-file could be placed at working length. Most canals were enlarged to a size 30 or 35. The mesial canals of one

mandibular molar were enlarged to size 40 and, in one mandibular molar, to a size 45. Some flaring with Hedstroem files was performed in the coronal two thirds of each canal. The technique generally resulted in a total of 3-4 mins of ultrasound per canal, with accompanying water as the principal irrigant and approximately 25 ml of Milton solution as additional irrigation. Ultrasonic files larger than 15 were not used, as it was the author's opinion from the preliminary study that they were too aggressive and that their use resulted in straightening of the canal.

Eight maxillary molars and twelve mandibular molars were instrumented with this technique.

7.3 PREPARATION OF SPECIMENS FOR THE SEM

On completion of instrumentation, the teeth were coded by an independent observer, using a table of random letter-number assignments (Fig.7.5). This enabled the SEM examination to be carried out blind by the author.

FIGURE 7.5

Coding Assignment

1.1	bc	1.17	bl	2.13	bb	3.9	ae	4.5	bn
1.2	ak	1.18	az	2.14	du	3.10	au	4.6	ck
1.3	bs	1.19	bm	2.15	dt	3.11	br	4.7	dr
1.4	db	1.20	da	2.16	ca	3.12	ci	4.8	ad
1.5	as	2.1	ce	2.17	ct	3.13	dh	4.9	cf
1.6	ba	2.2	cj	2.18	cr	3.14	am	4.10	al
1.7	bg	2.3	cl	2.19	df	3.15	cd	4.11	bx
1.8	cm	2.4	ax	2.20	dc	3.16	by	4.12	bo
1.9	dj	2.5	cu	3.1	cz	3.17	dg	4.13	aa
1.10	ay	2.6	cn	3.2	dk	3.18	ab	4.14	ap
1.11	bf	2.7	bd	3.3	bu	3.19	ds	4.15	bq
1.12	bj	2.8	ar	3.4	ac	3.20	dv	4.16	cp
1.13	cs	2.9	ao	3.5	cv	4.1	af	4.17	aq
1.14	ch	2.10	de	3.6	dm	4.2	aw	4.18	at
1.15	bl	2.11	cq	3.7	di	4.3	dn	4.19	dp
1.16	bw	2.12	ag	3.8	ah	4.4	an	4.20	dd

After coding, the teeth were decoronated and the roots were grooved on the buccal and lingual surfaces with a diamond disk. The two halves were fractured apart using a Hollenbach carver, and both halves, where sufficiently intact, were included in the study (33 root halves were not suitable for examination as fracture did not occur along the long axis of the canal). A total of 191 specimens out of a potential 224 were placed on aluminium stubs and stored at -12°C in a freezer prior to examination in the SEM. Storage times for the specimens varied from 2 days to 8 weeks depending on availability of the SEM. The final number of specimens relative to the various techniques and canal types is presented in Table 7.1.

TABLE 7.1

Number of specimens relative to Technique and Canal Type.

TECHNIQUE	MB	DB	MES	TOTAL
1	16	17	21	54
2	14	7	22	43
3	13	13	22	48
4	14	10	22	46
	57	47	87	191

MB = mesiobuccal roots of maxillary molars
DB = distobuccal roots of maxillary molars
MES = mesial roots of mandibular molars

7.4 THE SEM EXAMINATION

The specimens were allowed to thaw from storage in the freezer and were examined wet in a JEOL[45], JSM-840 Scanning Electron Microscope(SEM) by means of backscattered imaging (BSI) using the Robinson detector[46]. The

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[45] JEOL (Australasia) Pty Ltd, Dee Why, Sydney, Australia.

[46] Semra Pty.Ltd., Castle Hill, Australia.

voltage used was 15 kV with a probe current of 1×10^{-9} mA. The entire surface of the root canal was examined at magnifications ranging from 16x to 500x. Approximately 8-10 photomicrographs were taken of each specimen using an attached Mamiya[47] camera and Ilford[48] 120 mm film FP4. All specimens were examined and evaluated by the author.

7.4.1 Grading of Specimens

The following features were evaluated in the fractured specimens:

- pulp remnants;
- smear layer;
- instrument marks.

These features were recorded using a grading system as follows.

Grade 0 - a surface displaying no evidence of the feature.

Grade + - a surface displaying only sparse evidence of the feature.

Grade ++ - a surface displaying extensive evidence of the feature.

Grade U - (for unassessable) for those surfaces where smear layer could not be otherwise assessed (eg., 0, +, ++) owing to the presence of pulp remnants.

Grade W - (for wave pattern) a surface displaying instrument marks in an undulating wave pattern running diagonal to the direction of filing.

The apical, middle and coronal regions of each canal surface were assessed independently and a separate grade recorded for each. As an example, Fig. 8.1 shows a canal displaying extensive evidence of pulp remnants, graded ++, in the apical and coronal regions and no evidence of pulp remnants, graded O, in the middle region.

Of the 191 specimens evaluated, 180 were graded in the apical third, 191 in the middle third and 190 in the coronal third. The reasons for this variation are: the apical third of 11 specimens could not be assessed as fracture of the root did

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[47] Mamiya, Japan.

[48] Ilford Ltd., Mobberley, Cheshire, U.K.

not occur through the apex; and the coronal third of one specimen was not assessed as it was evident that the disc used to create grooves on the buccal and lingual surfaces had encroached on the canal.

Whilst gross assessment was made at the time of examination in the SEM from the image on the screen, most of the grades were given when assessing subsequently the photomicrographs. The grades given, and the other observations made concerning root canal anatomy and fractured instruments, were recorded on the specimen assessment sheet (Fig. 7.6). On completion of evaluation, the specimens were decoded and the original tooth number was recorded on the specimen assessment sheet.

In Figs 8.9 to 8.34, many photomicrographs illustrate the various grades of the three features evaluated. One example of each grade is listed below.

Pulp Remnants	-	grade 0	(Fig. 8.17)
		grade +	(Fig. 8.13)
		grade ++	(Fig. 8.9)
Smear Layer	-	grade U	(Fig. 8.21)
		grade +	(Fig. 8.23)
		grade ++	(Fig. 8.25)
Instrument Marks	-	grade 0	(Fig. 8.29)
		grade +	(Fig. 8.31)
		grade ++	(Fig. 8.33)

FIGURE 7.6

Specimen Assessment Sheet

SPECIMEN ASSESSMENT

Date: _____

TOOTH NO.(Coded) _____ SURFACE: _____

(Uncoded) _____

SPECIMEN NO. _____ FILM SHEET: _____

_____

_____

_____

GROSS ASSESSMENT

APICAL: _____

_____

_____

MIDDLE: _____

_____

_____

CORONAL: _____

_____

_____

GRADING SYSTEM:

	APICAL	MIDDLE	CORONAL
PULP DEBRIS			
SMEAR LAYER			
INSTRUMENT MARKS			

7.4.1.1 Grading for Pulp Remnants (Figs 8.1-8.20)

It quickly became obvious that only a part of the total canal system could be instrumented. For this reason, two separate measures (assessments) of pulp remnants were necessary in order to arrive at meaningful results: one for the entire canal system and one for that part of the system which was instrumented ("main prepared canal"). Thus, two scores were made for each region of the canal when the specimens were examined and graded for pulp remnants. For example, when "pulp remnants in the entire canal system" were evaluated, a specimen showing the presence of an undetected and uninstrumented accessory canal would automatically be given a score of ++ for pulp remnants, irrespective of the amount of pulp remaining in the main instrumented canal. The same would apply in specimens showing complex apical anatomy. Such a grading would therefore not always be a reflection of the efficacy of instrumentation. For this reason, a second score was given and referred to as "pulp remnants - main prepared canal". This referred only to the main canal which had been instrumented.

7.4.1.2 Grading for Smear Layer (Figs 8.21-8.28)

There were no surfaces entirely devoid of smear layer, therefore, the grade 0 was not used for this feature. Evidence of smear layer was considered sparse (+) if exposed dentinal tubules were evident at magnifications of approximately 80x; and extensive (++) where the surface was completely covered and displayed no evidence of exposed tubules. Smear layer could not always be assessed owing to the presence of pulp remnants and, in such cases, the grade U was given.

7.4.1.3 Grading for Instrument Marks (Figs 8.29-8.48)

Instrument marks were considered sparse (+) if there were few of them or if those present were not deep; they were considered extensive (++) if the surface was gouged. Surfaces were graded O when there was no evidence of instrument marks; this included surfaces where the presence of pulp remnants precluded

accurate assessment. Several surfaces displayed a wave pattern (Figs 8.39-8.48) which was recorded separately (W).

7.4.2 Evaluation Using Secondary Electron Imaging

When evaluation of the specimens using BSI was complete, some specimens were critical point dried and gold coated using a sputter coating device[49]. They were subsequently examined in the SEM using SEI.

7.5 PRESENTATION AND ANALYSIS OF DATA

Information recorded on the instrumentation record sheet is presented in Table 8.29.

Information recorded on the specimen assessment sheet was analyzed to enable the following comparisons to be made:

a) comparisons among the different techniques (Section 8.2.1);
b) comparisons among the apical, middle and coronal regions of the canal (Section 8.2.2);
c) comparisons among different canal types (Section 8.2.3).

7.5.1 Comparisons Among the Different Techniques

Comparisons made among the four instrumentation techniques are presented in Tables 8.1-8.12 which express the number of surfaces within each technique, graded 0, +, ++, or U for the features: pulp remnants - entire canal system; pulp remnants - main prepared canal; smear layer; and, instrument marks. These values are expressed as percentages of the total number of surfaces prepared with each technique and are presented both individually as a table (e.g., Table 8.1) and collectively as a histogram or bar chart (e.g., Chart 8.1). The apical, middle and coronal regions of the canals were assessed independently and the

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[49] SCD 030, Balzers Union Ltd., Liechtenstein.

results for the three regions are presented separately (e.g., Table 8.1, Chart 8.1; Table 8.2, Chart 8.2; and Table 8.3, Chart 8.3). The number of surfaces graded W is presented separately following Chart 8.12. The chi square test (Mendenhall et al., 1981) was used to determine if the differences among the techniques were statistically significant. The results are presented in association with each table.

7.5.1.1 Pulp Remnants; Techniques Compared

Distinction was made when comparing the effectiveness of each technique in removing pulp remnants, between pulp remnants in the entire canal system and those in the main prepared canal. The results are presented separately (Tables and Charts 8.1-8.6).

The results obtained when comparing the different techniques with respect to pulp remnants are expressed in the following tables and associated histograms.

Table 8.1 Pulp remnants in the apical region. - entire canal system.

Table 8.2 Pulp remnants in the middle region - entire canal system.

Table 8.3 Pulp remnants in the coronal region - entire canal system.

Table 8.4 Pulp remnants in the apical region - main prepared canal.

Table 8.5 Pulp remnants in the middle region - main prepared canal.

Table 8.6 Pulp remnants in the coronal region - main prepared canal.

7.5.1.2 Smear Layer; Techniques Compared

The results obtained when comparing the techniques with respect to smear layer are expressed in the following tables and associated histograms.

Table 8.7 Smear layer, apical region.

Table 8.8 Smear layer, middle region.

Table 8.9 Smear layer, coronal region.

7.5.1.3 Instrument Marks; Techniques Compared

The results obtained, when comparing the techniques with respect to instrument marks, are expressed in the following tables and associated histograms.

Table 8.10 Instrument marks, apical region.
Table 8.11 Instrument marks, middle region.
Table 8.12 Instrument marks, coronal region.

The number of surfaces graded W for each technique is presented following Table 8.12.

7.5.2 Comparisons Among the Different Regions of the Canal Irrespective of Technique

The whole sample of prepared canal surfaces was used to compare the apical, middle, and coronal regions with respect to pulp remnants - entire canal system, pulp remnants - main prepared canal, smear layer, and instrument marks. These comparisons were made irrespective of the technique used for canal preparation. The results are presented in Tables 8.13-8.16 which express the number of surfaces graded 0, +, ++, or U for each particular feature, within each region of the canal. These values are expressed as percentages of the total number of apical, middle and coronal surfaces, both individually in table form (e.g., Table 8.13) and collectively as a histogram (e.g., Chart 8.13).

The following tables and associated histograms represent the comparisons made among the three regions of the canal with respect to pulp remnants, smear layer, and instrument marks:

Table 8.13 Pulp remnants - entire canal system, whole sample.
Table 8.14 Pulp remnants - main prepared canal, whole sample.
Table 8.15 Smear layer, whole sample.
Table 8.16 Instrument marks, whole sample.

The chi square test was used to determine if the differences between the three regions of the canals were statistically significant. The results are presented in association with each table.

The scores for pulp remnants - entire canal system and pulp remnants - main prepared canal were compared for the apical, middle and coronal regions of each canal and are presented in Chart 8.14.1. The chi square test was used to determine if the differences were statistically significant and the results are presented in association with Chart 8.14.1.

The number of surfaces within the whole sample of prepared canals which were graded W is presented following Table 8.16.

7.5.3 Comparisons Among Canal Types Irrespective of Technique

Comparisons were made among different canal types: mesiobuccal and distobuccal canals of maxillary molars; and mesial canals of mandibular molars, irrespective of the technique used to prepare the canals. The results are presented in Tables 8.17-8.28 and express the number of surfaces within each canal type graded 0, +, ++, or U for the features: pulp remnants - entire canal system; pulp remnants - main prepared canal; smear layer; and instrument marks. These values are expressed as percentages of the total number of surfaces pertaining to each canal type, both individually in table form (e.g., Table 8.17) and collectively as a histogram (e.g., Chart 8.17). The apical, middle, and coronal regions of the canals were assessed independently and the results for each are presented separately (e.g., Table 8.17, Chart 8.17; Table 8.18, Chart 8.18; and Table 8.19, Chart 8.19).

The chi square test was used to determine if the differences among the canal types were statistically significant and the results are presented in association with each table.

7.5.3.1 Pulp Remnants; Canal Types Compared

The results obtained when comparing the different canal types with respect to pulp remnants are expressed in the following tables and associated histograms.

Table 8.17 Pulp remnants in the apical region - entire canal system.
Table 8.18 Pulp remnants in the middle region - entire canal system.
Table 8.19 Pulp remnants in the coronal region - entire canal system.
Table 8.20 Pulp remnants in the apical region - main prepared canal.
Table 8.21 Pulp remnants in the middle region - main prepared canal.
Table 8.22 Pulp remnants in the coronal region - main prepared canal.

7.5.3.2 Smear Layer; Canal Types Compared

The results obtained when comparing the different canal types with respect to smear layer are expressed in the following tables.

Table 8.23 Smear layer, apical region.
Table 8.24 Smear layer, middle region.
Table 8.25 Smear layer, coronal region.

7.5.3.3 Instrument Marks; Canal Types Compared

The results obtained when comparing the different canal types with respect to instrument marks are expressed in the following tables.

Table 8.26 Instrument marks, apical region.
Table 8.27 Instrument marks, middle region.
Table 8.28 Instrument marks, coronal region.

The number of surfaces pertaining to each canal type which were graded W is presented following Table 8.28.

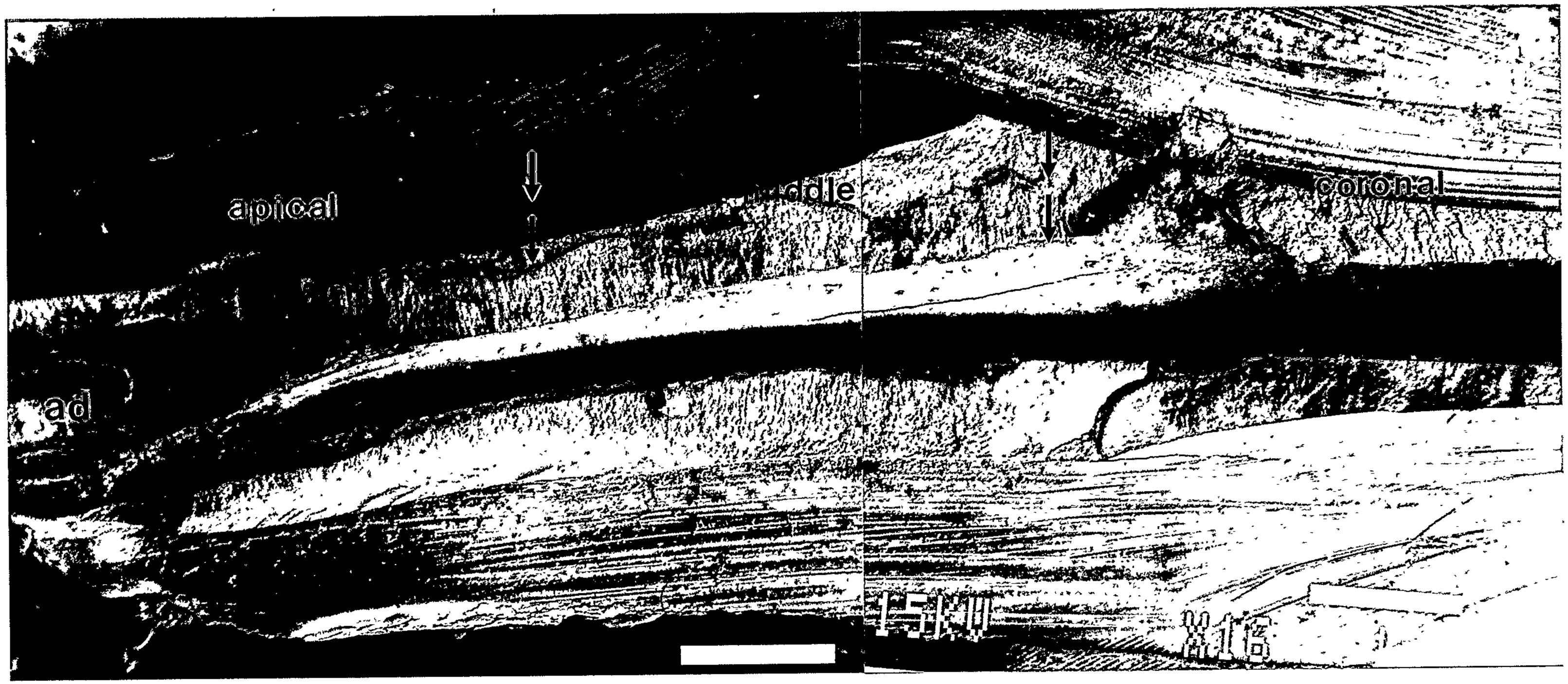
CHAPTER EIGHT

RESULTS

8.1 MORPHOLOGICAL OBSERVATIONS

Because of the large number of scanning electron micrographs taken in the study, only a representative sample is presented below to give the reader a morphological basis to the data presented subsequently.

FIGURE 8.1



A distobuccal canal (maxillary) graded ++ for pulp remnants in the coronal region and 0 in the middle region. When the entire canal system was evaluated, this specimen was graded ++ for pulp remnants in the apical region (note pulp remnants in apical delta [ad]) but graded +, when only the main prepared canal was evaluated (Technique 4). Bar = 1 mm

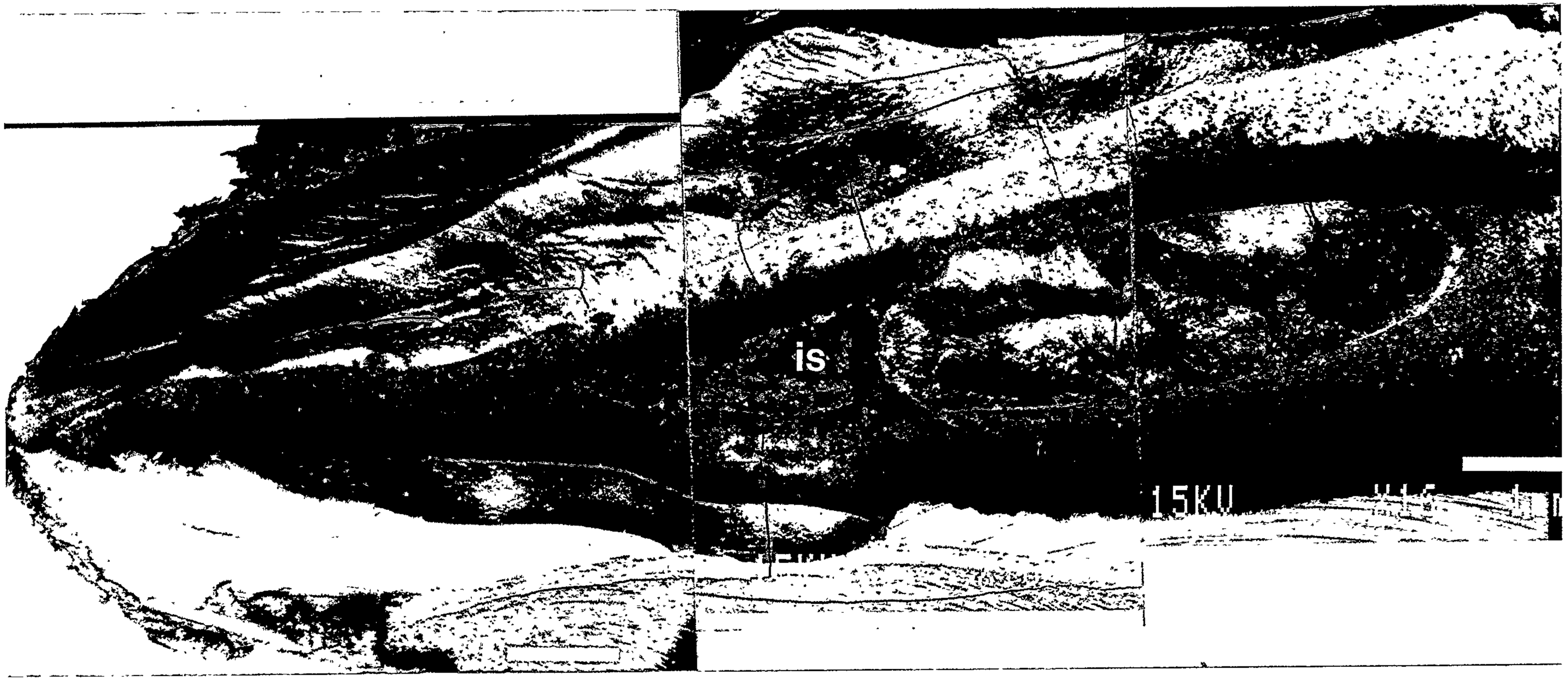
FIGURE 8.2

A mesiobuccal canal (maxillary) graded ++ for pulp remnants in the apical middle and coronal regions when the entire canal system was evaluated. When only the main prepared canal was evaluated the middle region was graded + for pulp remnants. An uninstrumented accessory mesiobuccal canal is evident, which communicates along its length with the main canal (Technique 3). Bar = 1 mm.

FIGURE 8.3

Mesial canals (mandibular) graded ++ for pulp remnants in the coronal region, and + in the middle region. The main prepared canals were graded + for pulp remnants but when the entire canal system was evaluated the apical region was graded ++ due to pulp remnants in the isthmus (is) (Technique 3). Bar = 1 mm.

FIGURE 8.4

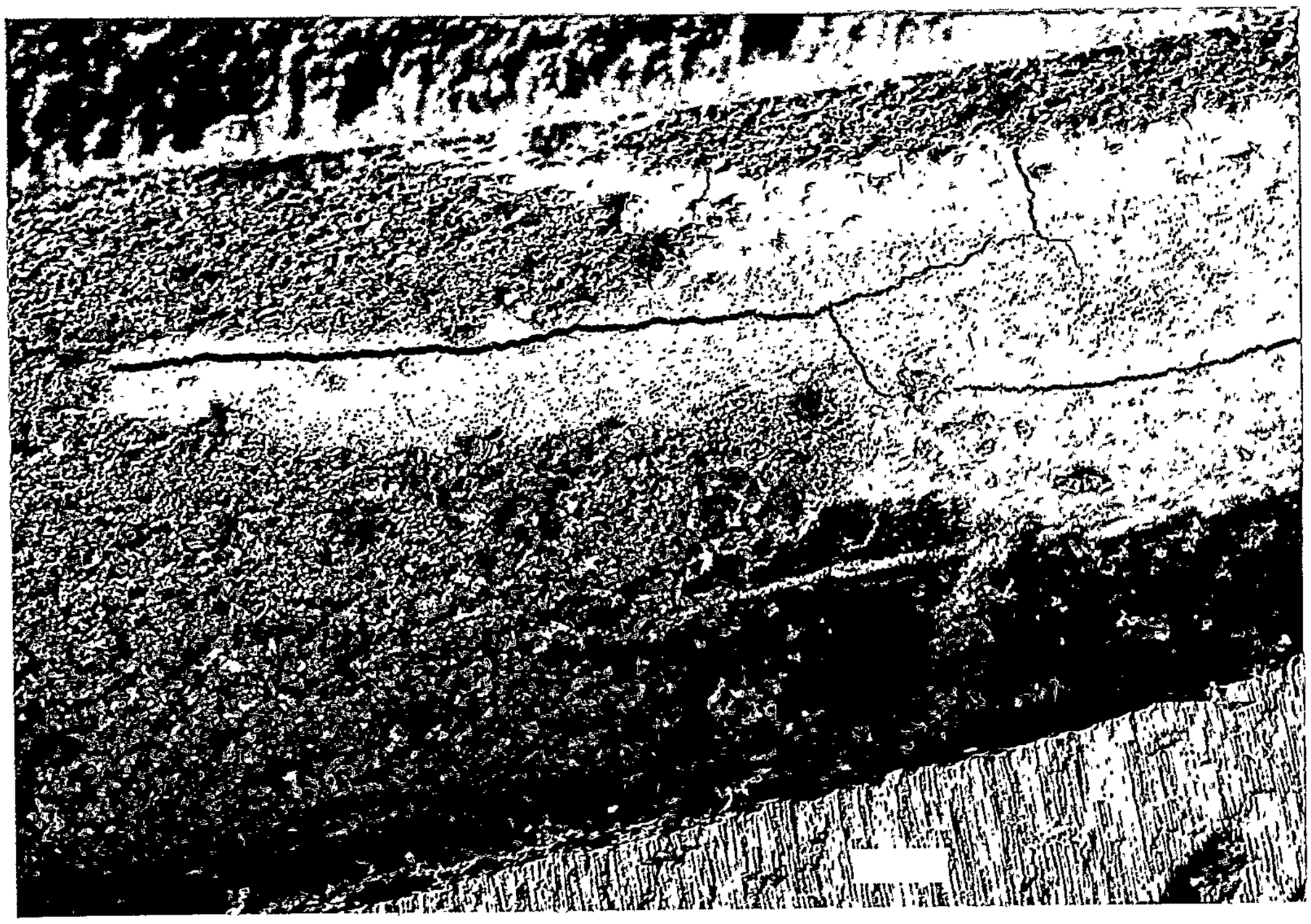


Convergent mesial canals (mandibular) graded ++ for pulp remnants in the apical, middle and coronal regions. Communication between the canals is evident with extensive areas of untouched pulp tissue in the isthmus (is). One canal contains more pulp remnants than the other (Technique 2). Bar = 1 mm.

FIGURE 8.5

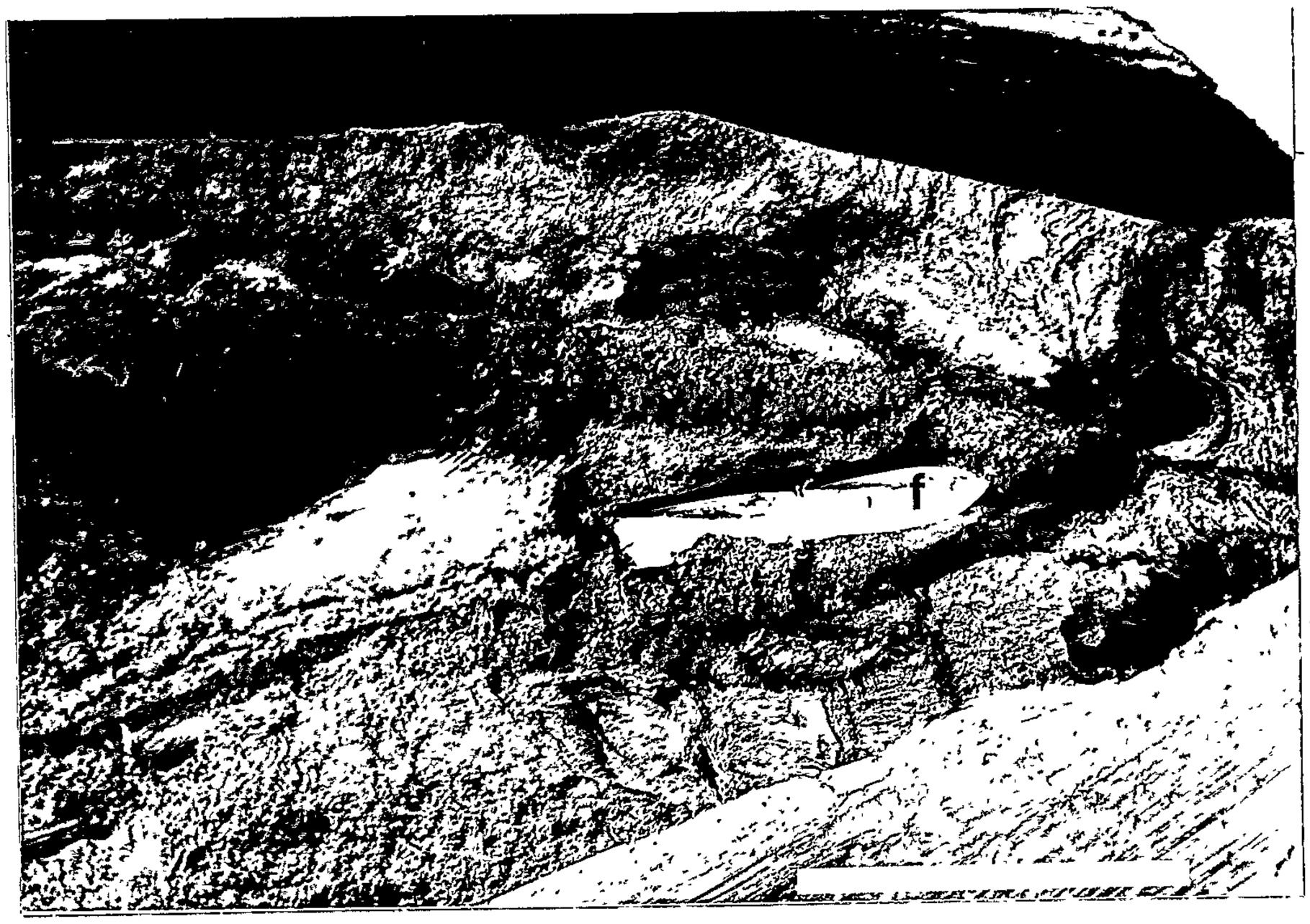
A mesiobuccal canal (maxillary) graded ++ for pulp remnants in the coronal region and 0 for pulp remnants in the middle region of the main prepared canal. A cul-de-sac with inaccessible pulp remnants is evident. The middle region was graded ++ for pulp remnants when the entire canal system was evaluated owing to the cul-de-sac of inaccessible pulp remnants (c) (Technique 4). Bar = 1 mm.

