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Innervation of the Human Periodontium

II. Fine Structure of Simple Mechanoreceptors

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ABSTRACT—The fine structure of myelinated nerve fibres and of the proximal, central and distal portions of the simple mechanoreceptors are described and discussed.

(*Received for publication April, 1973*)

Introduction

Observations of neural periodontal tissue by light microscopy showed that essentially there were three types of mechanoreceptors.[1] In that report the method of preparation of the material was described.

This paper presents information on the fine structure of simple mechanoreceptors as revealed by electronmicroscopy. Examination of the material showed that proximal, central, and distal regions could be identified and the observations are reported accordingly.

Observations

1. *Proximal region*

The proximal part of simple mechanoreceptors consisted of myelinated nerve fibres (2–4 μm diam.) surrounded by endoneurium and encapsulated. Loose connective tissue surrounded the capsule (Fig. 1, 2). The Schwann cell cytoplasm had a basal lamina intimately associated with collagen fibrils which formed the endoneurium. The capsule consisted, in one instance, of the processes of two capsular cells which made tight or close junctions with each other (Fig. 1); in other instances the capsule was more complex and consisted of cell bodies and processes of three or more capsular cells (Fig. 2).

The nucleus of the capsular cells had one or more nucleoli and a peripheral condensation of chromatin (Fig. 2); the cytoplasm contained rather small mitochondria with regular cristæ, intra-cytoplasmic filaments and some profiles of rough surfaced endoplasmic reticulum (Fig. 2).

The plasma membranes of the capsular cells were associated with an inconstant basal lamina (Fig. 1). The tissue surrounding the capsule and interposed between capsular cells contained very fine collagen fibres approximately 1 μm diameter and extensive areas of afibrillar ground substance.

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[1] Griffin, C. J., and Harris, R.—Innervation of human periodontium I. Classification of periodontal receptors. Austral. D. J., 19 : 1, 51–56 (Feb.) 1974.

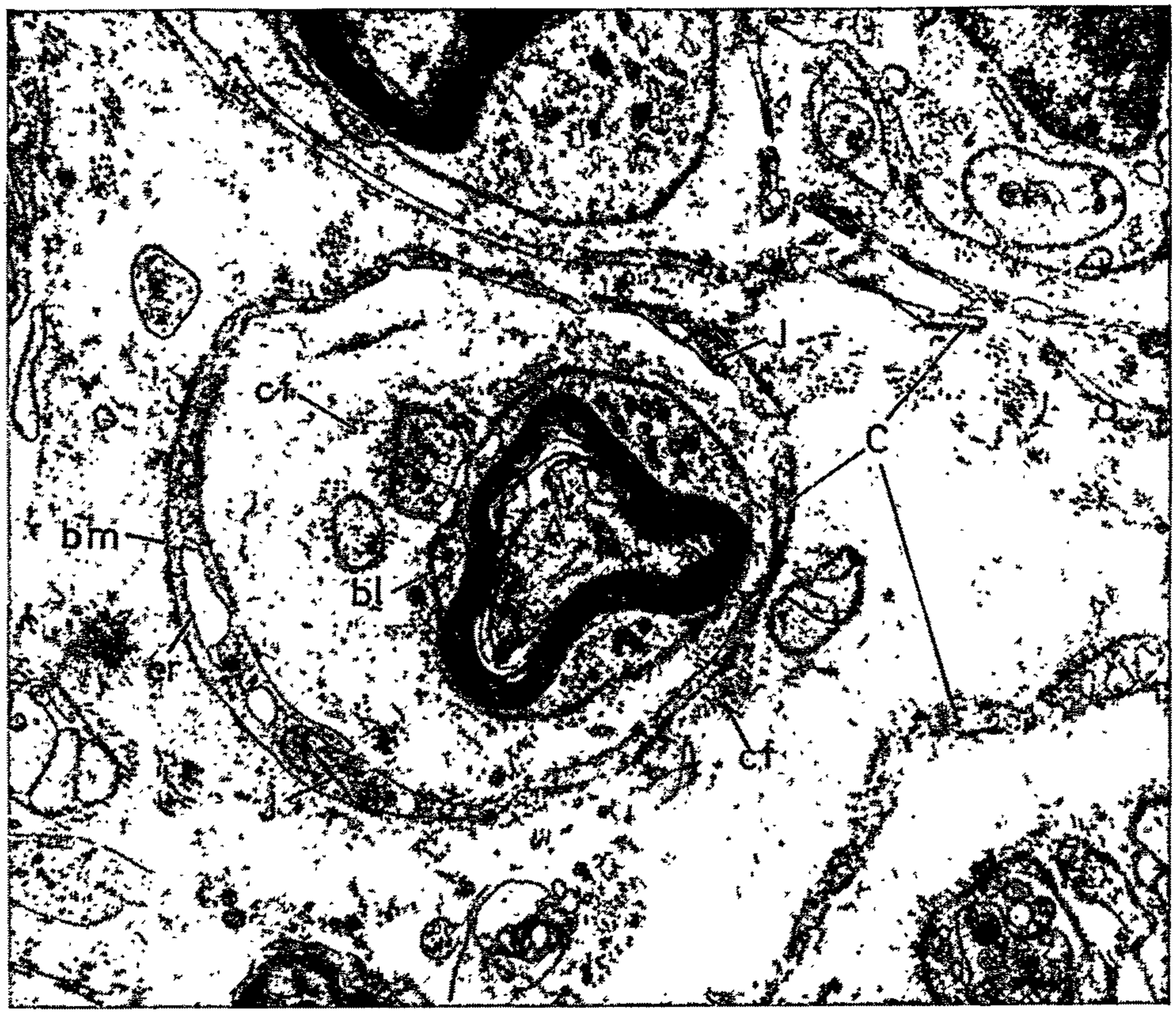

Fig. 1.—Proximal part. A, axon of myelinated nerve fibre ; bl, basal lamina of Schwann cell ; cf, small epineural and endoneural collagen fibre ; C, process of capsular cell ; bm, basal lamina of capsular cell ; j, close junctions of capsular cell ; er, rough surfaced endoplasmic reticulum. ×15,000.

2. *Central region*

The central region contained myelinated nerve fibres and unmyelinated nerve fibres. The myelinated nerve fibre of each receptor was surrounded by Schwann cell cytoplasm and basal laminæ (Fig. 3, 4). In some cases the processes of the capsular cells formed a septum between the myelinated and unmyelinated portions of the complex (Fig. 3, 6). The unmyelinated neural complex consisted of large and small fibres and the axons contained very small mitochondira, neuro-filaments and neuro-fibrils (Fig. 5). Some axons terminated in Schwann cell bays (lacunar endings) whilst others terminated in close proximity to the endoneurium. The Schwann cell cytoplasm enclosed the unmyelinated axons completely, except where the latter terminated as lacunar or exposed endings. However, a basal lamina separated both types of endings from the endoneurium (Fig. 5).

Of particular interest were the components of the Schwann cell lacunæ ; except for the terminal axons no clearly discernible elements were present. The endoneurium consisted of a sparse number of collagen fibres, generally in close proximity to the basal laminæ of Schwann cells.

Ground substance was interposed between the endoneurium and the capsule of the simple mechanoreceptors (Fig. 3–6). The