FIGURE 8.6



Middle region of a mesial canal (mandibular) graded ++ for pulp remnants. A very clean canal surface juxtaposes an area covered with pulp remnants (Technique 2). Bar = 100 μm.

FIGURE 8.7



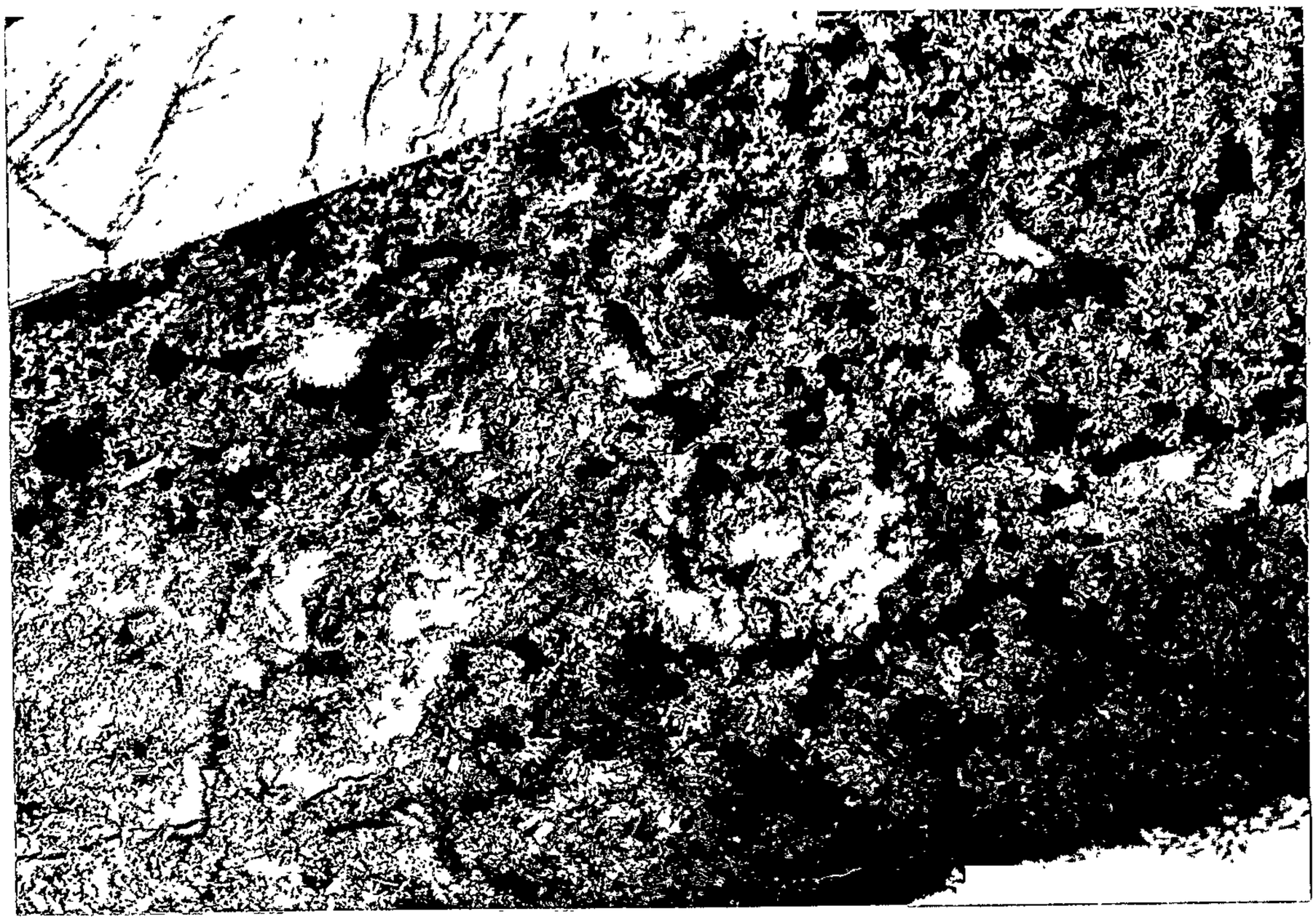
Apical region of a mesial canal (mandibular) displaying large amounts of remaining pulp tissue with a fractured instrument tip (f) lodged near the apex (Technique 3). Bar = 1 mm.

FIGURE 8.8

Apical region of mesial canals (mandibular) displaying very complex anatomy with inaccessible areas of pulp in isthmus (is). This specimen was not graded in the apical region as fracture of the root did not occur directly through the canals.

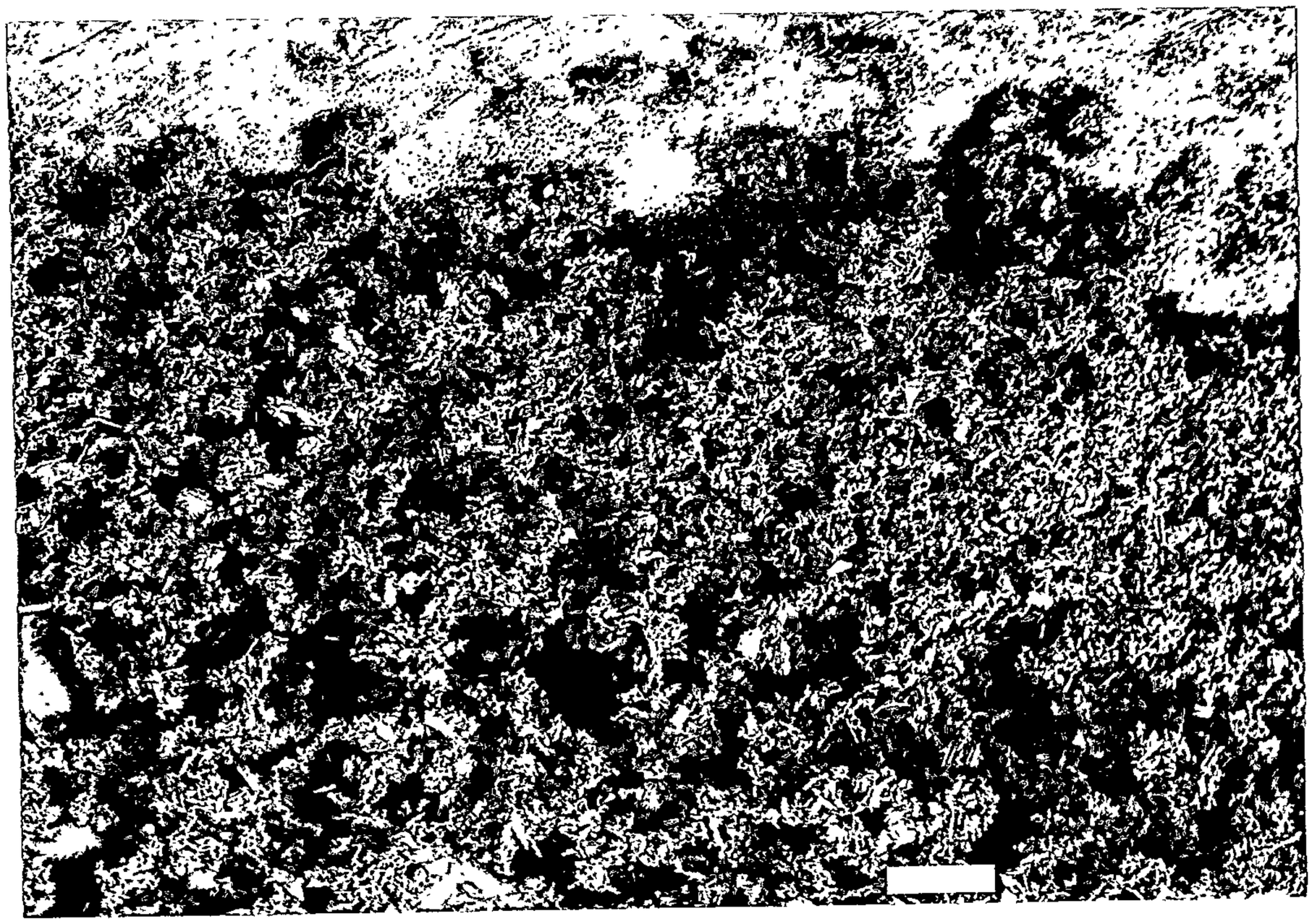
8.1.1 Pulp Remnants

FIGURE 8.9



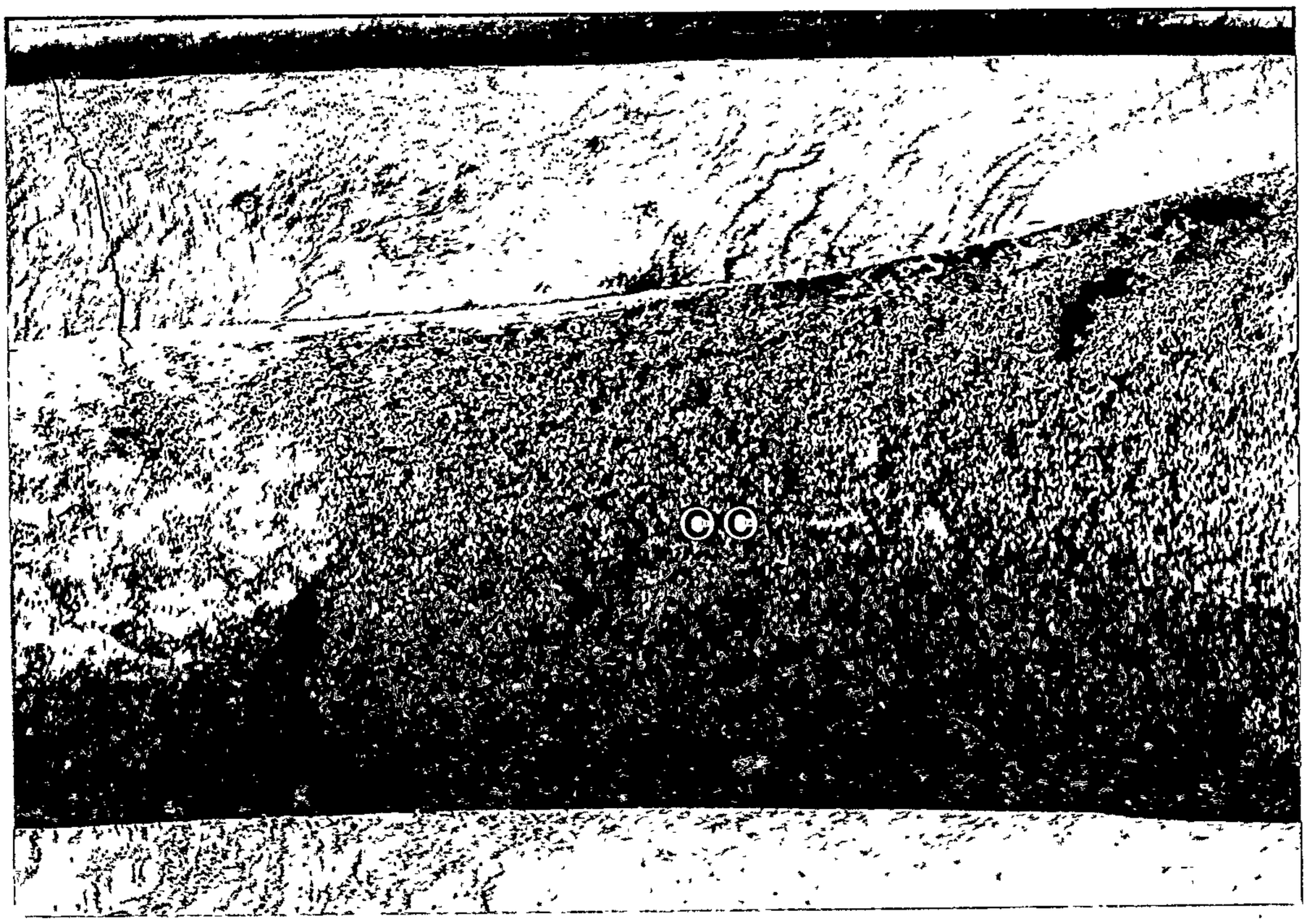
Middle region of a mesial canal (mandibular) graded ++ for pulp remnants (Technique 3). Bar = 100 μm.

FIGURE 8.10



Coronal region of a mesial canal (mandibular) graded ++ for pulp remnants (Technique 3). Bar = 100 μm.

FIGURE 8.11



Coronal region of a distobuccal canal (maxillary) graded ++ for pulp remnants. "Cervical collar" of debris (cc) is evident (Technique 2). Bar = 100 µm.

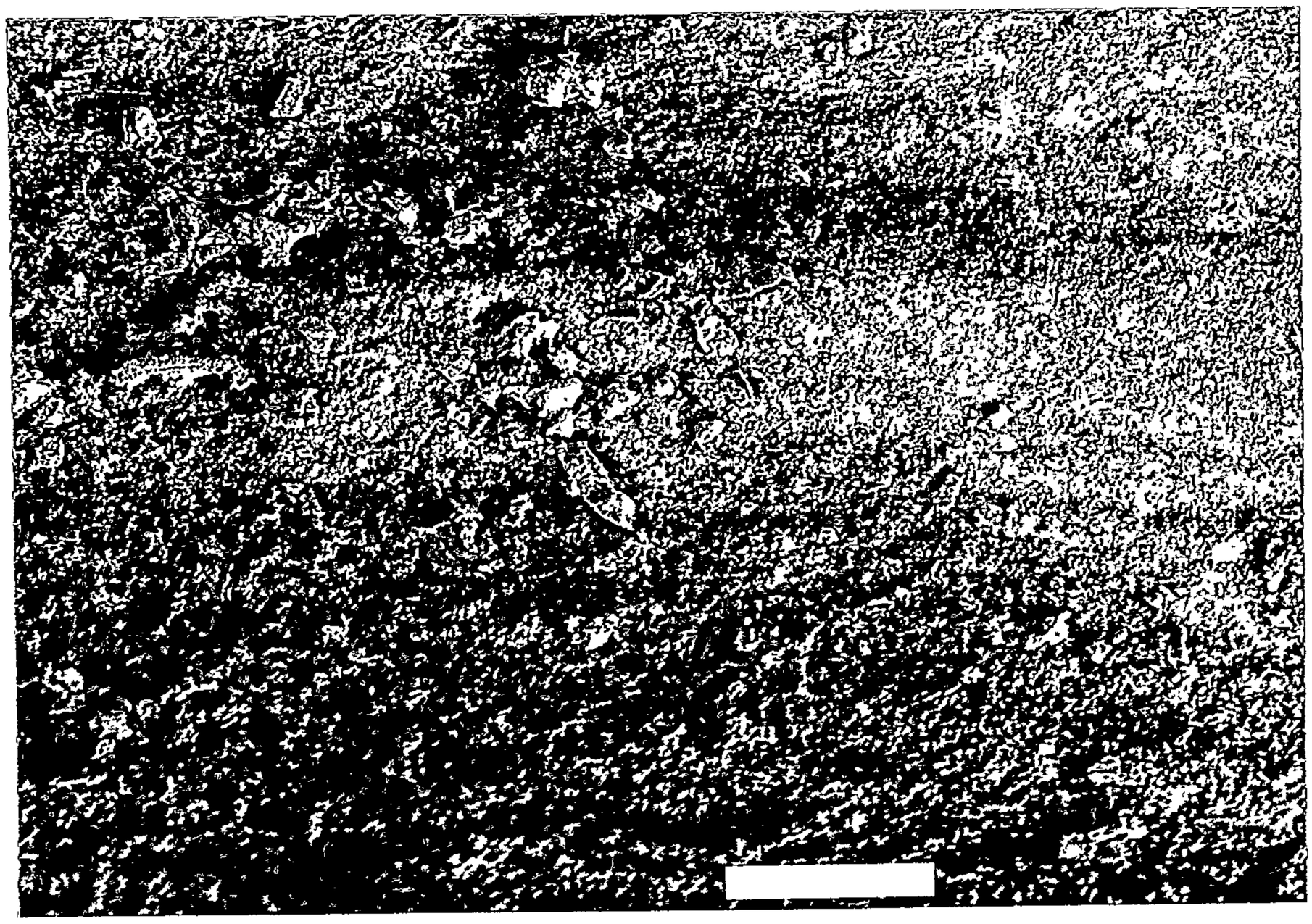
FIGURE 8.12

Coronal region of a distobuccal canal (maxillary) graded ++ for pulp remnants. "Cervical collar" of debris (cc) is evident (Technique 3). Bar = 1 mm.

FIGURE 8.13

Apical region of a mesial canal (mandibular) graded + for pulp remnants (Technique 1). Bar = 100 μm.

FIGURE 8.14



Middle region of a mesial canal (mandibular) graded + for pulp remnants (Technique 2). Bar = 100 μm.

FIGURE 8.15

Middle region of a mesial canal (mandibular) graded + for pulp remnants (Technique 3). Exposed dentinal tubules (t) and lateral canal (l) are evident. Bar = 100 μm.

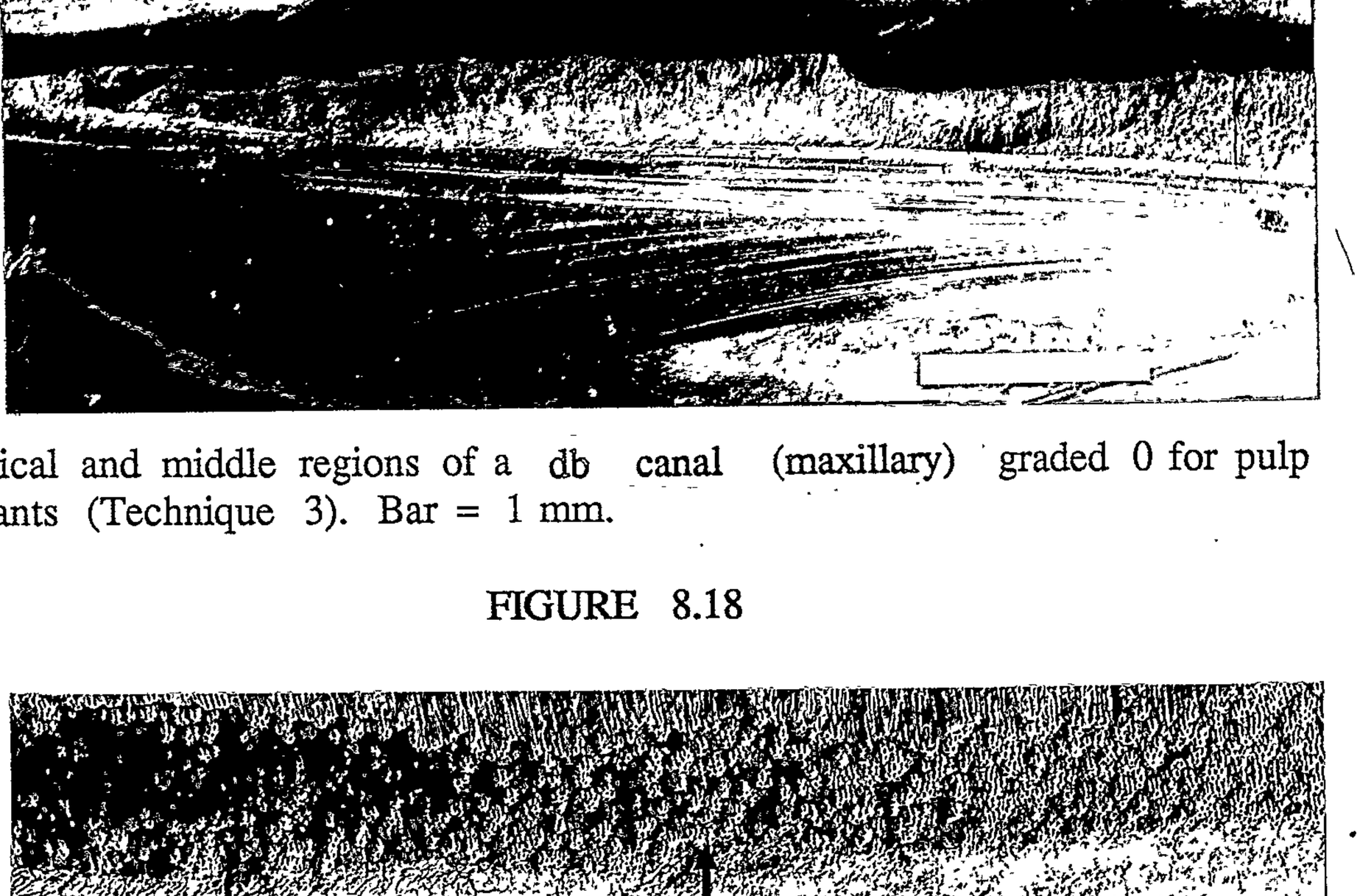
FIGURE 8.16

Middle region of a mesial canal (mandibular) graded + for pulp remnants (Technique 2). Bar = 100 μm.

FIGURE 8.17

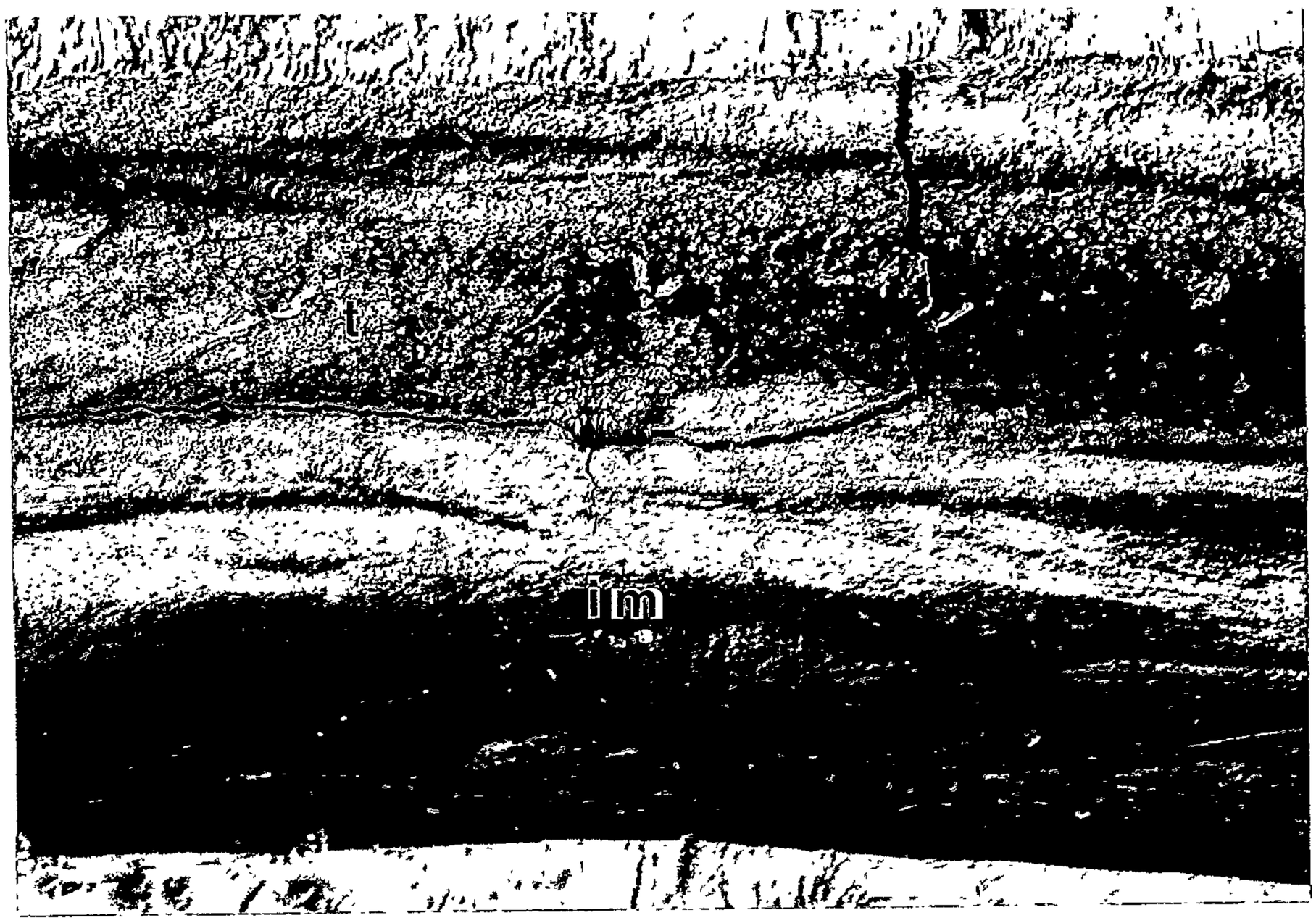
Apical and middle regions of a db canal (maxillary) graded 0 for pulp remnants (Technique 3). Bar = 1 mm.

FIGURE 8.18



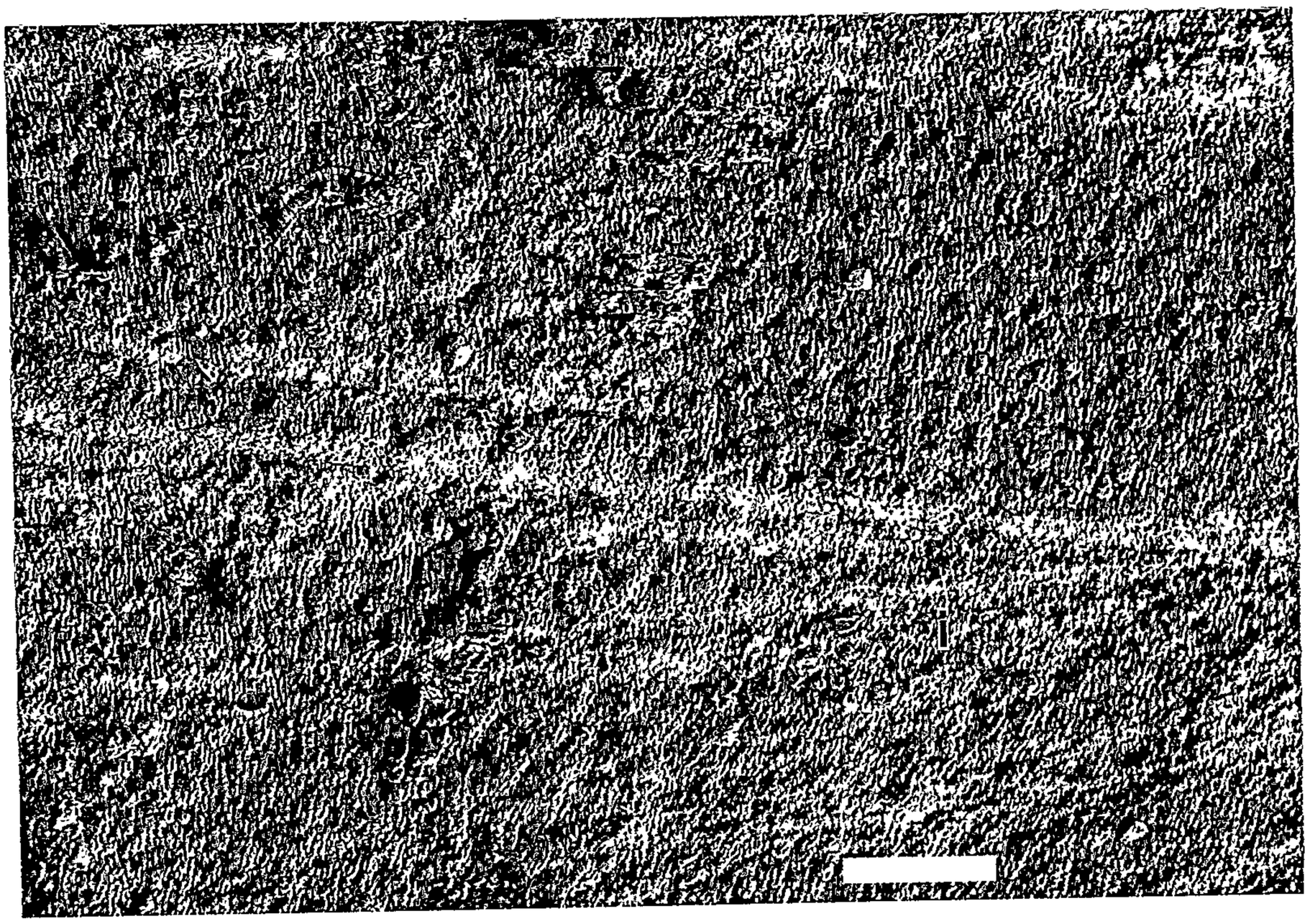
Apical region of a db canal (maxillary) graded 0 for pulp remnants (Technique 3). Instrument marks (im) are evident in association with smear layer. The calcospheritic surface of the dentine (d) is indicative of no instrument contact in this area. Bar = 100 μm.

FIGURE 8.19



Apical region of a mesial canal (mandibular) graded 0 for pulp remnants (Technique 4). Instrument marks (im) are evident in association with smear layer. Exposed dentinal tubules (t) are evident. Bar = 100 μm.

FIGURE 8.20



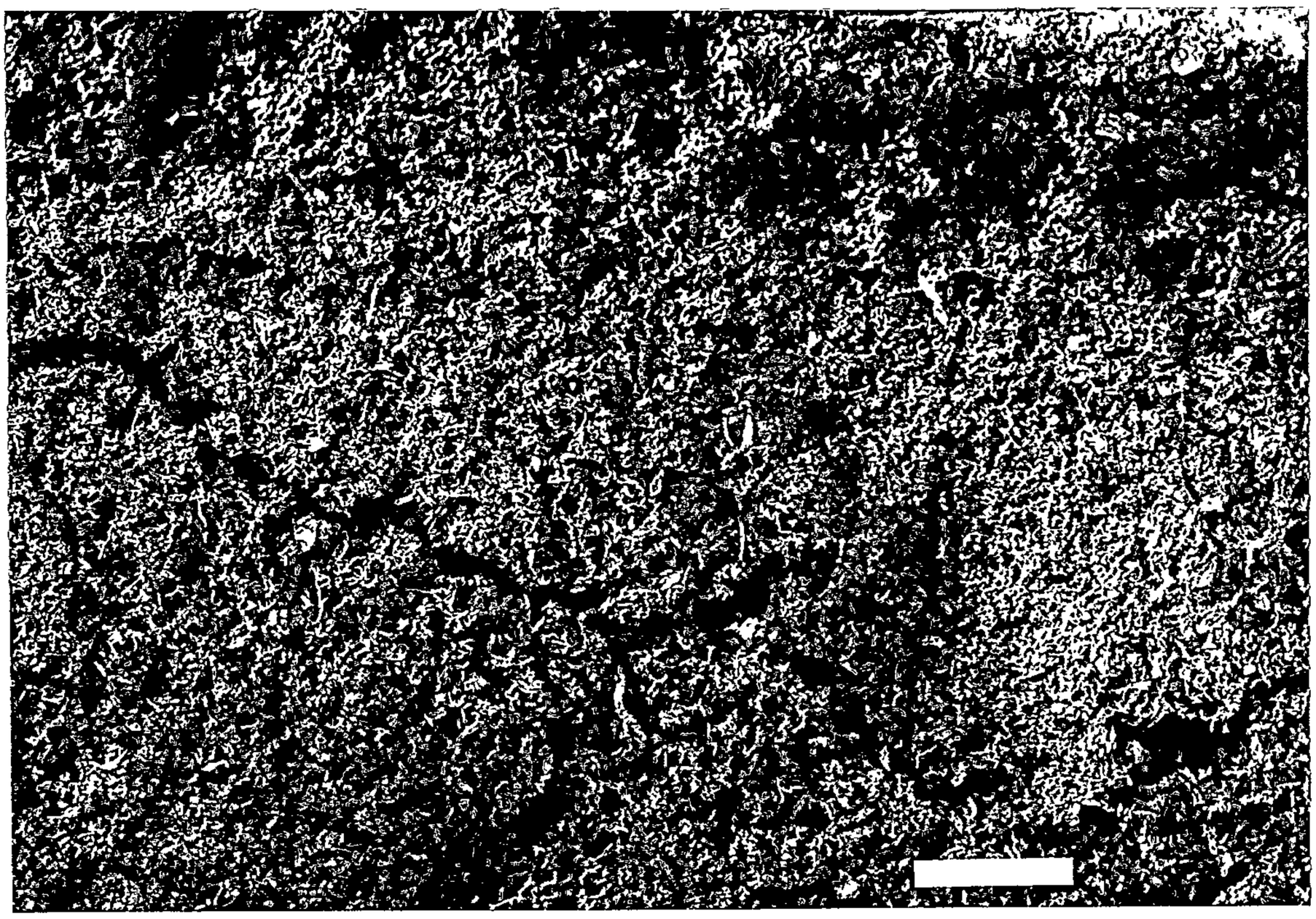
Middle region of a mesial canal (mandibular) graded 0 for pulp remnants (Technique 4). Areas of instrument contact (i) have created a smear layer on the calcospheritic surface of the dentine. Bar = 100 μm.

8.1.2 Smear Layer

FIGURE 8.21

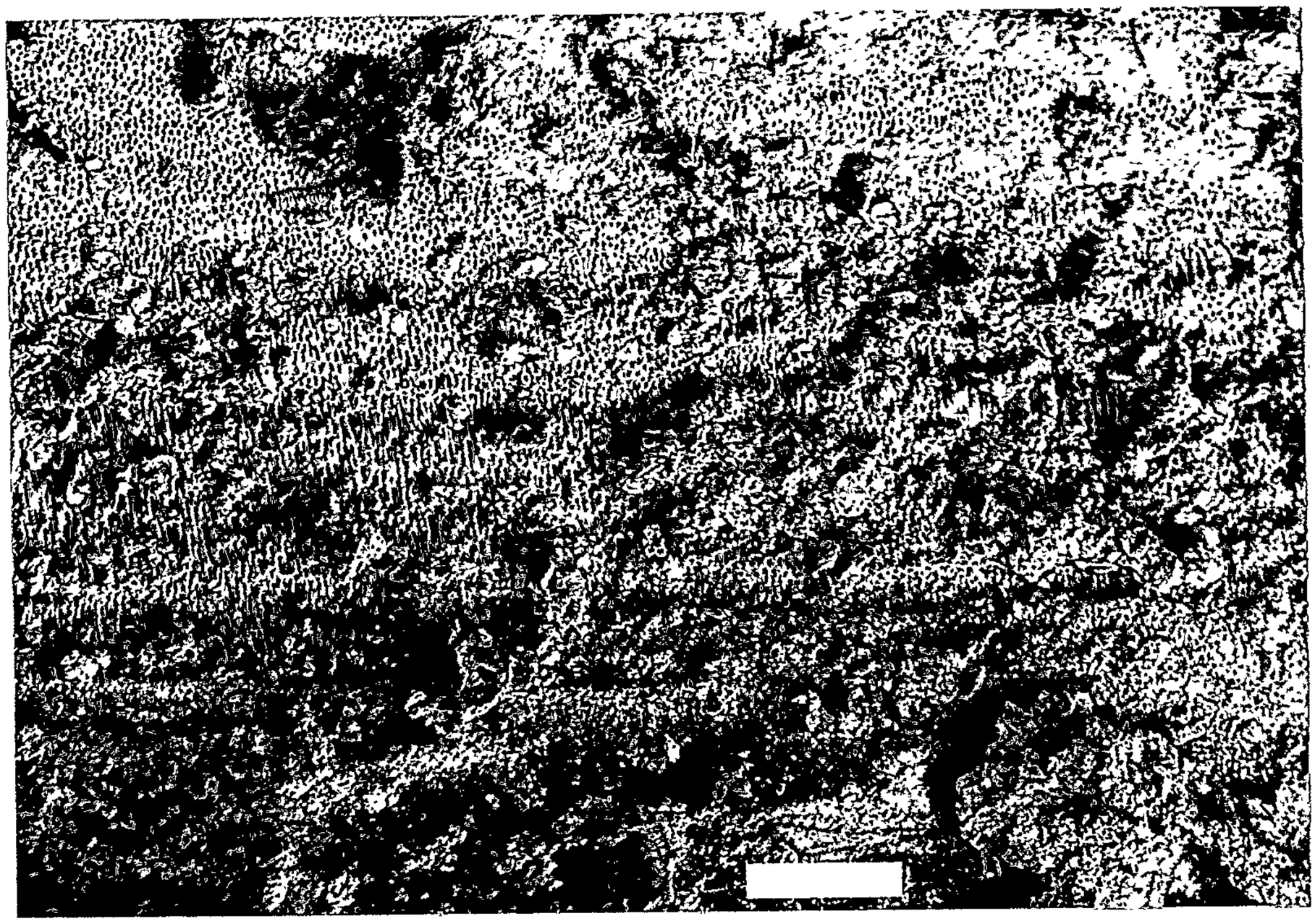
Apical region of a mesial canal (mandibular) graded U for smear layer (Technique 2). Bar = 1 mm.

FIGURE 8.22



Apical region of a mesial canal (mandibular) graded U for smear layer (Technique 2). Bar = 100 μm.

FIGURE 8.23

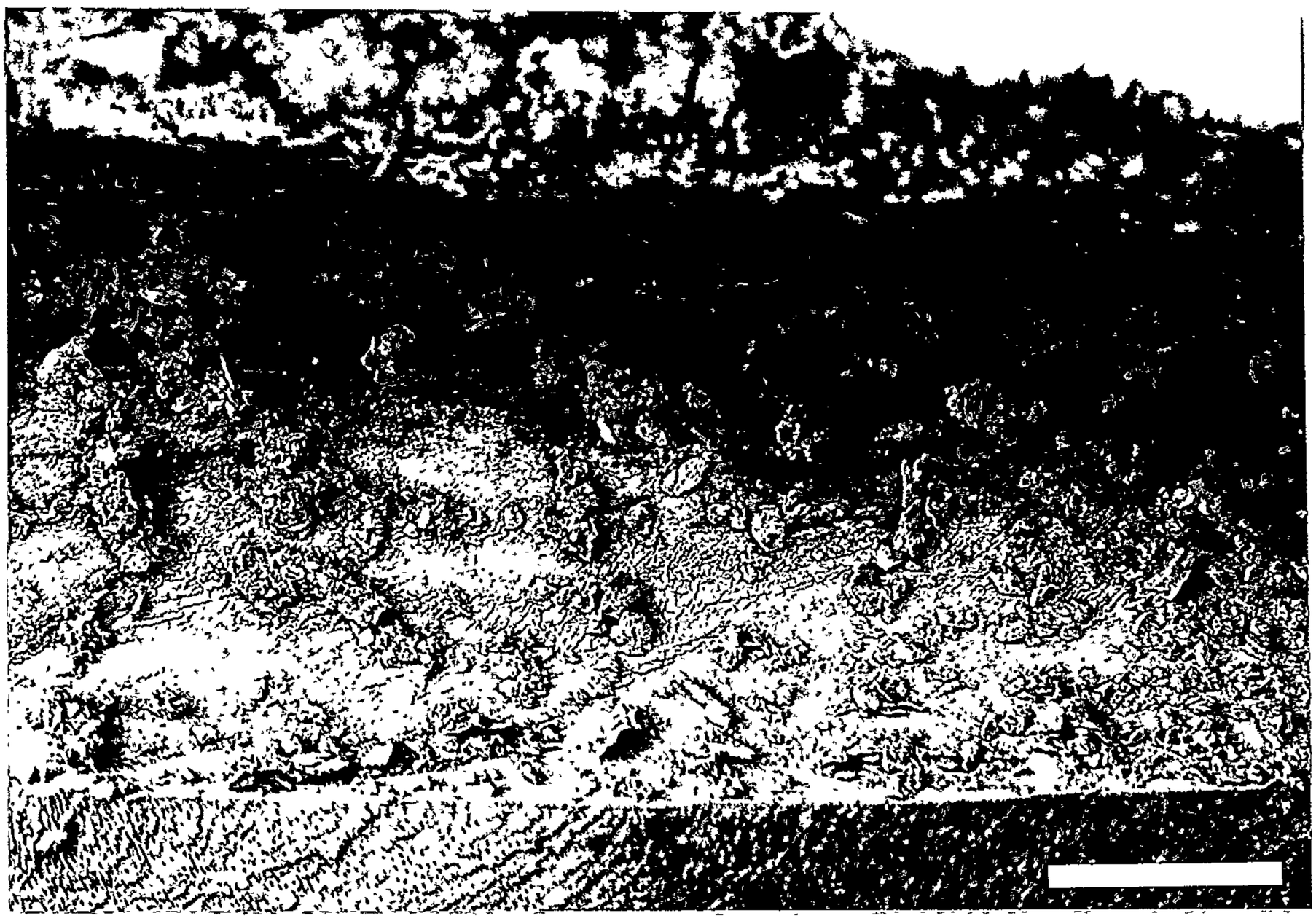


Middle region of a mesial canal (mandibular) graded + for smear layer (Technique 3). Bar = 100 µm.

FIGURE 8.24

Middle region of a mesial canal (mandibular) graded + for smear layer (Technique 3). Bar = 100 µm.

FIGURE 8.25

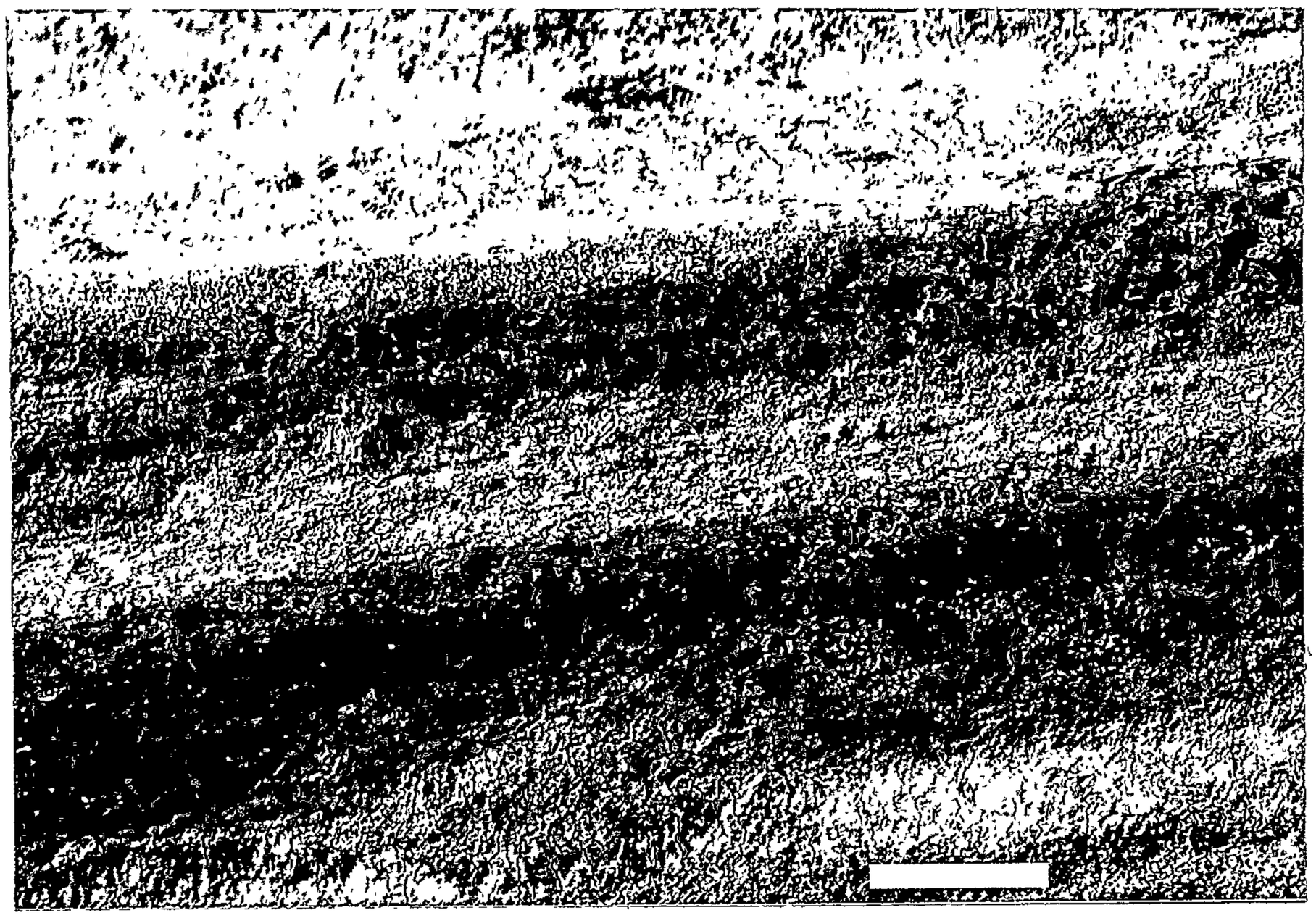


Coronal region of a db canal (maxillary) graded ++ for smear layer (Technique 1). Bar = 100 µm.

FIGURE 8.26

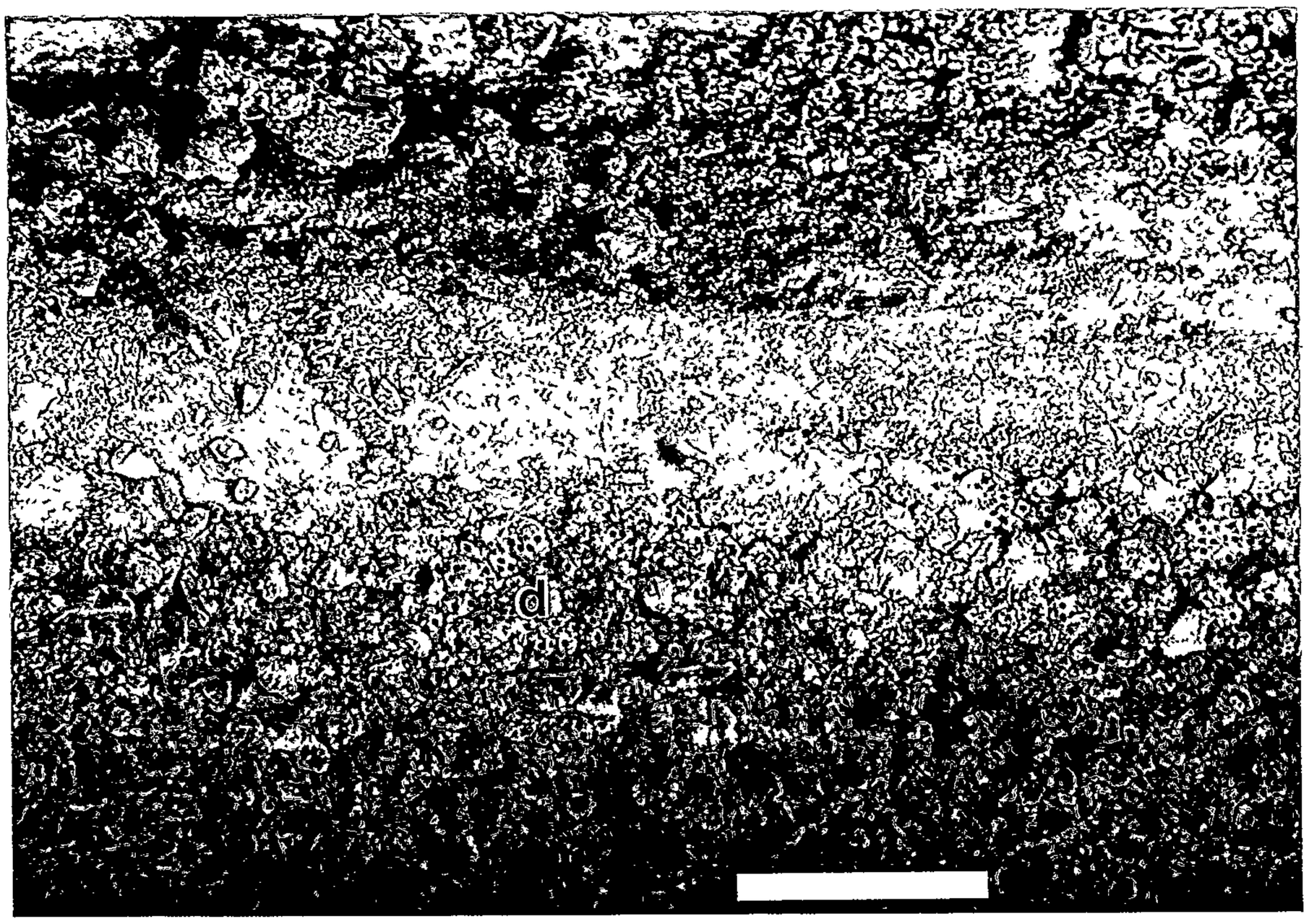
Coronal region of a mesial canal (mandibular) graded ++ for smear layer (Technique 2). Bar = 100 µm.

FIGURE 8.27



Coronal region of a mesial canal (mandibular) graded ++ for smear layer (Technique 2). Bar = 100 μm.

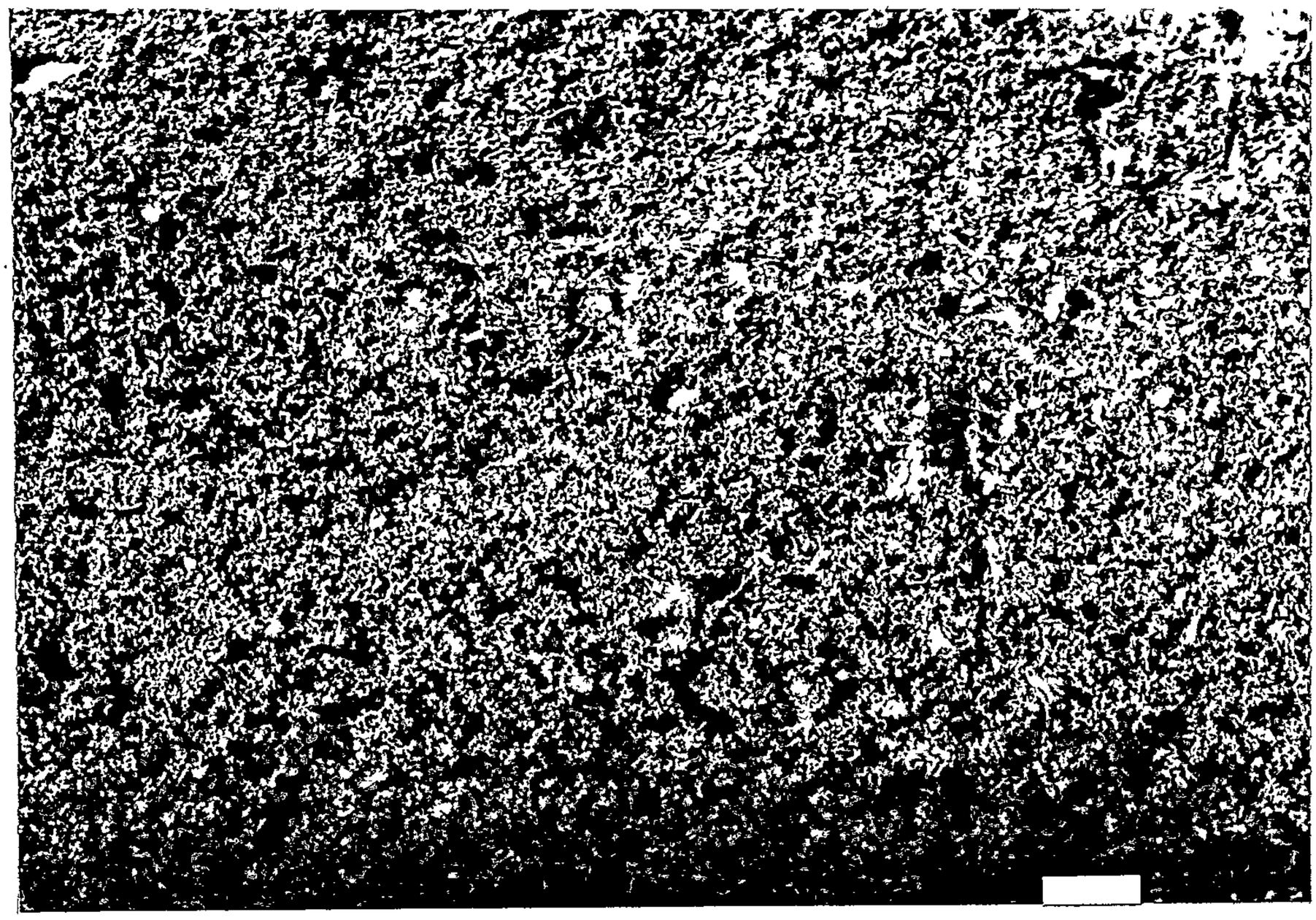
FIGURE 8.28



Coronal region of a mesial canal (mandibular) graded ++ for smear layer (Technique 2). Calcospheritic pattern of dentine is evident in some areas (d). Bar = 100 μm.

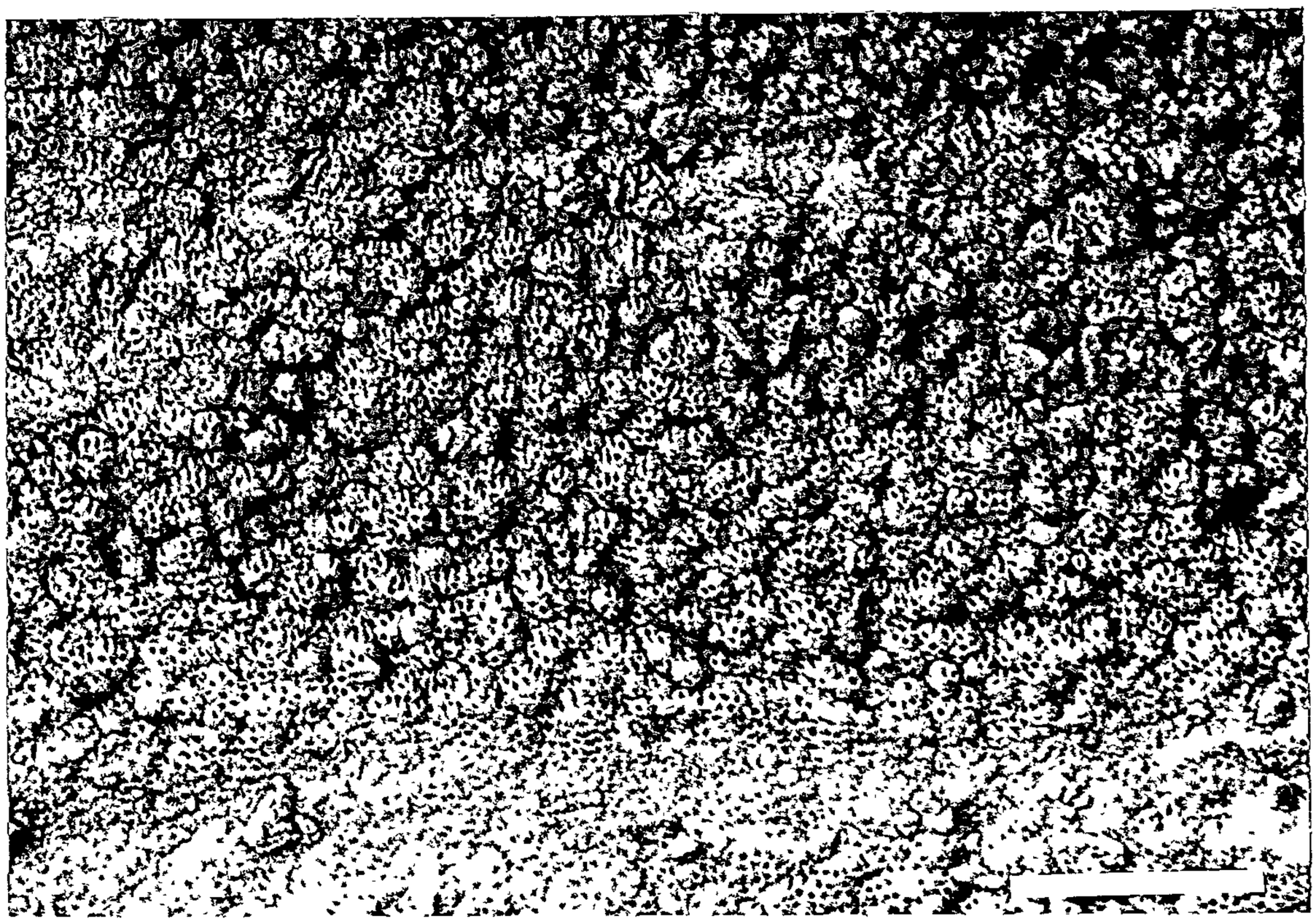
8.1.3 Instrument Marks

FIGURE 8.29



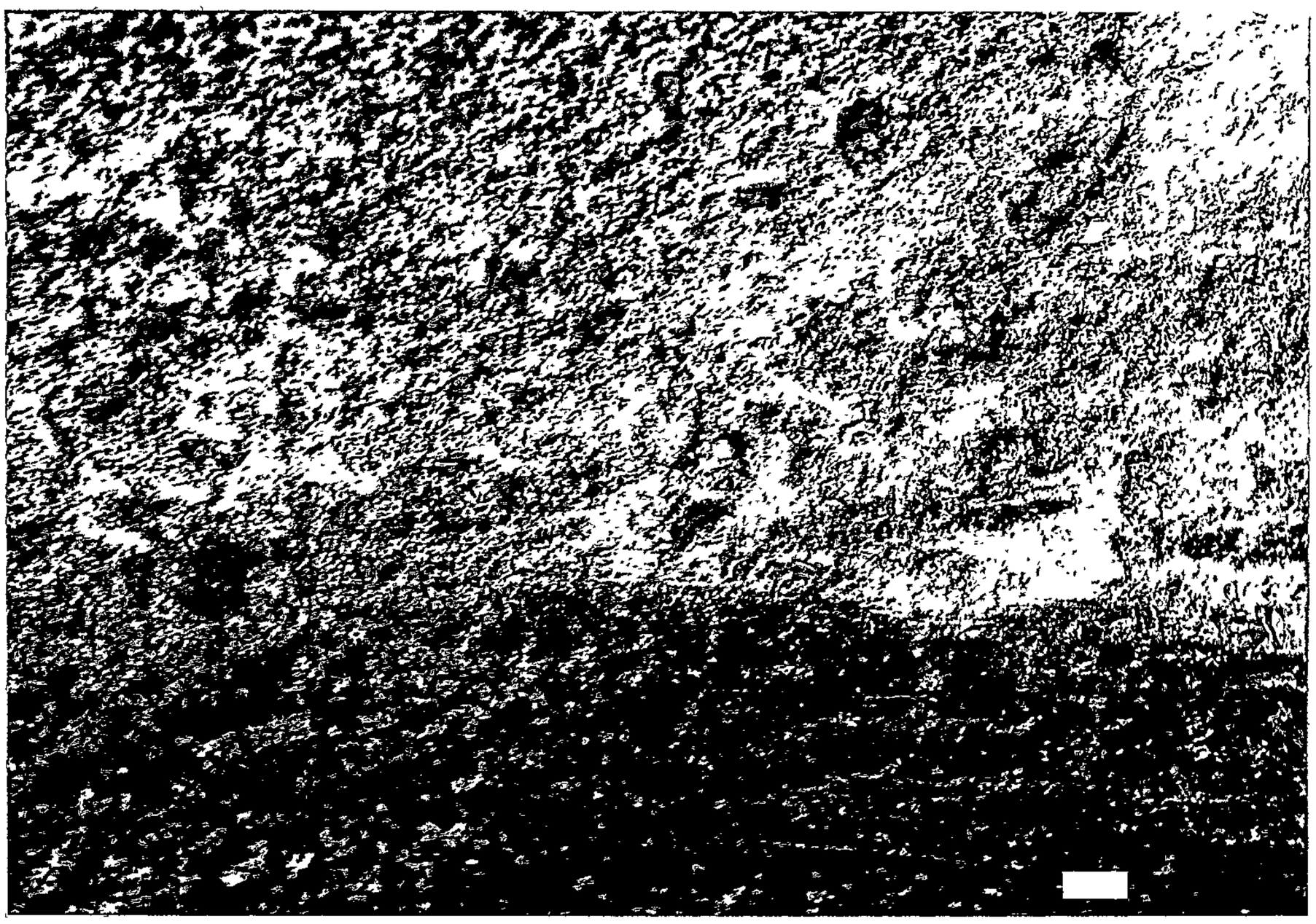
Coronal region of a db canal (maxillary) graded 0 for instrument marks (Technique 1). Bar = 100 μm.

FIGURE 8.30



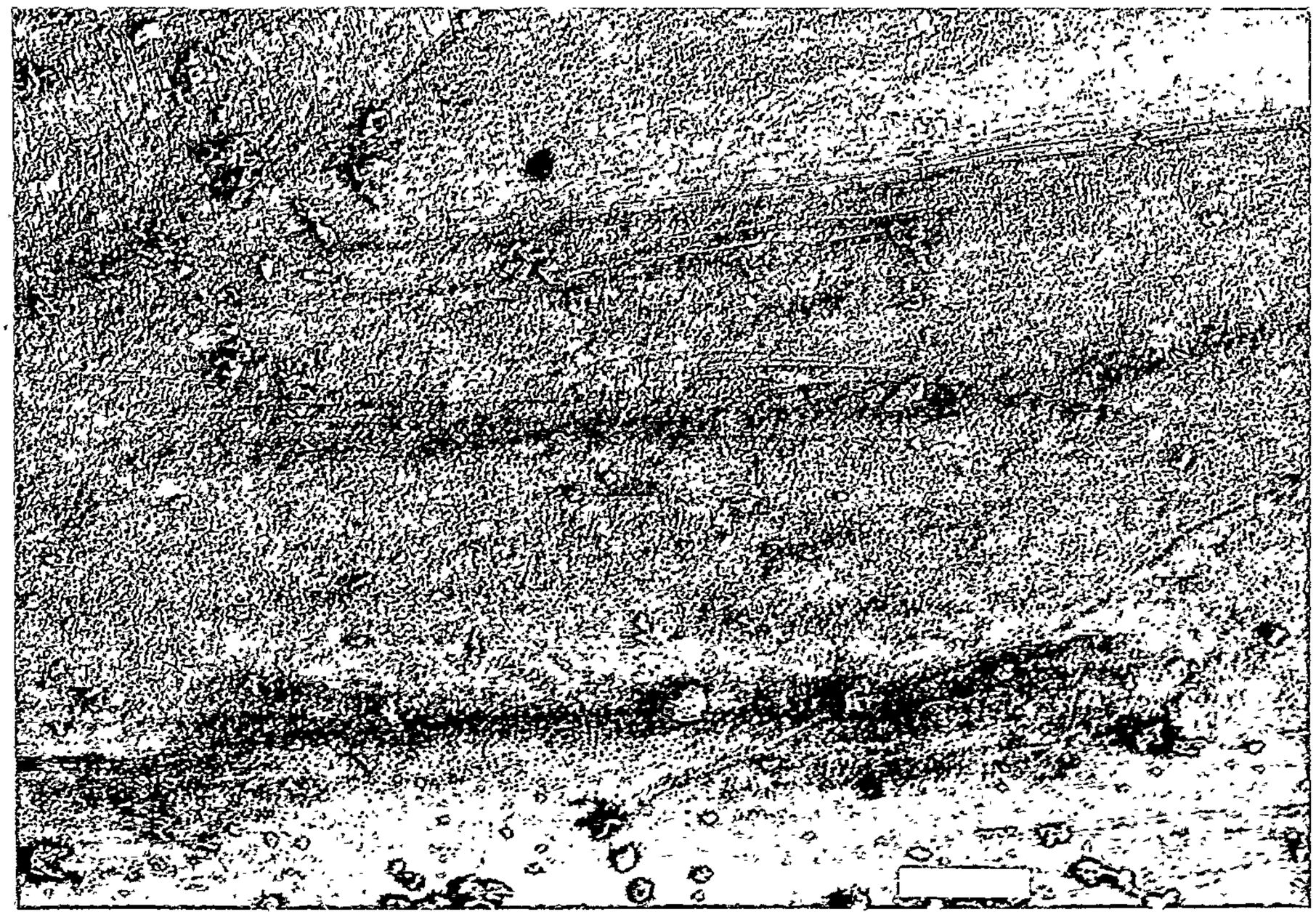
Middle region of a mesial canal (mandibular) graded 0 for instrument marks (Technique 1). Bar = 100 μm.

FIGURE 8.31



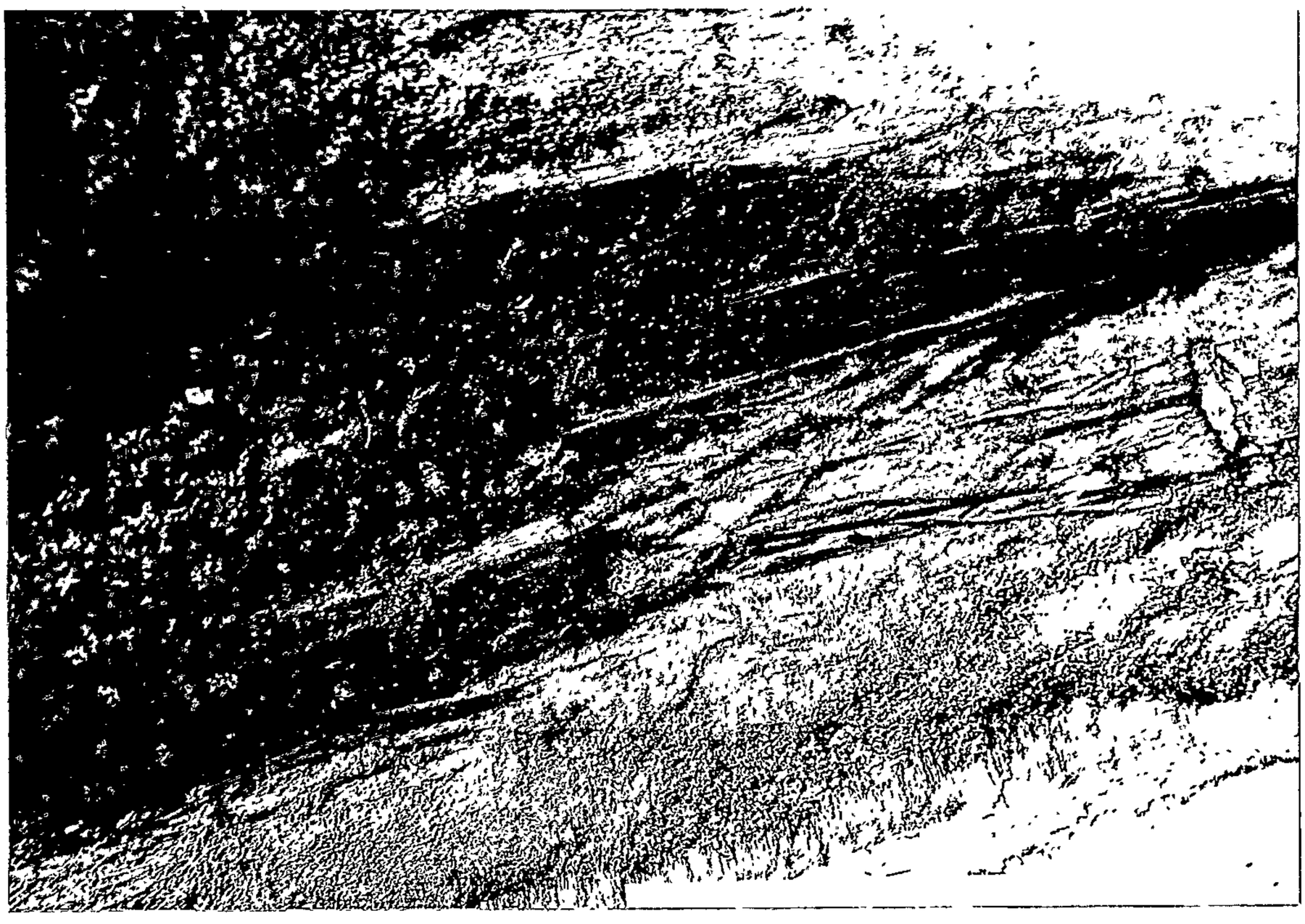
Coronal region of a mesial canal (mandibular) graded + for instrument marks (Technique 2). Bar = 100 μm.

FIGURE 8.32



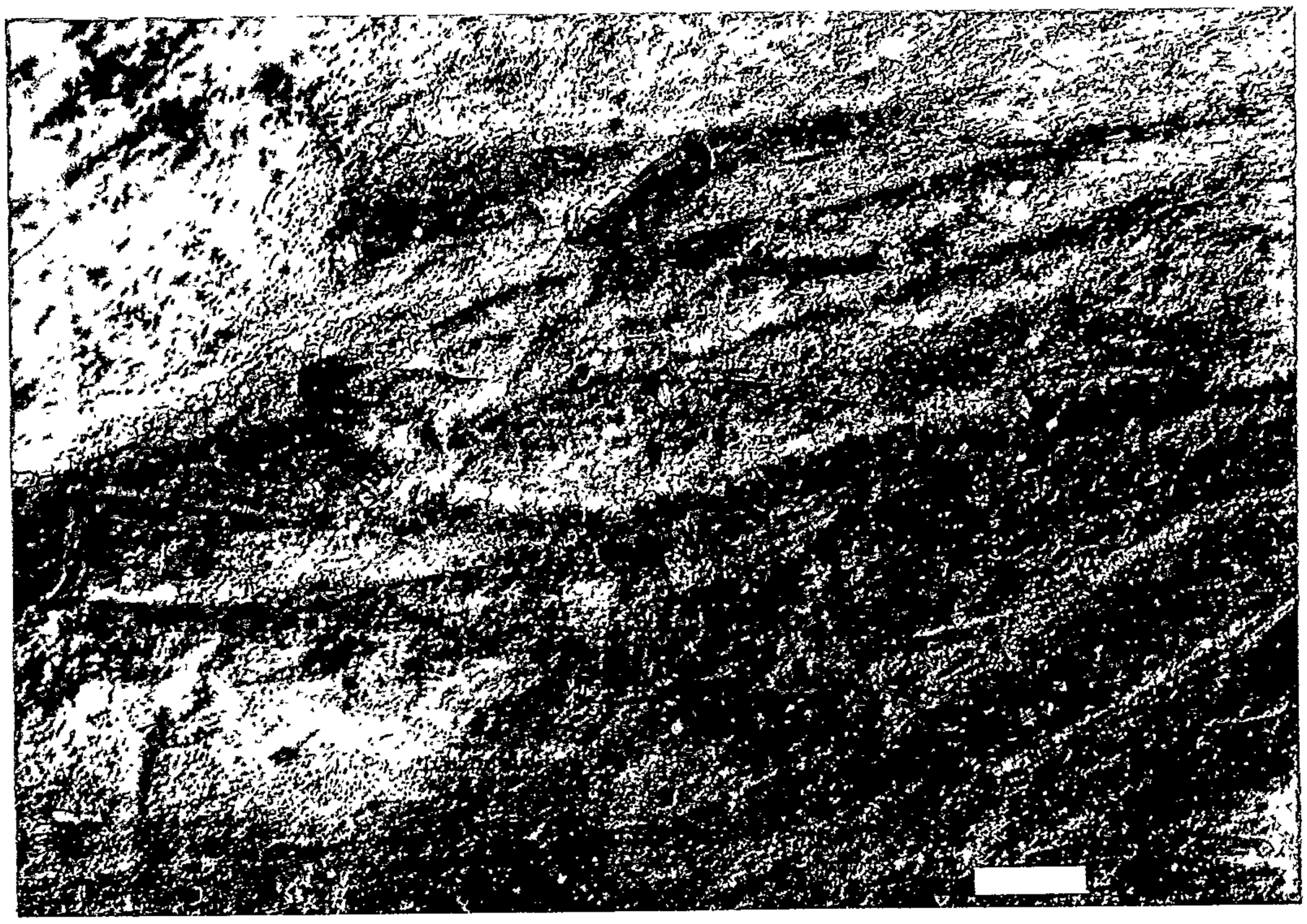
Middle region of a mesial canal (mandibular) graded + for instrument marks (Technique 2). Bar = 100 μm.

FIGURE 8.33



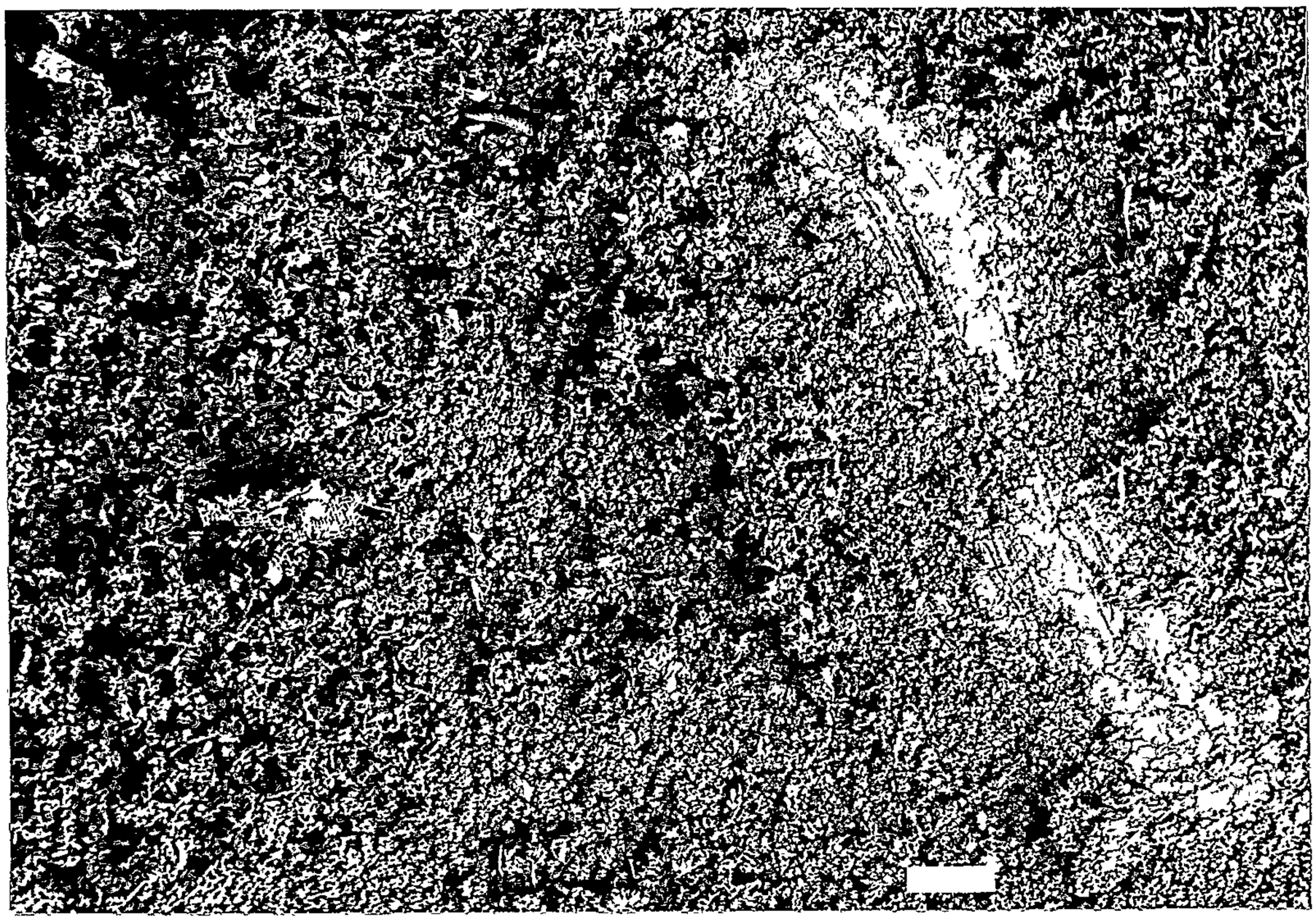
Coronal region of a mesiobuccal canal (maxillary) graded ++ for instrument marks (Technique 1). Bar = 1 mm.

FIGURE 8.34



Coronal region of a mesiobuccal canal (maxillary) graded ++ for instrument marks (Technique 1). Bar = 100 μm.

FIGURE 8.35

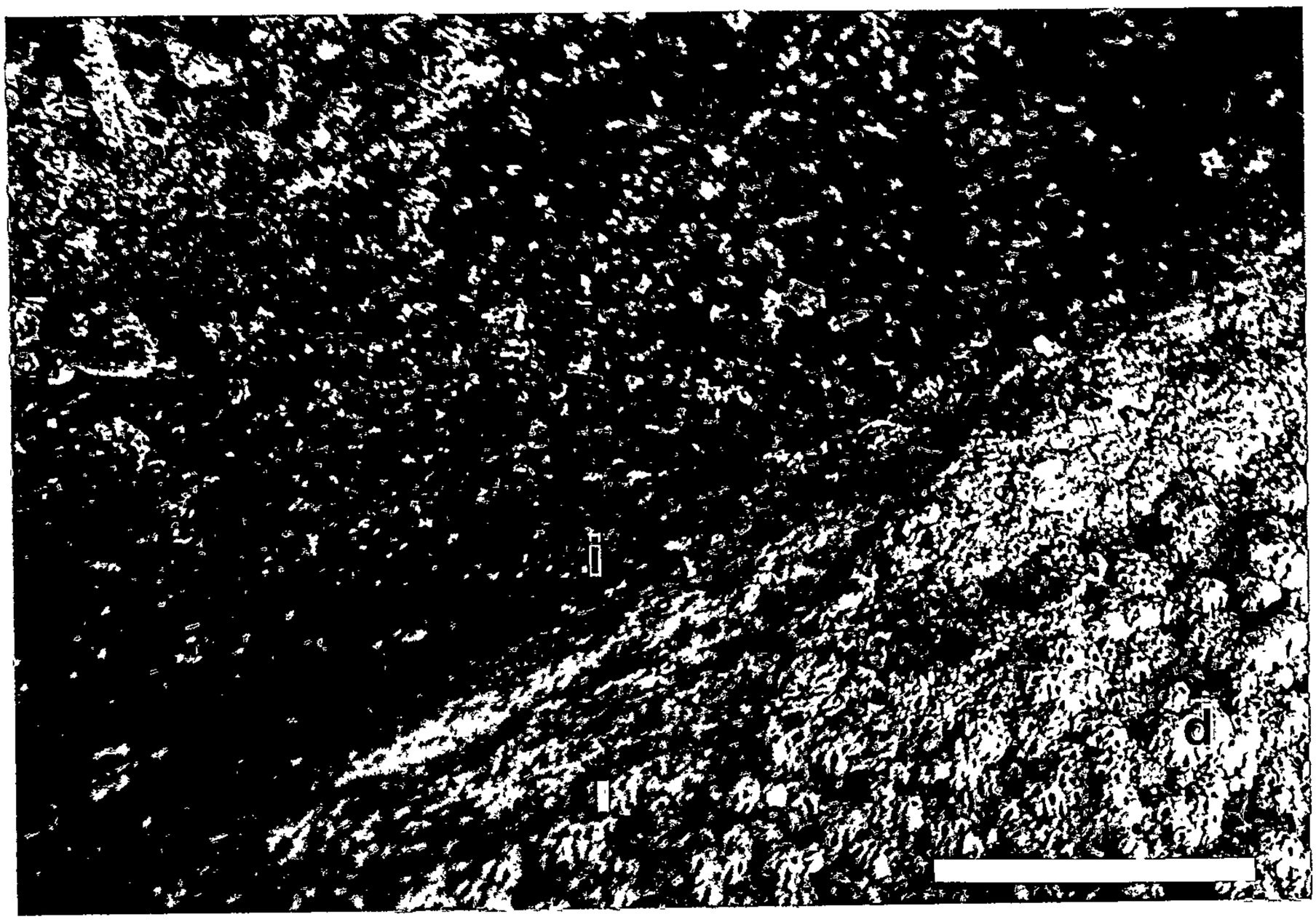


Apical region of a mesial canal (mandibular) displaying isolated instrument mark on a dentine surface otherwise not contacted by instruments. Extensive evidence of pulp remnants (Technique 1). Bar = 100 μm.

FIGURE 8.36

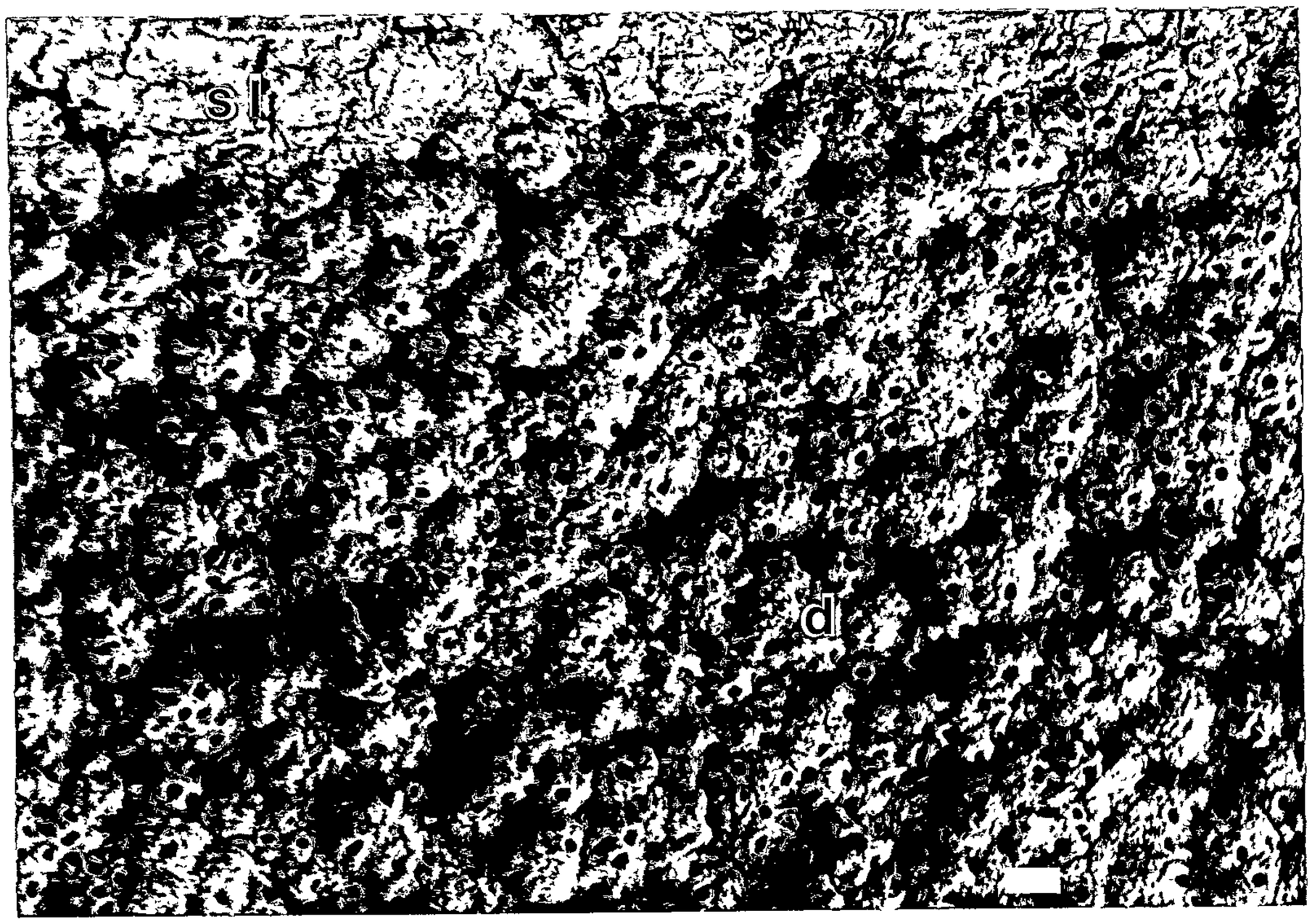
Middle region of a distobuccal canal (maxillary) graded ++ for instrument marks (Technique 4). Exposed dentinal tubules (t) are evident at the base of the "gashes". Bar = 100 μm.

FIGURE 8.37



Middle region of a mesial canal (mandibular) where smear layer (++) with instrument marks (i) juxtaposes an area of calcospheritic dentine (d) with smear layer 0 and instrument marks 0 (Technique 2). Bar = 100 μm.

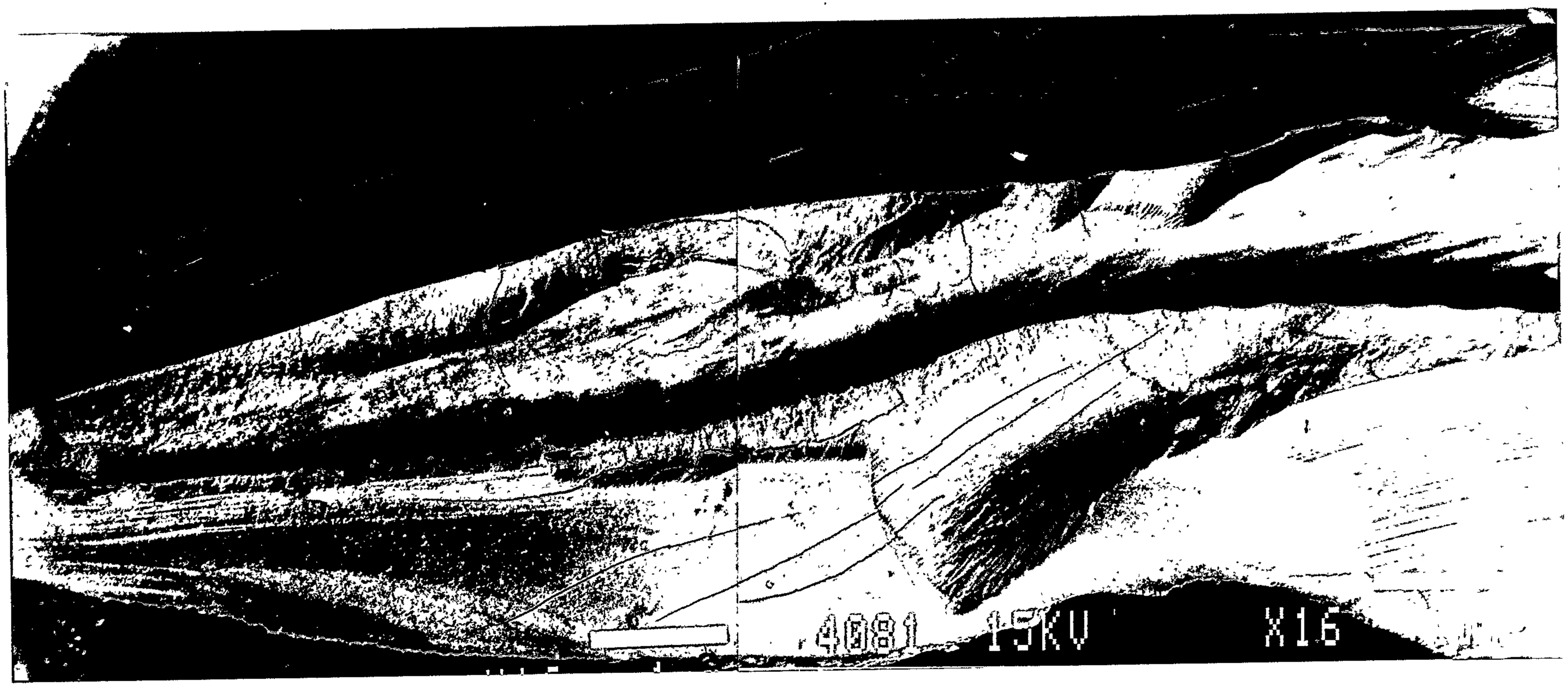
FIGURE 8.38



Middle region of a mesial canal (mandibular) which mostly displays calcospheritic surface of dentine (d) where there are no instrument marks. A small area of smear layer (sl) is evident in association with instrument marks (Technique 2). Bar = 10 μm.

8.1.4 Wave Pattern

FIGURE 8.39

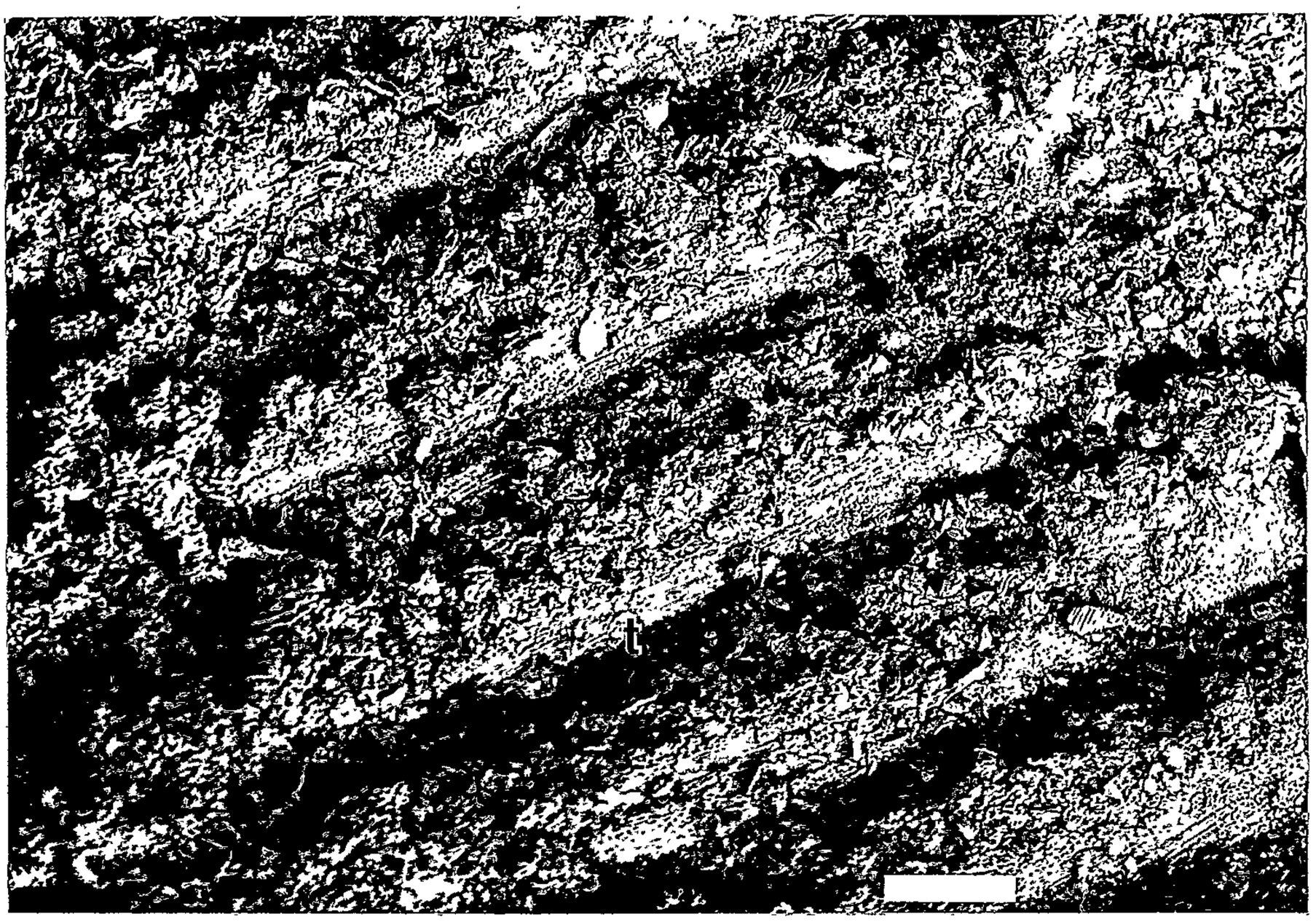


A distobuccal canal (maxillary) graded 0 for pulp remnants in the coronal and middle regions and + in the apical region. The wave pattern (w) is evident in the coronal region, in association with a very clean canal (Technique 3). Bar = 1 mm.

FIGURE 8.40

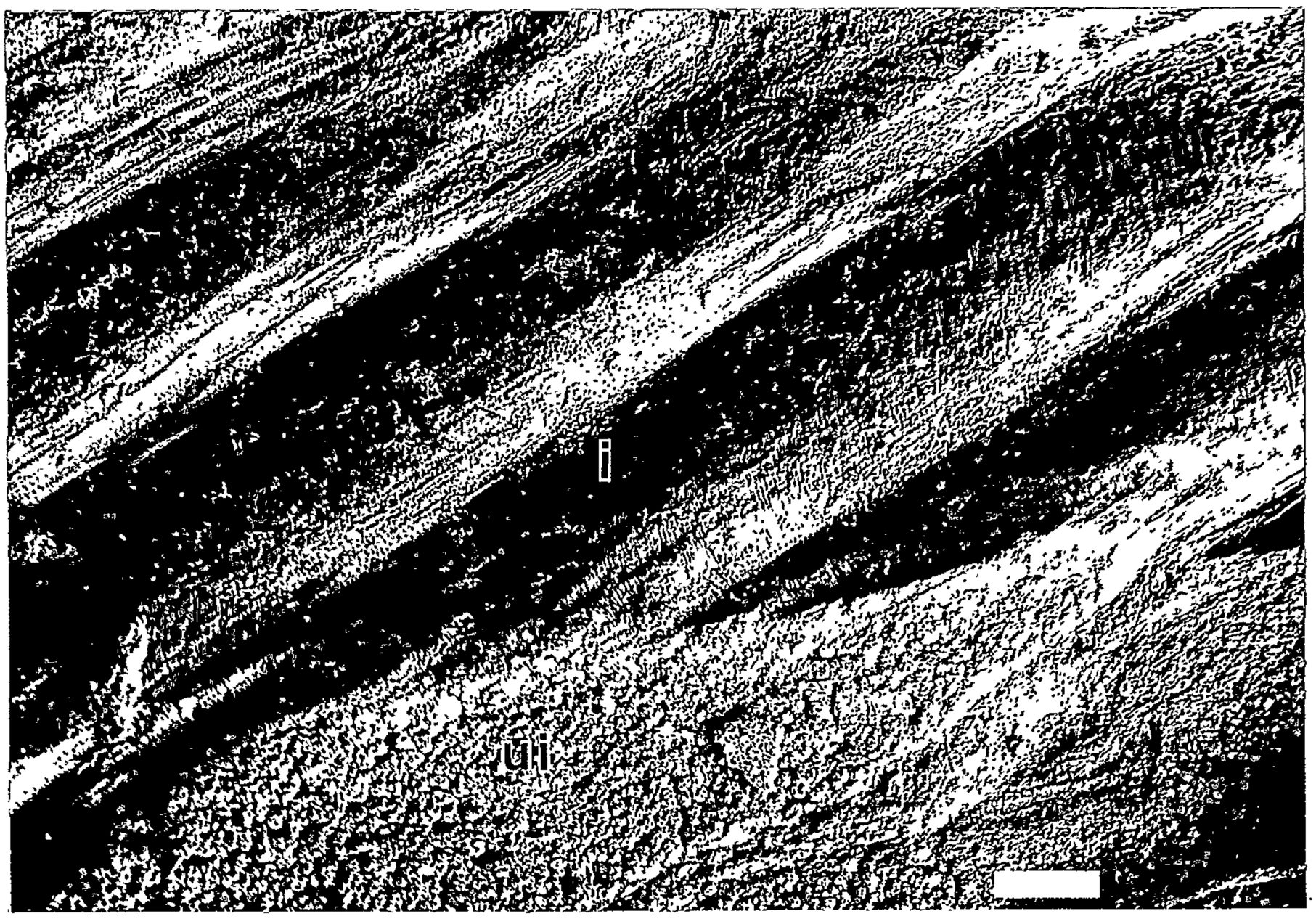
Mesial canal (mandibular) displaying the wave pattern (w) in the coronal region in association with extensive evidence of pulp remnants (Technique 4). Bar = 1 mm.

FIGURE 8.41



Coronal region of a mesial canal (mandibular) displaying the wave pattern in association with extensive evidence of pulp remnants. Exposed dentinal tubules (t) are evident at the base of the troughs (Technique 4). Bar = 100 μm.

FIGURE 8.42

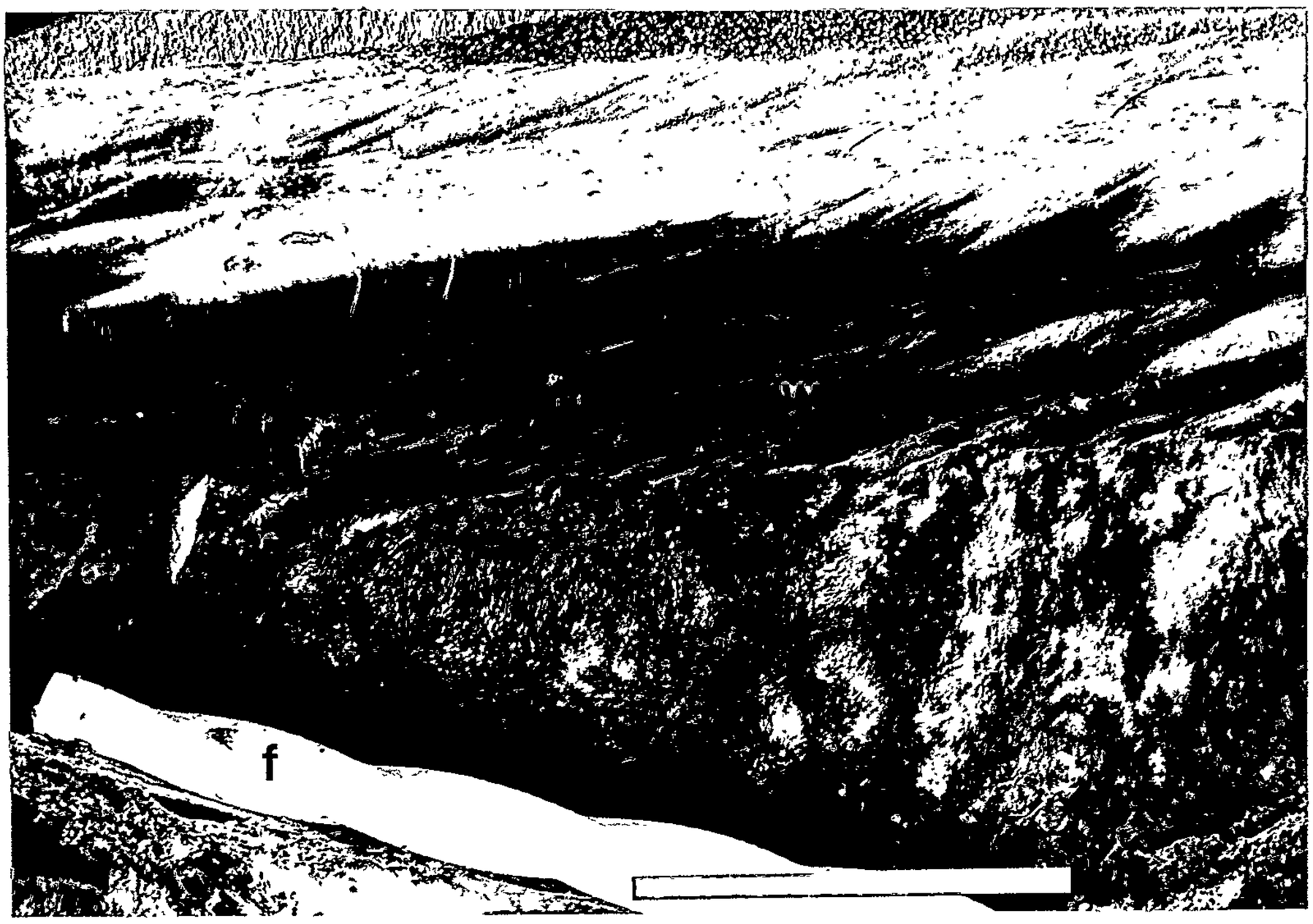


Coronal region of a mesial canal (mandibular) displaying the wave pattern in association with no pulp remnants. Exposed dentinal tubules are evident on both instrumented (i) and uninstrumented surfaces (ui) (Technique 3). Bar = 100 μm.

FIGURE 8.43

Apical region of a mesial root (mandibular) displaying the wave pattern (w) in association with no pulp remnants in the main prepared canal (Technique 4). There is extensive evidence of pulp remnants in the isthmus area and apical delta. Note the fractured instrument (f). Bar = 1 mm.

FIGURE 8.44



Apical region of the specimen shown in Fig. 8.43. Wave pattern (w) associated with a very clean surface (Technique 4). Fractured instrument (f) is evident. Bar = 1 mm.

FIGURE 8.45

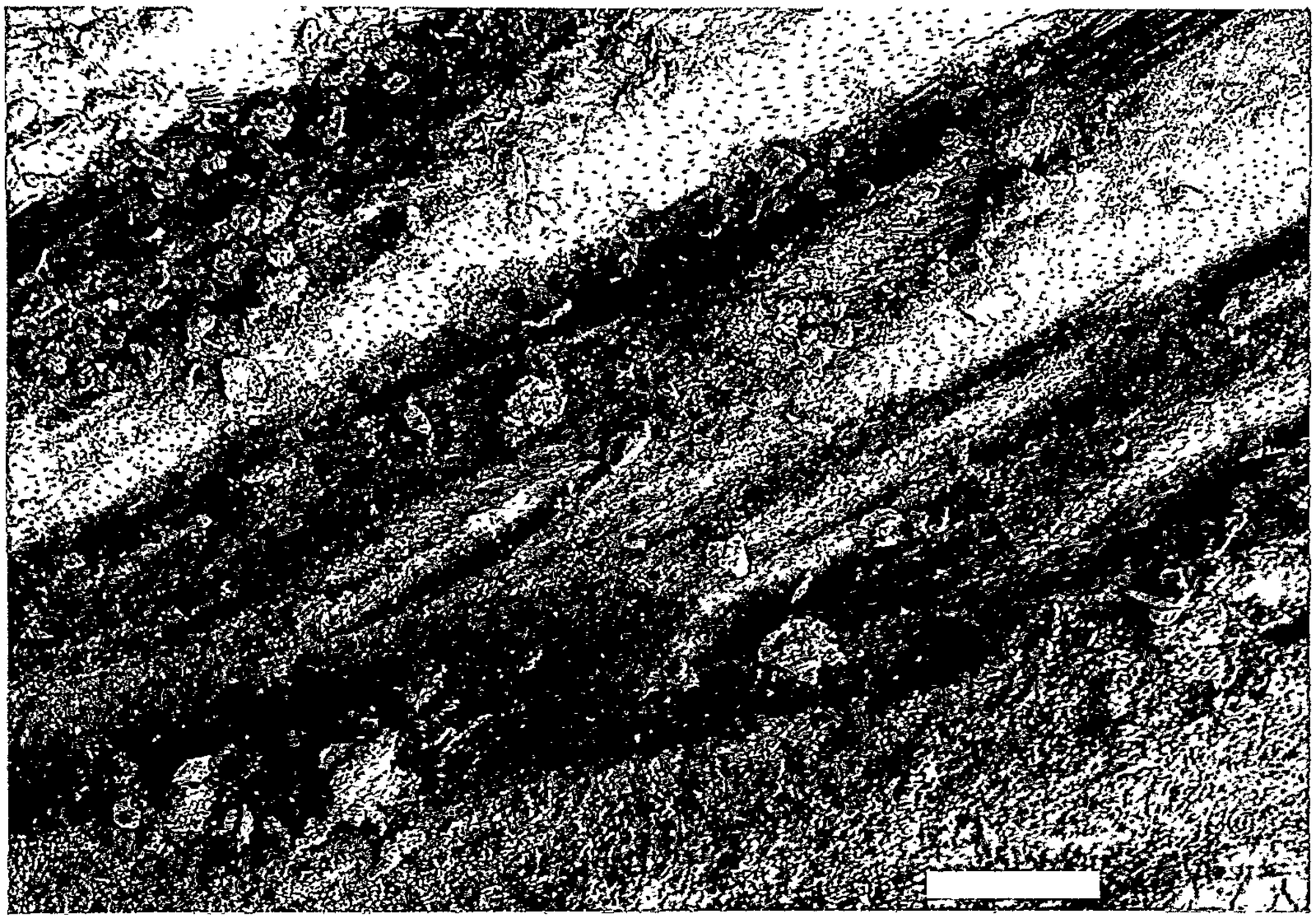
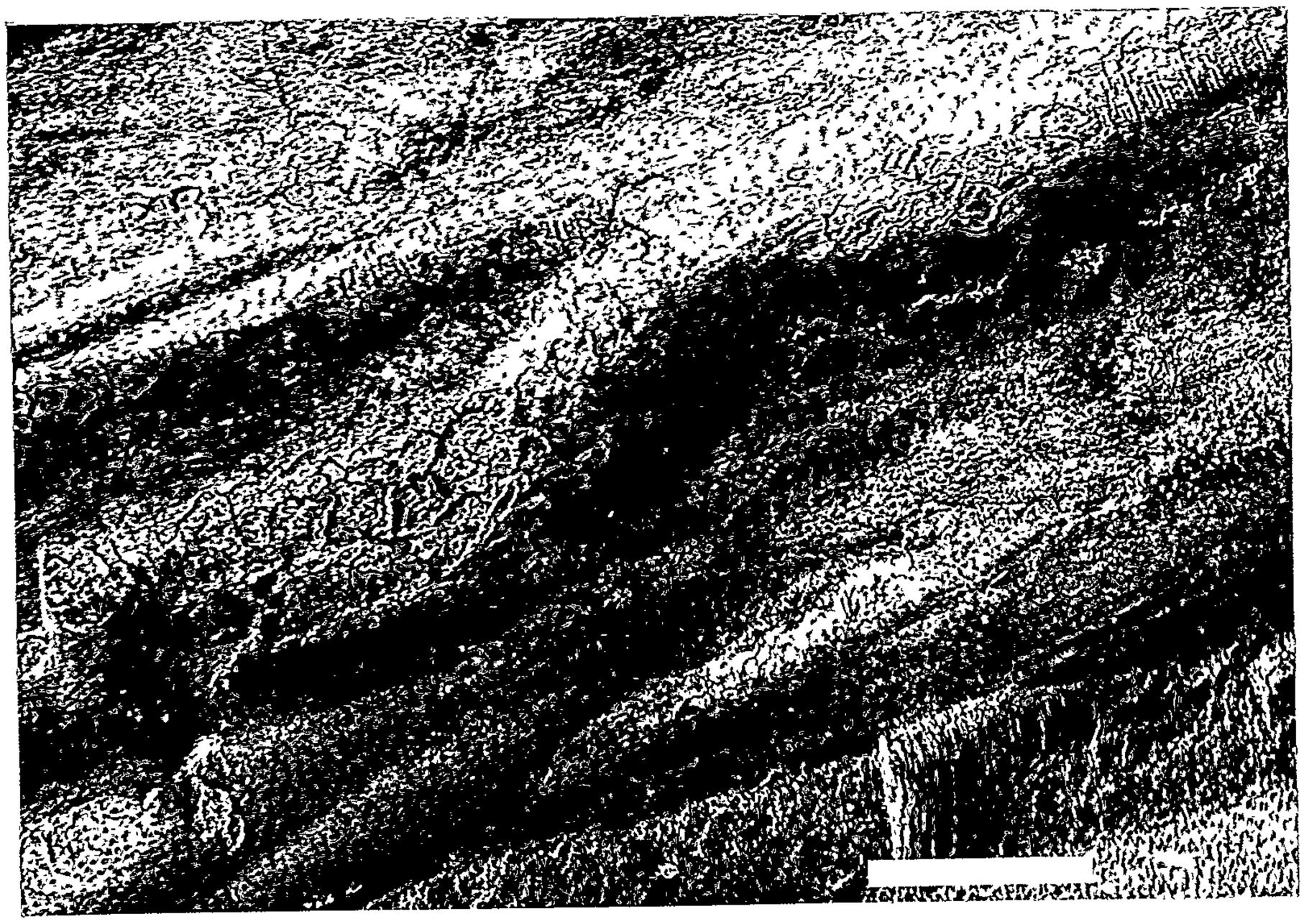
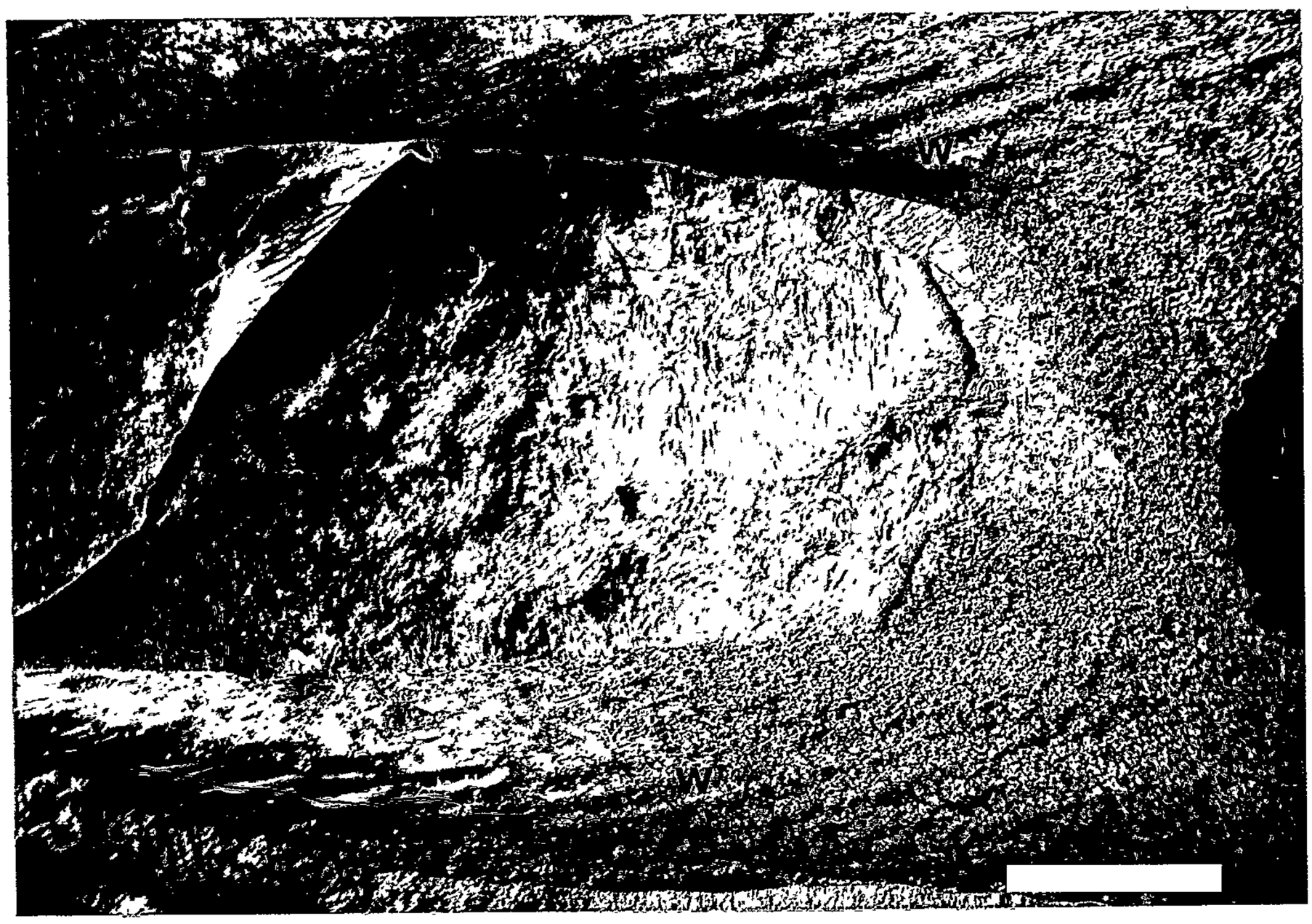


FIGURE 8.46



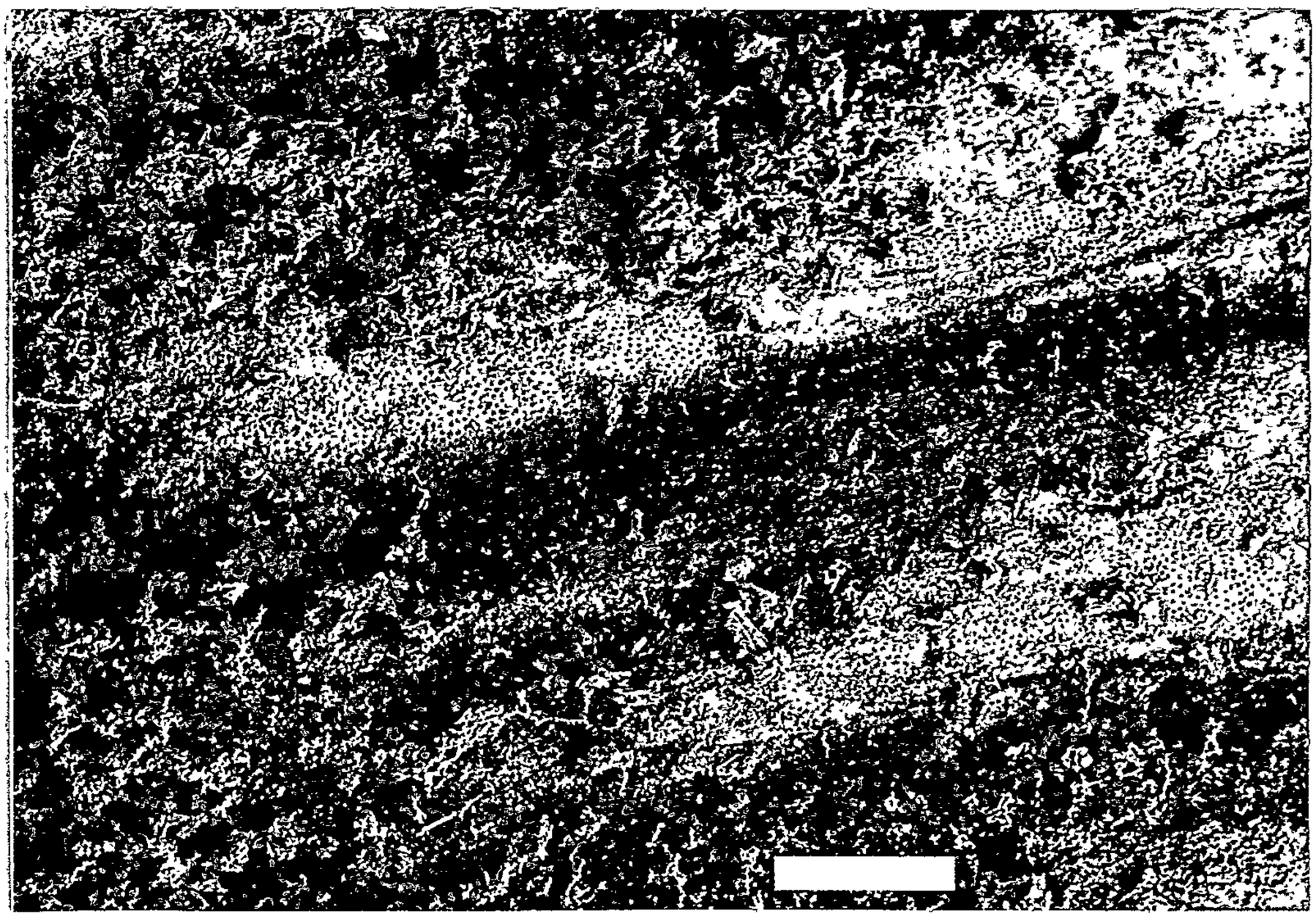
The micrographs above (8.45 and 8.46) are high power views of the specimen shown in 8.43 and 8.44. Dentinal tubules are evident, particularly in the troughs of the wave but the surface is not smear-free. Bar = 100 μm.

FIGURE 8.47



Coronal region of mesial canals (mandibular) displaying wave pattern (w) and extensive pulp remnants (Technique 4). Bar = 1 mm.

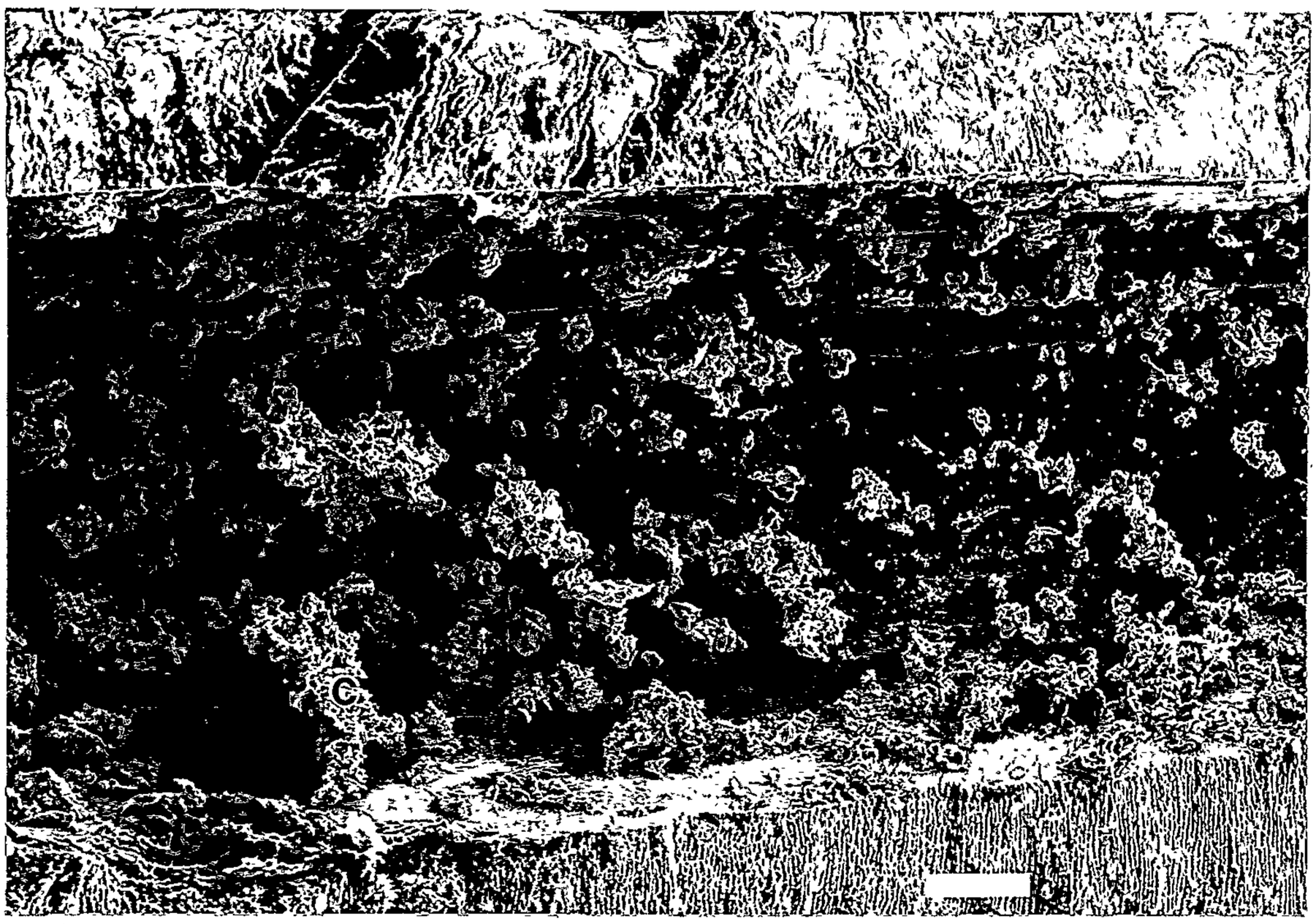
FIGURE 8.48



Middle region of distobuccal canal (maxillary) graded + for pulp remnants and + for smear layer. Wave pattern is evident (Technique 3). Bar = 100 µm.

8.1.5 Comparisons between SEI and BSI

FIGURE 8.49



A secondary electron image of middle region of a mesial canal (mandibular). This image is more three-dimensional than the backscattered images but contrast between hard and soft tissues is minimal. Note charging (c) of soft tissues. Bar = 100 μm.

FIGURE 8.50

A secondary electron image of middle region of a mesial canal (mandibular). This image is more three-dimensional than the backscattered images but contrast between hard and soft tissues is minimal. Note charging (c) of soft tissues. Bar = 100 μm.

FIGURE 8.51

A secondary electron image of apical region of a mesial canal (mandibular). Charging (c) of soft tissues is evident (Technique 4). Bar = 1 mm.

FIGURE 8.52

A backscattered image of surface shown in Fig. 8.51. Charging of soft tissues is not evident. Contrast between hard and soft tissues is greater than in Fig. 8.51. Bar = 1 mm.

FIGURE 8.53

Secondary electron image of coronal region of a mesiobuccal canal (maxillary) (Technique 4). Minimal contrast between hard (h) and soft (s) tissue and collapse of soft tissue (cs) is evident. Bar = 1mm.

FIGURE 8.54

Backscattered image of surface shown in Fig. 8.53. Contrast between hard (h) and soft (s) tissue is greater than in Fig. 8.53. There is less evidence of soft tissue collapse. Bar = 1 mm.

8.2 PRESENTATION OF THE DATA

The detail of the actual system of evaluation and presentation of results, as it was developed for this study, has been explained extensively in Chapter 7 (Materials and Methods). The tables and histograms (charts) which follow represent the accumulated data.

8.2.1 Comparisons among the Techniques

Tables 8.1-8.12 represent comparisons among the instrumentation techniques when specimens were graded for:

pulp remnants - entire canal system (Section 8.2.1.1);
pulp remnants - main prepared canal (Section 8.2.1.2);
smear layer (Section 8.2.1.3);
instrument marks (Section 8.2.1.4).

The chi square value for each comparison and a comment outlining the pertinent observations are presented in association with each table. An asterisk has been used to denote a difference that was statistically significant at a 95 per cent confidence level (that is, $P \leq 0.05$).

8.2.1.1 Pulp remnants - Entire Canal System

Comparisons among the instrumentation techniques with respect to pulp remnants in the entire canal system are presented in the following three tables and associated histograms (8.1, 8.2, 8.3).

The chi square test failed to reveal any significant differences (for $P>0.05$) among the techniques in either apical middle or coronal regions.

TABLE 8.1

GRADING FOR PULP REMNANTS IN THE APICAL REGION

Entire Canal System; Techniques Compared

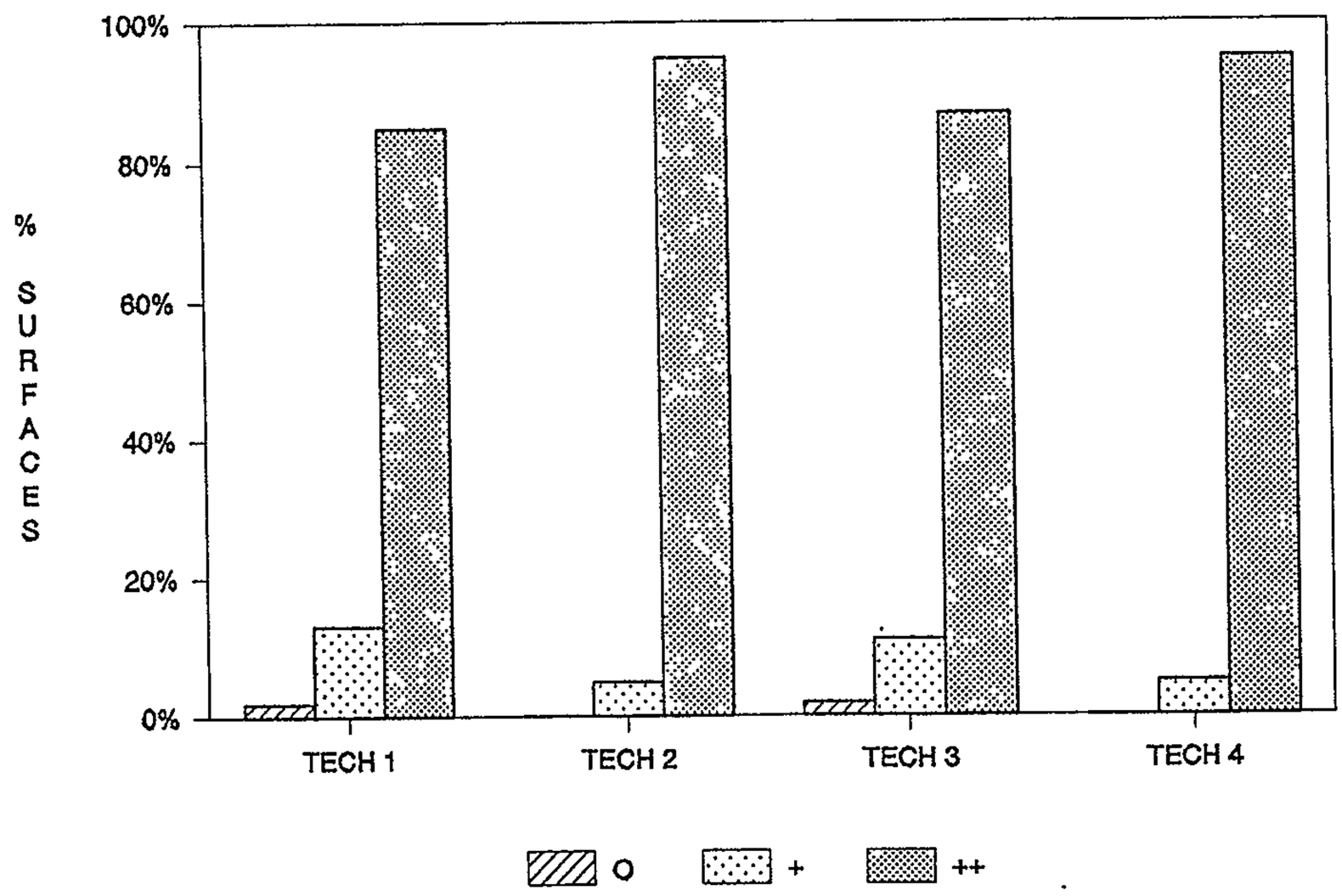
	Actual values					Percentages		
	0	+	++	Total		0	+	++
Tech. 1	1	7	44	52	Tech. 1	2	13	85
Tech. 2	0	2	39	41	Tech. 2	0	5	95
Tech. 3	1	5	39	45	Tech. 3	2	11	87
Tech. 4	0	2	40	42	Tech. 4	0	5	95

Chi square 5.22. This approximation for chi square is probably invalid as during computation it was noted that there were 4 cells with expected counts less than 1.0.

CHART 8.1

GRADING FOR PULP REMNANTS IN THE APICAL REGION

Entire Canal System; Techniques Compared



Comment. Most surfaces in all techniques were graded ++, indicating that all techniques left extensive evidence of pulp remnants in the apical region of the canal in the majority of cases.

TABLE 8.2

GRADING FOR PULP REMNANTS IN THE MIDDLE REGION

Entire Canal System; Techniques Compared

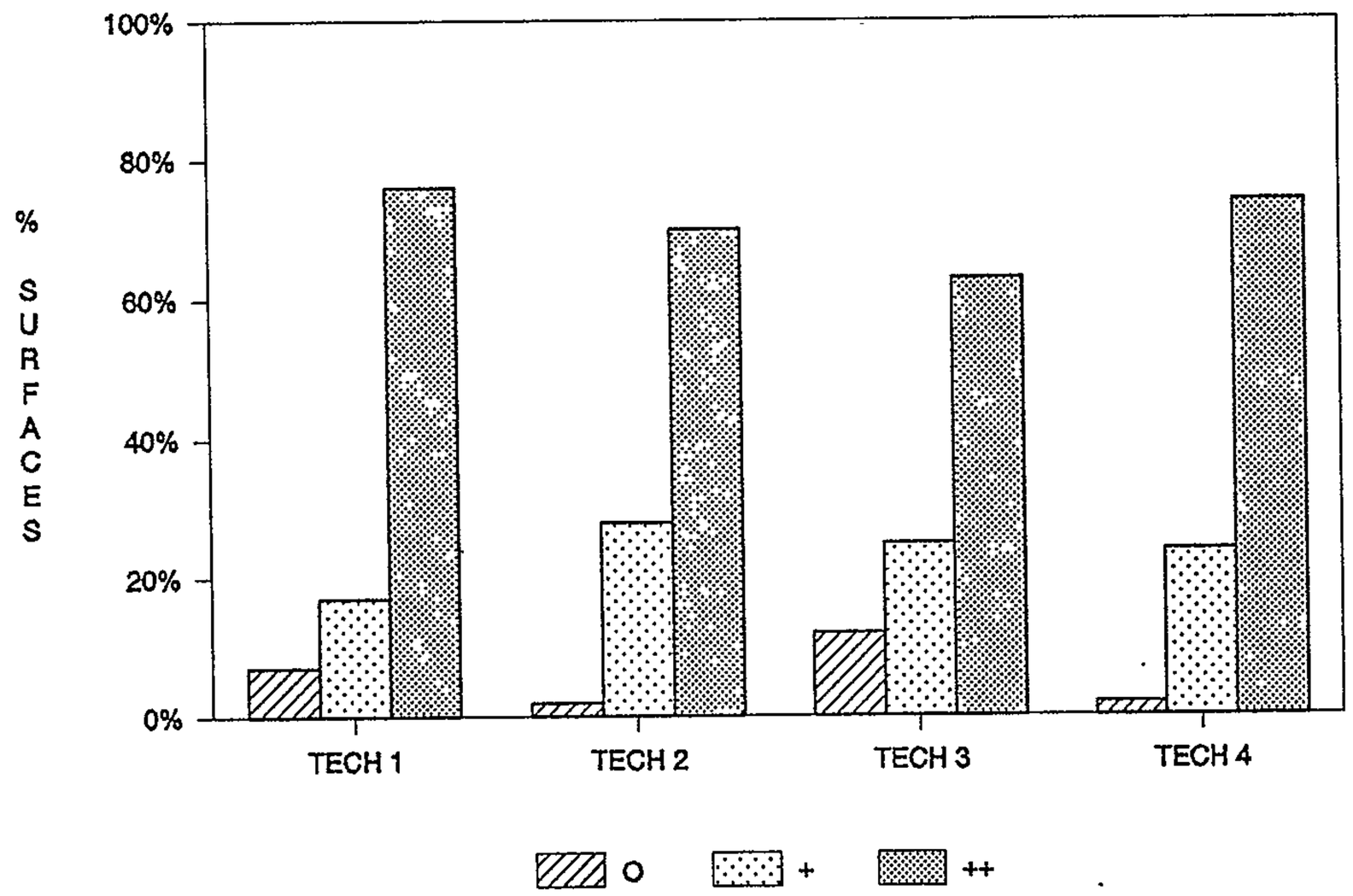
	Actual values				Percentages			
	0	+	++	Total		0	+	++
Tech. 1	4	9	41	54	Tech. 1	7	17	76
Tech. 2	1	12	32	43	Tech. 2	2	28	70
Tech. 3	6	12	30	48	Tech. 3	12	25	63
Tech. 4	1	11	34	46	Tech. 4	2	24	74

Chi square = 7.58

CHART 8.2

GRADING FOR PULP REMNANTS IN THE MIDDLE REGION

Entire Canal System; Techniques Compared



Comment. The percentage of 0 scores is highest and that of ++ scores lowest in Technique 3 indicating a trend (P>0.05), in the middle region, for fewer pulp remnants when canals were prepared by Technique 3.

TABLE 8.3

GRADING FOR PULP REMNANTS IN THE CORONAL REGION

Entire Canal System; Techniques Compared

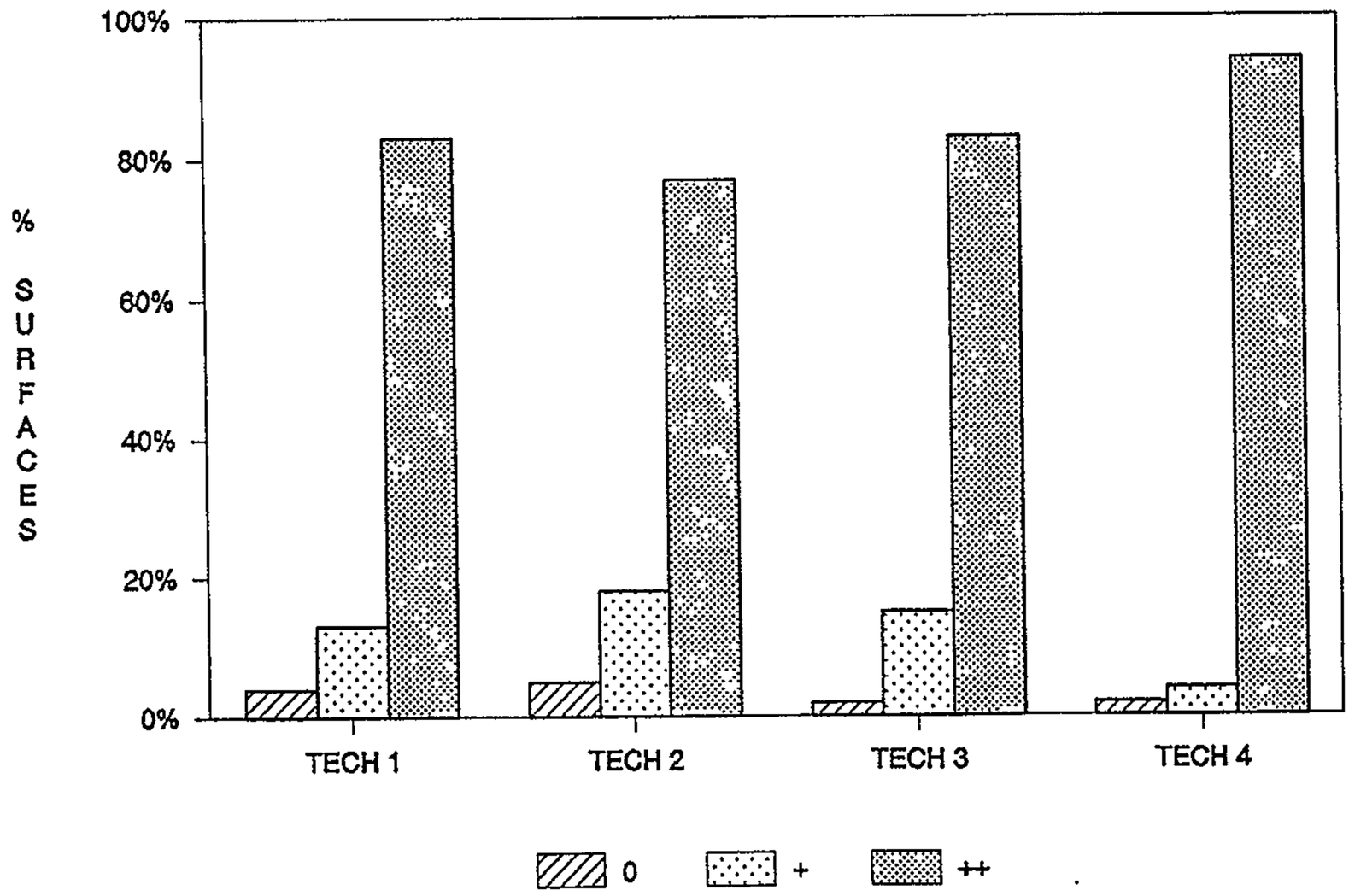
	Actual values					Percentages		
	0	+	++	Total		0	+	++
Tech. 1	2	7	44	53	Tech. 1	4	13	83
Tech. 2	2	8	33	43	Tech. 2	5	18	77
Tech. 3	1	7	40	48	Tech. 3	2	15	83
Tech. 4	1	2	43	46	Tech. 4	2	4	94

chi square = 5.32

CHART 8.3

GRADING FOR PULP REMNANTS IN THE CORONAL REGION

Entire Canal System; Techniques Compared



Comment. The percentage of ++ scores is highest and that of 0 and + scores is lowest in Technique 4 indicating a trend (P>0.05), in the coronal region, for more pulp remnants when canals were prepared by Technique 4.

8.2.1.2 Pulp Remnants - Main Prepared Canal

The chi square test failed to reveal any significant differences among the techniques (for $P \leq .05$) in either apical, middle or coronal regions.

TABLE 8.4

GRADING FOR PULP REMNANTS IN THE APICAL REGION

Main Prepared Canal; Techniques Compared

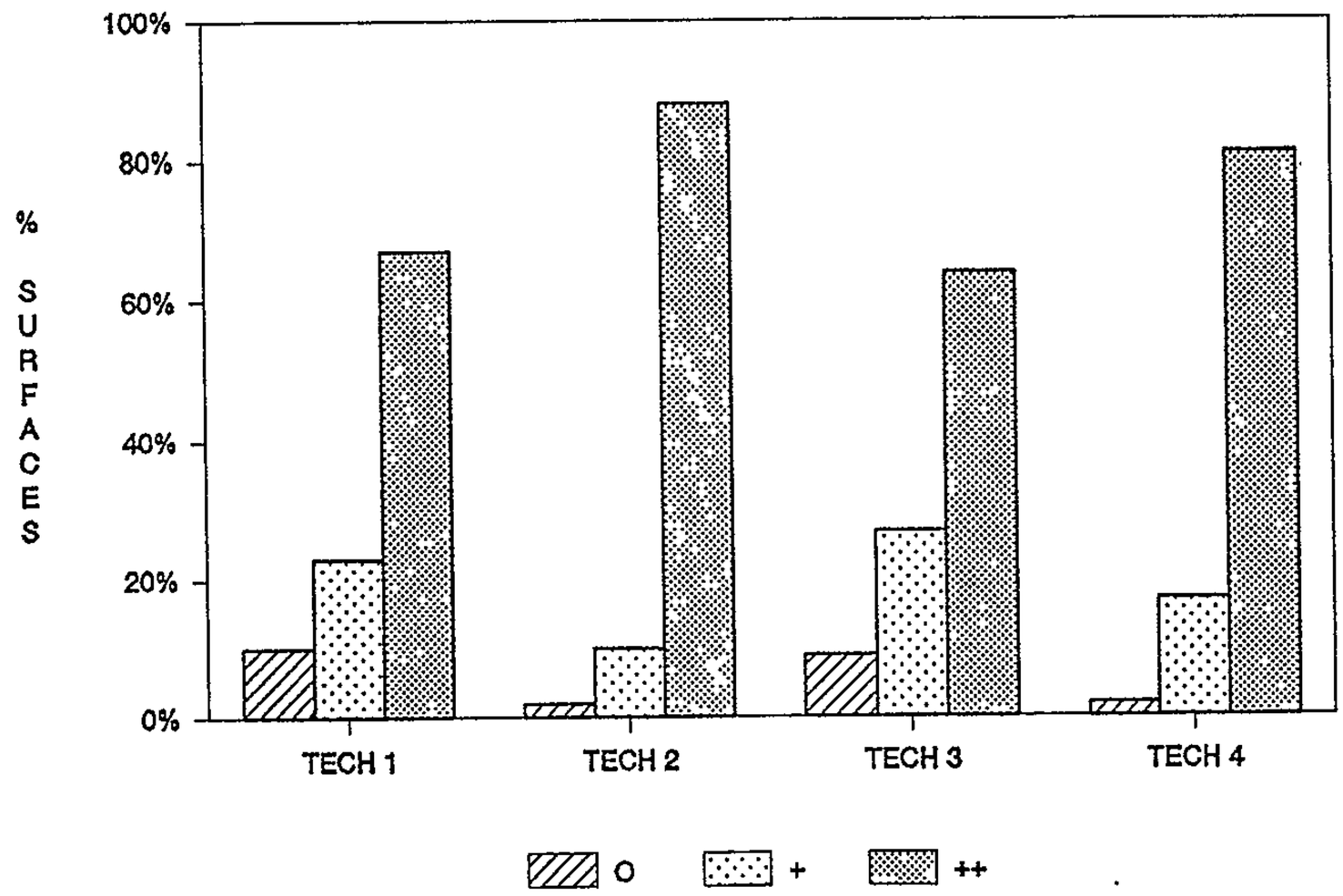
	Actual values					Percentages		
	0	+	++	Total		0	+	++
Tech. 1	5	12	35	52	Tech. 1	10	23	67
Tech. 2	1	4	36	41	Tech. 2	2	10	88
Tech. 3	4	12	29	45	Tech. 3	9	27	64
Tech. 4	1	7	34	42	Tech. 4	2	17	81

Chi square = 9.36

CHART 8.4

GRADING FOR PULP REMNANTS IN THE APICAL REGION

Main Prepared Canal; Techniques Compared



Comment. The percentage of 0 scores is higher in Techniques 1 and 3 than in Techniques 2 and 4 and the percentage of ++ scores is lowest in Technique 3. There was a trend ($P>0.05$), in the apical region, for less evidence of pulp remnants when canals were prepared by Techniques 1 and 3.

TABLE 8.5

GRADING FOR PULP REMNANTS IN THE MIDDLE REGION

Main Prepared Canal; Techniques Compared

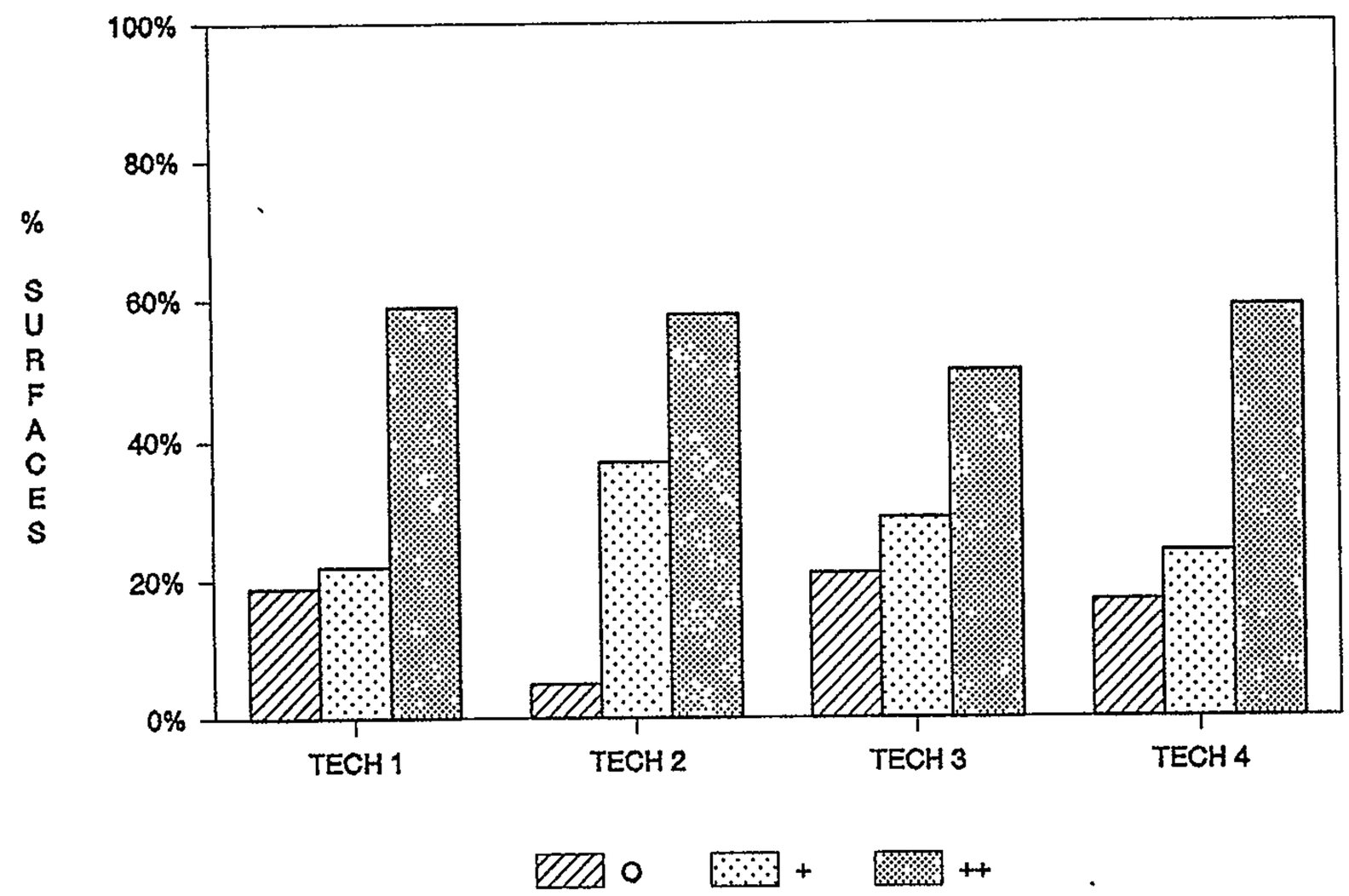
	Actual values				Percentages			
	0	+	++	Total	0	+	++	
Tech. 1	10	12	32	54	Tech. 1	19	22	59
Tech. 2	2	16	25	43	Tech. 2	5	37	58
Tech. 3	10	14	24	48	Tech. 3	21	29	50
Tech. 4	8	11	27	46	Tech. 4	17	24	59

chi square = 7.26

CHART 8.5

GRADING FOR PULP REMNANTS IN THE MIDDLE REGION

Main Prepared Canal; Techniques Compared



Comment. Technique 2 had somewhat fewer canals with 0 scores and Technique 3 had fewer canals with ++ scores. These trends were not significant (P>0.05).

TABLE 8.6

GRADING FOR PULP REMNANTS IN THE CORONAL REGION

Main Prepared Canal; Techniques Compared

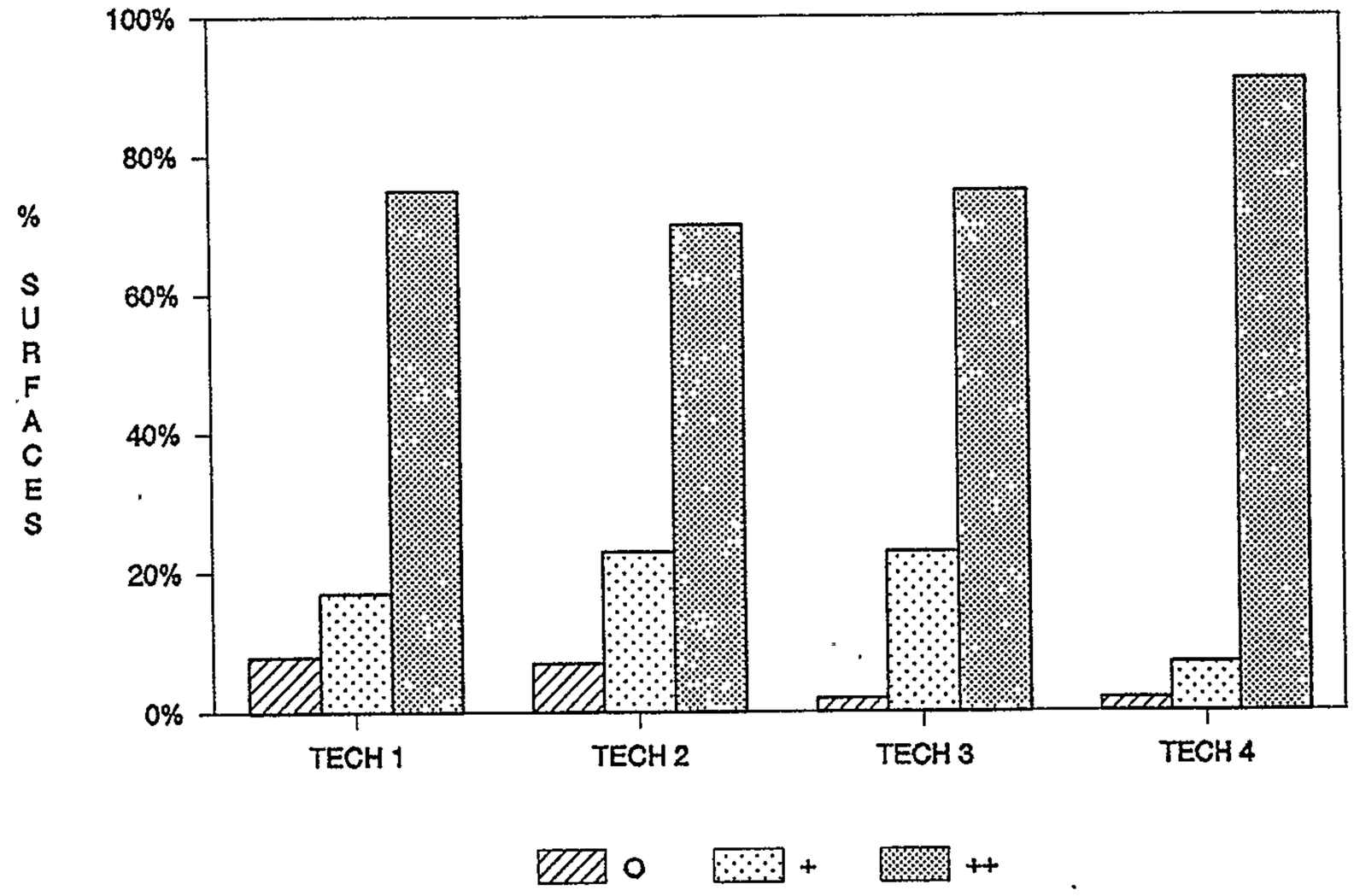
	Actual values					Percentages		
	0	+	++	Total		0	+	++
Tech. 1	4	9	40	53	Tech. 1	8	17	75
Tech. 2	3	10	30	43	Tech. 2	7	23	70
Tech. 3	1	11	36	48	Tech. 3	2	23	75
Tech. 4	1	3	42	46	Tech. 4	2	7	91

chi square = 9.04

CHART 8.6

GRADING FOR PULP REMNANTS IN THE CORONAL REGION

Main Prepared Canal; Techniques Compared



Comment. The percentage of ++ scores is highest and the percentages of 0 and + scores are lowest in Technique 4. This trend indicated that, in the coronal region, more pulp remnants were found in canals prepared by Technique 4.

8.2.1.3 Smear Layer

No surfaces were devoid of smear layer, therefore, no 0 scores were recorded. "U" is a grade given for surfaces which could not otherwise be assessed, (+ or ++) owing to the presence of pulp remnants. The chi square test revealed that differences among the techniques are significant in the coronal region only (for $P \leq .05$).

TABLE 8.7

GRADING FOR SMEAR LAYER IN THE APICAL REGION

Techniques Compared

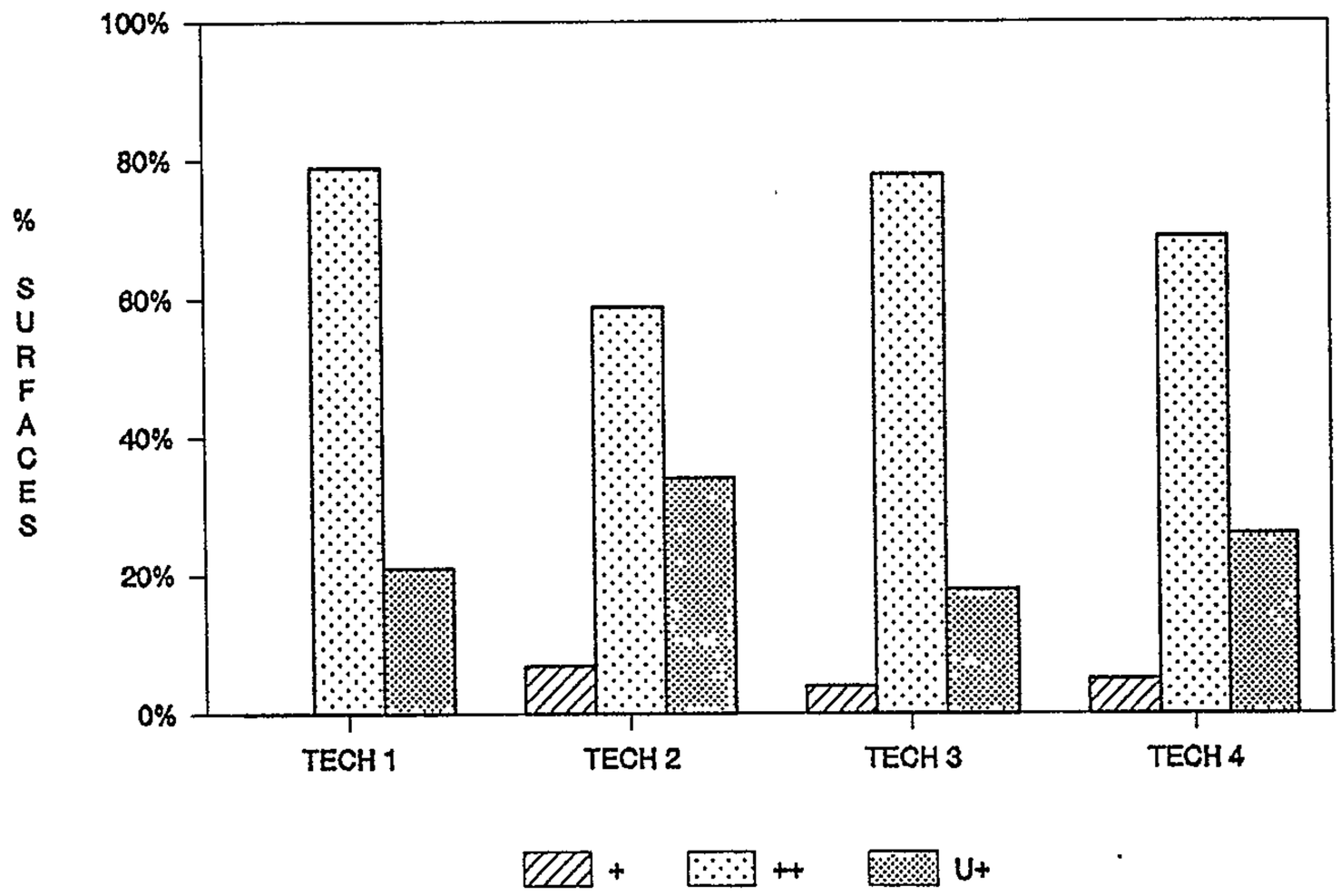
	Actual values					Percentages		
	+	++	U	Total		+	++	U
Tech. 1	0	41	11	52	Tech. 1	0	79	21
Tech. 2	3	24	14	41	Tech. 2	7	59	34
Tech. 3	2	35	8	45	Tech. 3	4	78	18
Tech. 4	2	29	11	42	Tech. 4	5	69	26

chi square = 7.69

CHART 8.7

GRADING FOR SMEAR LAYER IN THE APICAL REGION

Techniques Compared



Comment. For all techniques, a majority of surfaces were graded ++, indicating extensive evidence of smear layer in the apical region of the canal, regardless of technique.

TABLE 8.8

GRADING FOR SMEAR LAYER IN THE MIDDLE REGION

Techniques Compared

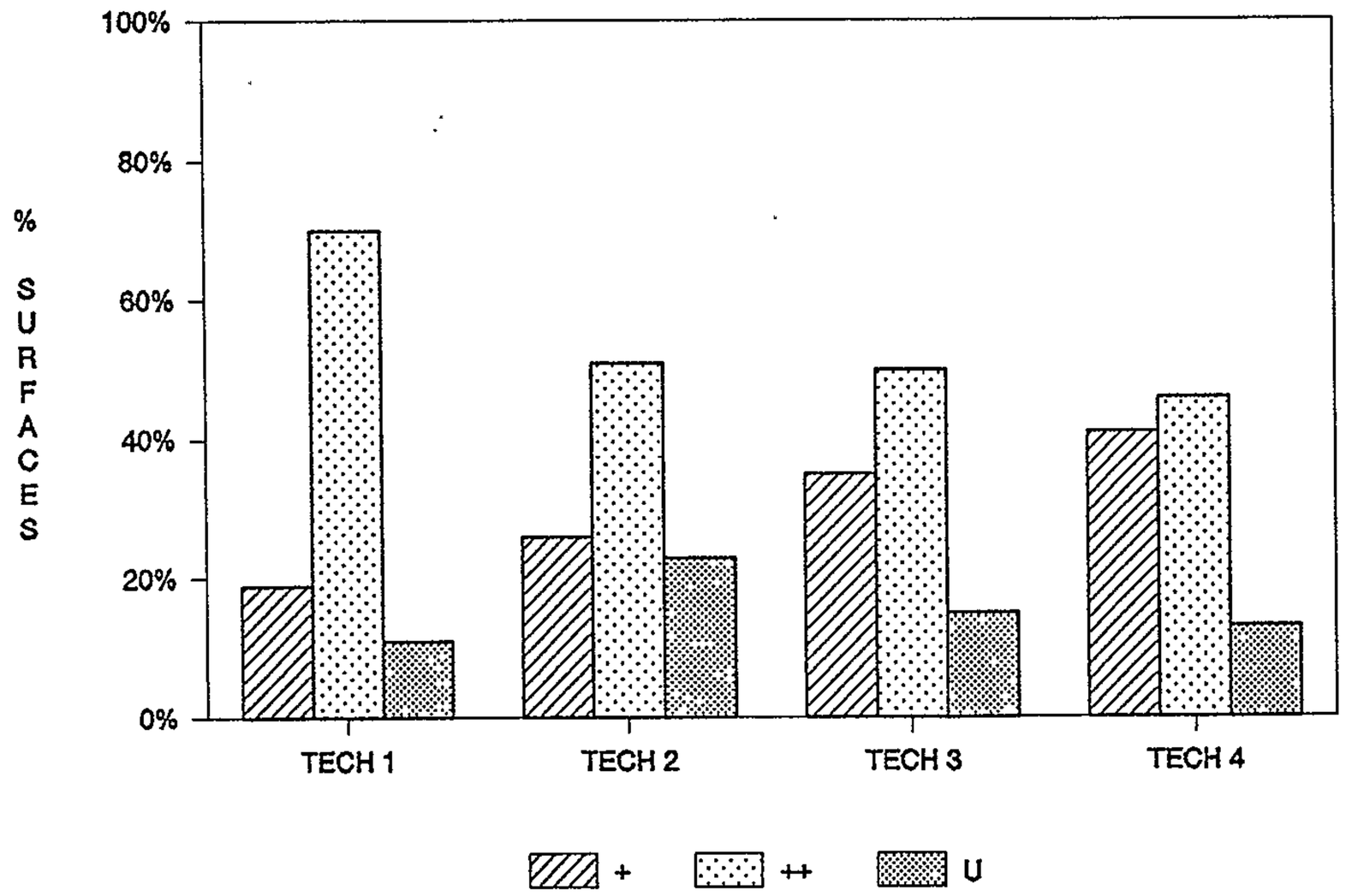
	Actual values				Percentages			
	+	++	U	Total		+	++	U
Tech. 1	10	38	6	54	Tech. 1	19	70	11
Tech. 2	11	22	10	43	Tech. 2	26	51	23
Tech. 3	17	24	7	48	Tech. 3	35	50	15
Tech. 4	19	21	6	46	Tech. 4	41	46	13

chi square = 11.08

CHART 8.8

GRADING FOR SMEAR LAYER IN THE MIDDLE REGION

Techniques Compared



Comment. The percentage of ++ scores is highest and that of + scores is lowest in Technique 1 indicating a trend (P>0.05), in the middle region, for Technique 1 to result in more surfaces with extensive evidence of smear layer.

TABLE 8.9

GRADING FOR SMEAR LAYER IN THE CORONAL REGION

Techniques Compared

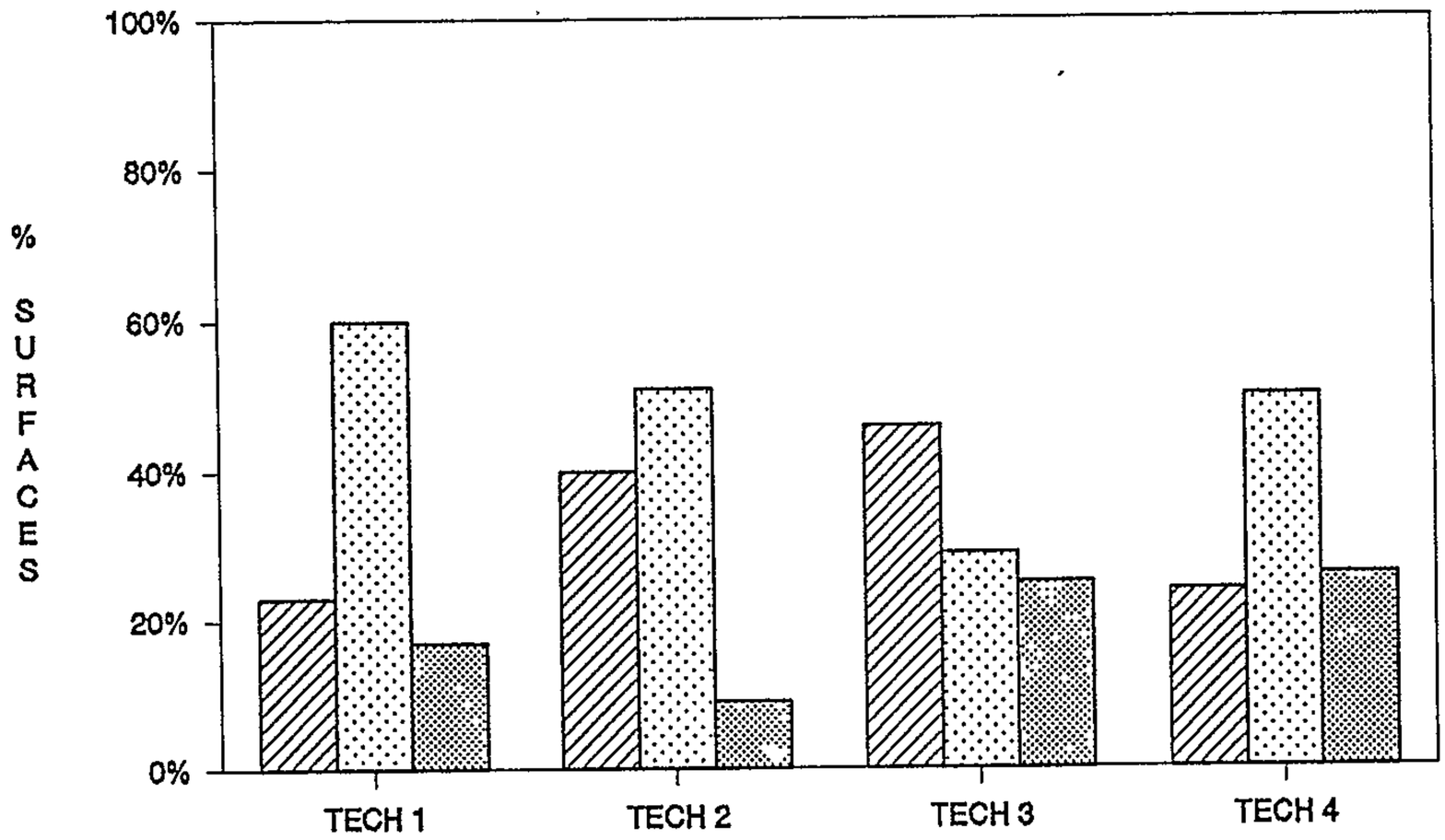
	Actual values					Percentages		
	+	++	U	Total		+	++	U
Tech. 1	12	32	9	53	Tech. 1	23	60	17
Tech. 2	17	22	4	43	Tech. 2	40	51	9
Tech. 3	22	14	12	48	Tech. 3	46	29	25
Tech. 4	11	23	12	46	Tech. 4	24	50	26

chi square = 15.50*

CHART <x9

GRADING FOR SMEAR LAYER IN THE CORONAL REGION

Techniques Compared



Comment. The percentage of + scores was highest and that of ++ scores was lowest in Technique 3 indicating that, in the coronal region, exposed dentinal tubules (sparse evidence of smear layer) were more frequently observed in canals prepared by Technique 3. The differences are statistically significant.

8.2.1.4 Instrument Marks

The chi square test revealed that differences among the techniques with respect to instruments marks are significant in the coronal region only.

TABLE 8.10

GRADING FOR INSTRUMENT MARKS IN THE APICAL REGION

Techniques Compared

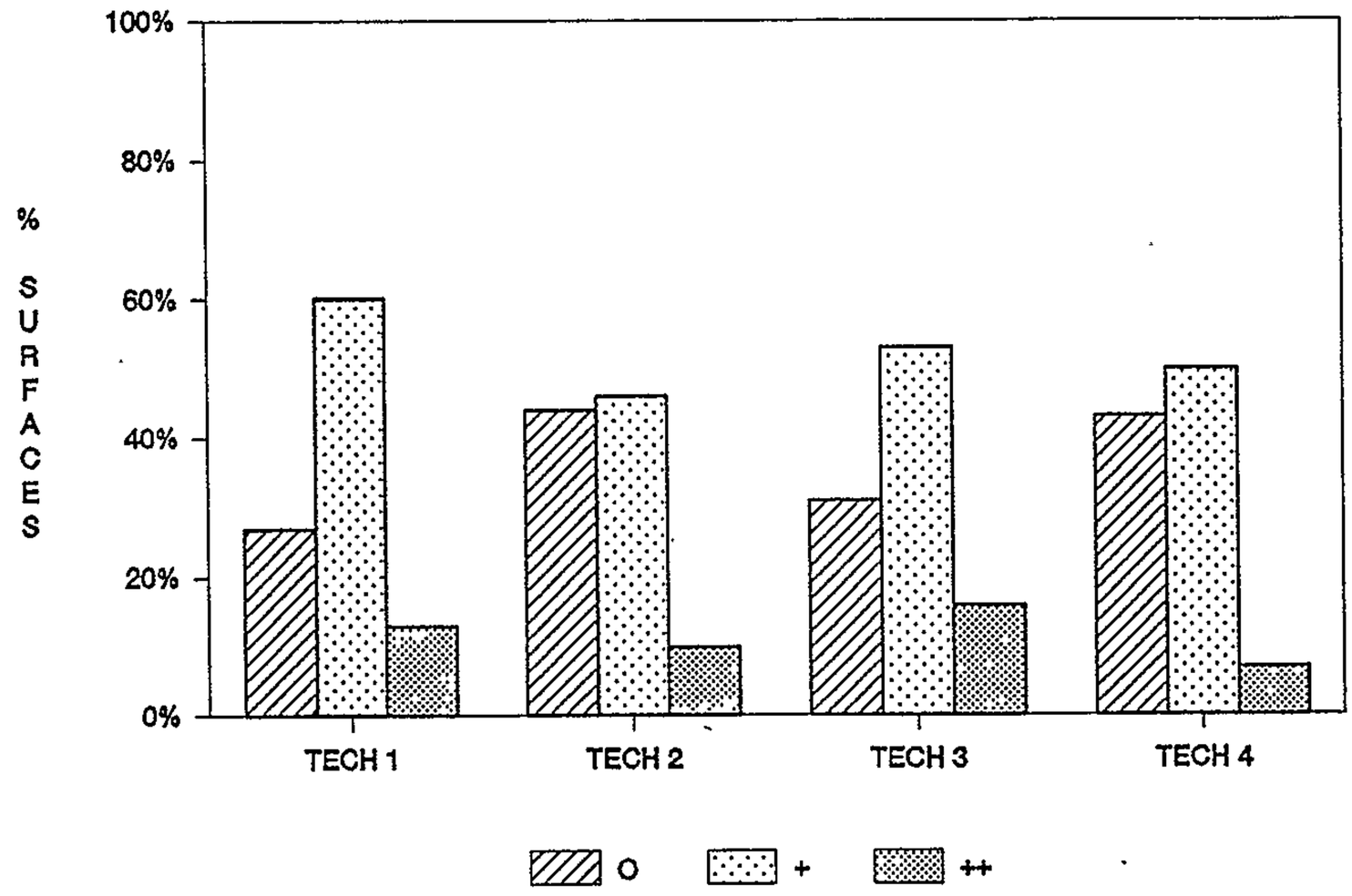
	Actual values					Percentages		
	0	+	++	Total		0	+	++
Tech.1	14	31	7	52	Tech.1	27	60	13
Tech.2	18	19	4	41	Tech.2	44	46	10
Tech.3	14	24	7	45	Tech.3	31	53	16
Tech.4	18	21	3	42	Tech.4	43	50	7

chi square = 5.21

CHART 8.10

GRADING FOR INSTRUMENT MARKS IN THE APICAL REGION

Techniques Compared



Comment. The percentage of + scores was highest and that of 0 scores was lowest in Technique 1. Technique 1 tended to produce more instrument marks ($P>0.05$).

TABLE 8.11

GRADING FOR INSTRUMENT MARKS IN THE MIDDLE REGION

Techniques Compared

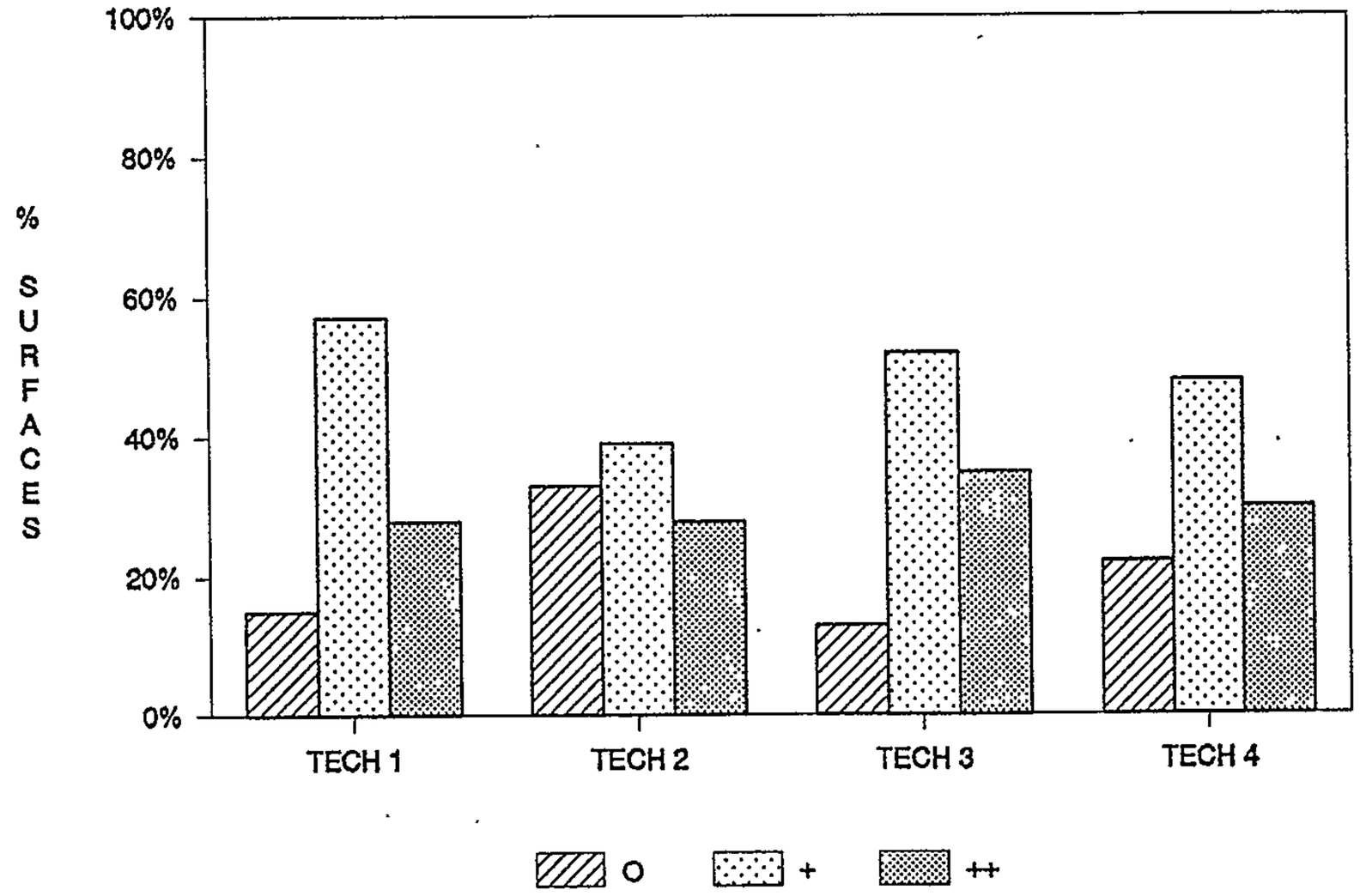
	Actual values					Percentages		
	0	+	++	Total		0	+	++
Tech. 1	8	31	15	54	Tech. 1	15	57	28
Tech. 2	14	17	12	43	Tech. 2	33	39	28
Tech. 3	6	25	17	48	Tech. 3	13	52	35
Tech. 4	10	22	15	46	Tech. 4	22	48	30

chi square = 7.80

CHART 8.11

GRADING FOR INSTRUMENT MARKS IN THE MIDDLE REGION

Techniques Compared



Comment. Differences among techniques were not statistically significant. However, Technique 2 produced the greatest percentage of canals with 0 grading ($P>0.05$).

TABLE 8.12

GRADING FOR INSTRUMENT MARKS IN THE CORONAL REGION

Techniques Compared

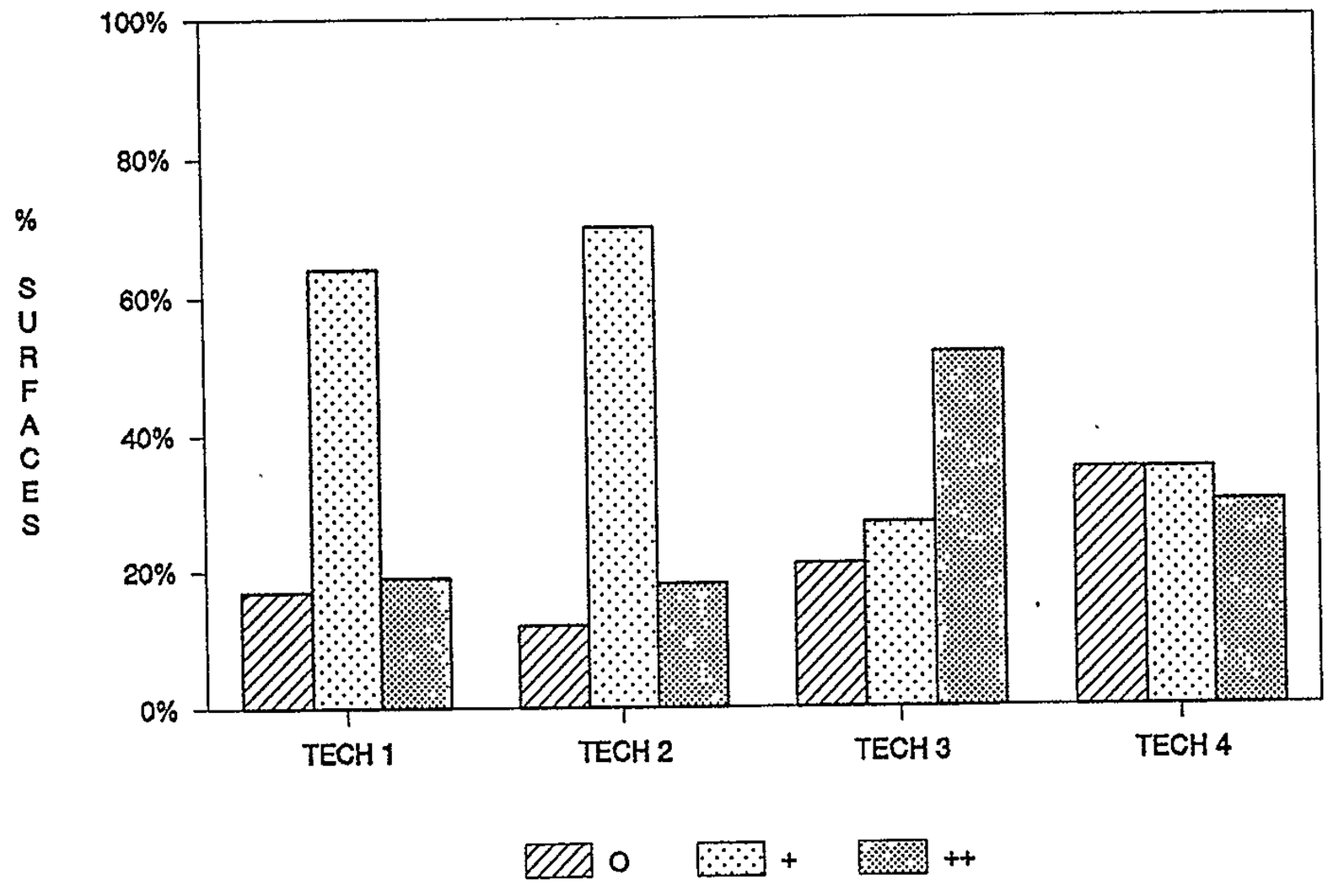
	Actual values					Percentages		
	0	+	++	Total		0	+	++
Tech. 1	9	34	10	53	Tech. 1	17	64	19
Tech. 2	5	30	8	43	Tech. 2	12	70	18
Tech. 3	10	13	25	48	Tech. 3	21	27	52
Tech. 4	16	16	14	46	Tech. 4	35	35	30

chi square = 31.09*

CHART 8.12

GRADING FOR INSTRUMENT MARKS IN THE CORONAL REGION

Techniques Compared



Comment. Differences among the techniques were statistically significant. Technique 4 produced the greatest percentage of canals with 0 grade for instrument marks and Technique 3 produced the greatest percentage with ++ grading.

8.2.1.5 Wave Pattern

Twenty specimens were graded "W" (for the presence of a wave pattern) as follows.

Technique 1	0
Technique 2	0
Technique 3	14 (coronal region), 2 (middle region)
Technique 4	6 (coronal region), 2 (middle region), 1 (apical region)

These results indicate that the wave pattern on canal surfaces is associated with the ultrasonic Techniques, 3 and 4.

8.2.2 Comparisons among Different Regions of the Canal Irrespective of Technique.

Tables and charts 8.13-8.16 represent comparisons among the apical, middle and coronal regions of the whole sample of prepared canals, irrespective of technique, when the specimens were graded for the features:

pulp remnants - entire canal system;
pulp remnants - main prepared canal;
smear layer ; and
instrument marks.

The chi square value for each comparison and a comment outlining the pertinent observations are presented in association with each table. An asterisk has been used to denote a difference that was statistically significant at a 95 per cent confidence level (that is, $P \leq 0.05$).

The chi square test revealed that the differences among the three regions of the canals with respect to the above features are significant (for $P<0.05$).

TABLE 8.13

GRADING FOR PULP REMNANTS

Entire Canal System; Whole Sample

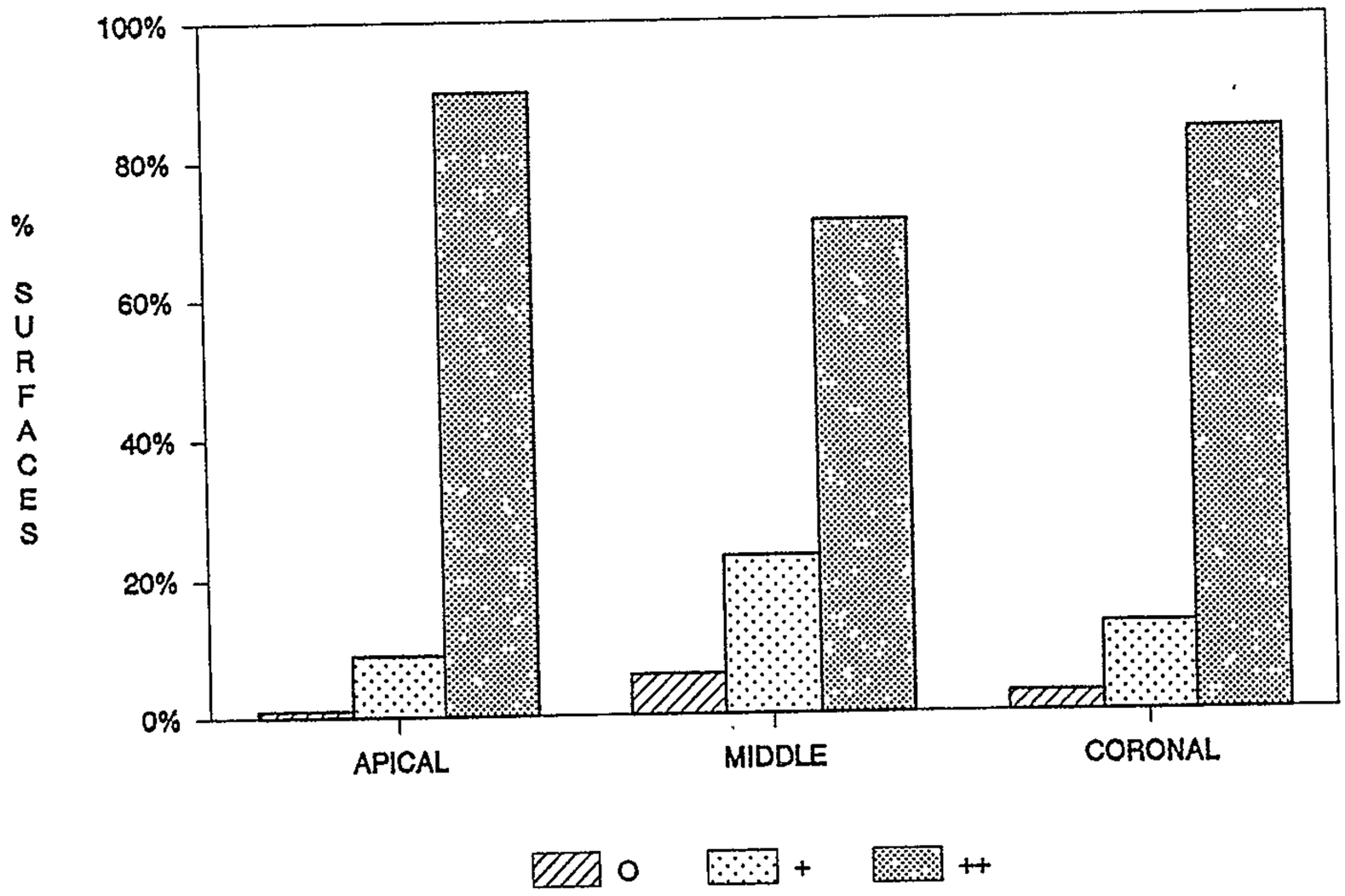
	Actual values					Percentages		
	0	+	++	Total		0	+	++
Apical	2	16	162	180	Apical	1	9	90
Middle	12	44	135	191	Middle	6	23	71
Coronal	6	24	160	190	Coronal	3	13	84
TOTAL	20	84	457					

chi square = 24.87*

CHART 8.13

GRADING FOR PULP REMNANTS

Entire Canal System; Whole Sample



Comment. The majority of surfaces were graded ++ indicating that most surfaces of the whole sample of prepared canals displayed extensive evidence of pulp remnants, irrespective of the technique used. The percentages of 0 and + scores are highest and the percentage of ++ scores is lowest in the middle region of the canal indicating that fewer pulp remnants were found in the middle region.

TABLE 8.14

GRADING FOR PULP REMNANTS

Main Prepared Canal; Whole Sample

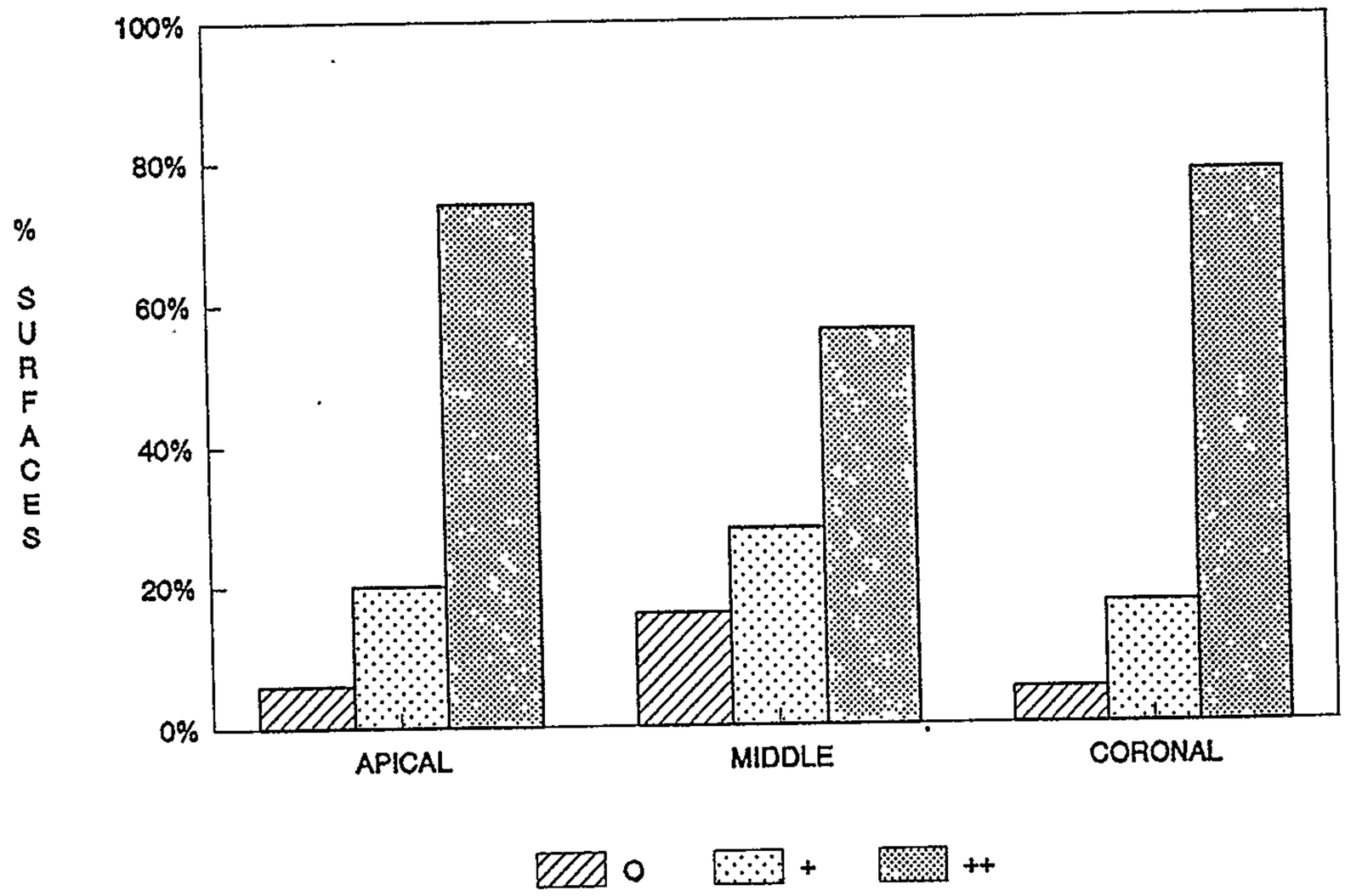
	Actual values				Percentages			
	0	+	++	Total		0	+	++
Apical	11	35	134	180	Apical	6	20	74
Middle	30	53	108	191	Middle	16	28	56
Coronal	9	33	148	190	Coronal	5	17	78
TOTAL	50	121	390					

chi square = 27.71*

CHART 8.14

GRADING FOR PULP REMNANTS

Main Prepared Canal; Whole Sample



Comment. The percentage of 0 scores was highest and the percentage of ++ scores was lowest in the middle region indicating that there was less evidence of pulp remnants in the middle region of the canal.

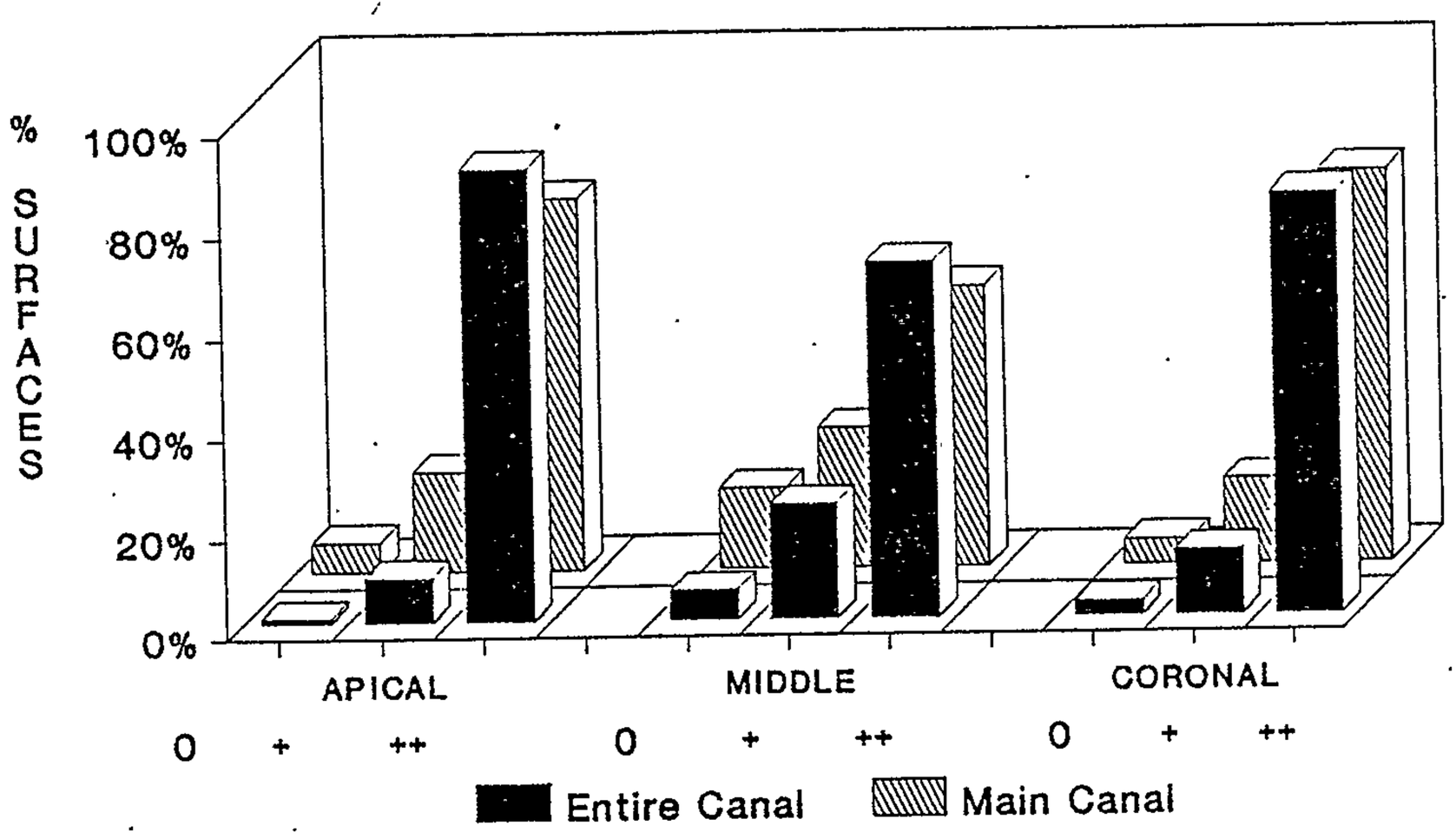
The values shown in Table 8.13 (pulp remnants - entire canal system) were compared with the values in Table 8.14 (pulp remnants - main prepared canal), and the following values for chi square were computed:

Apical - 15.8*;
Middle - 11.6*;
Coronal - 2.4.

CHART 8.14.1

PULP REMNANTS

Entire Canal System cf. Main Prepared Canal



Comment. The percentage of ++ scores in the apical and middle regions is lower, and the percentage of 0 scores is higher when only the main prepared canal was assessed; these differences are significant. There is little difference between the two sets of scores in the coronal region.

TABLE 8.15

GRADING FOR SMEAR LAYER

Whole Sample

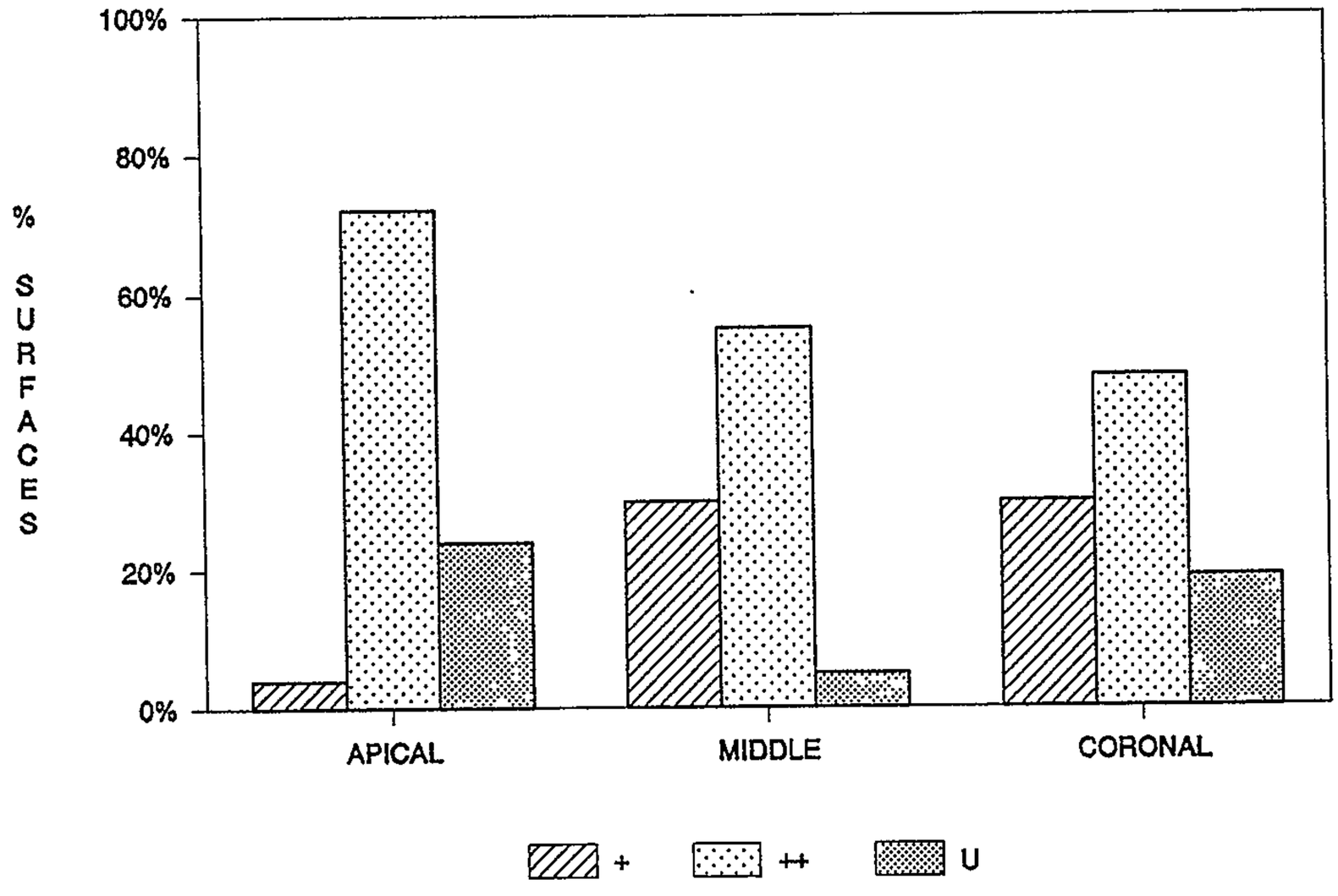
	Actual values					Percentages				
	+	++	U	Total		0	+	++	U	
Apical	7	129	44	180	Apical	0	4	72	24	
Middle	57	105	29	191	Middle	0	30	55	15	*
Coronal	62	91	37	190	Coronal	0	33	48	19	
TOTAL	110	325	110							

chi square = 51.98*

CHART 8.15

GRADING FOR SMEAR LAYER

Whole Sample



Comment. The majority of surfaces were graded ++ indicating that most surfaces of the whole sample of prepared canals displayed extensive evidence of smear layer irrespective of the technique used. The percentage of ++ scores is highest and that of + scores is lowest in the apical region indicating that extensive evidence of smear layer was most frequently observed in the apical region. The percentage of + scores is similar in the middle and coronal regions. The percentage of U scores is highest in the apical and lowest in the middle region.

TABLE 8.16

GRADING FOR INSTRUMENT MARKS

Whole Sample

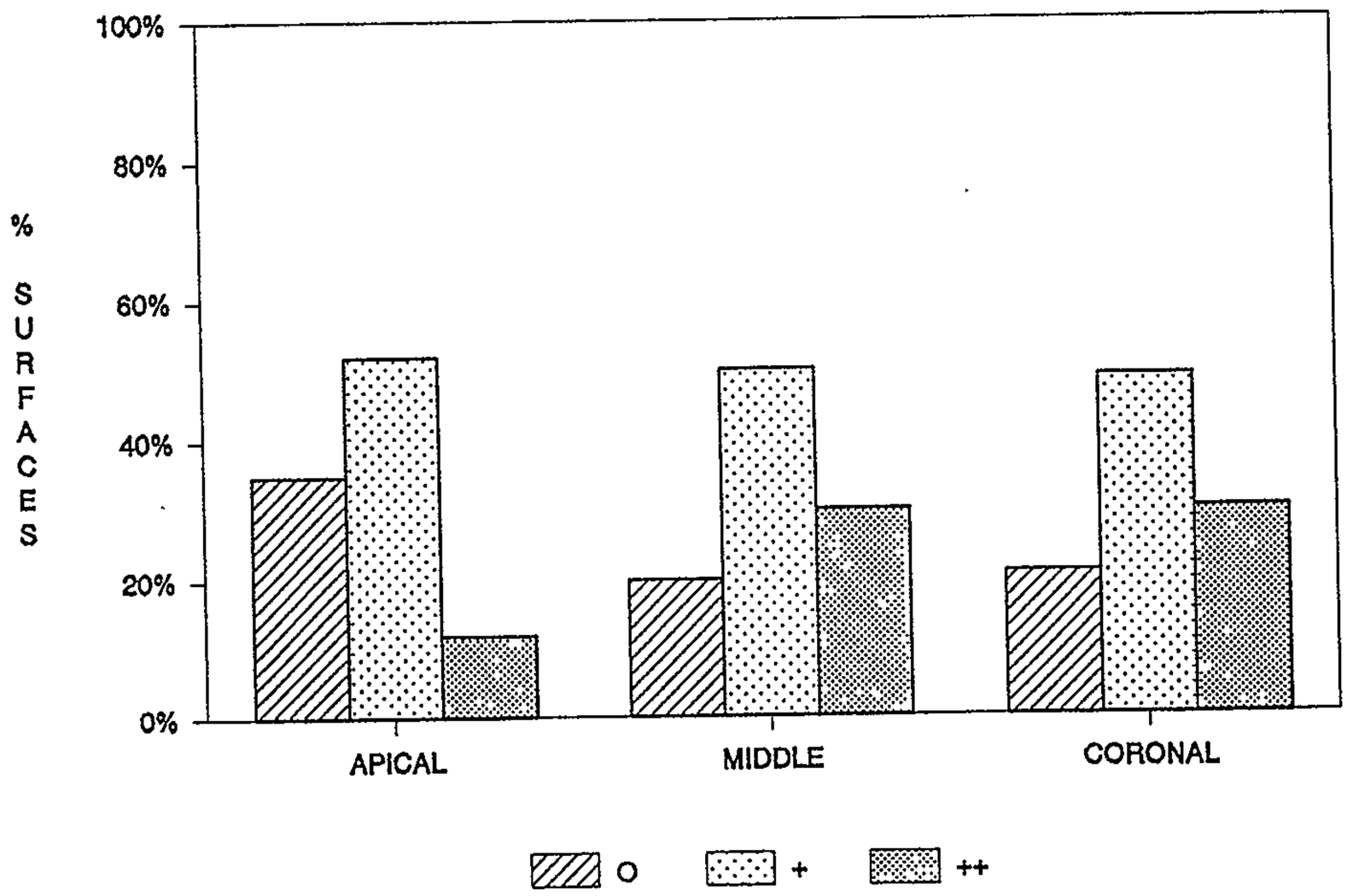
	Actual values					Percentages		
	0	+	++	Total		0	+	++
Apical	64	95	21	180	Apical	35	52	12
Middle	38	95	58	191	Middle	20	50	30
Coronal	40	93	57	190	Coronal	21	49	30
TOTAL	142	283	136					

chi square = 28.64*

CHART 8.16

GRADING FOR INSTRUMENT MARKS

Whole Sample



Comment. Moderate instrument marks (+) occurred most frequently and appeared evenly distributed between apical, middle and coronal regions. The apical region was most frequently ($P<0.05$) devoid of any instrument marks and contained the least number of surfaces with extensive instrument marks (++). There was little difference between the coronal and middle thirds.

8.2.2.1 Wave Pattern

W was recorded for the coronal region in twenty specimens. Four of these specimens were also graded W in the middle region and one was graded W in all three regions of the canal (Fig. 8.43)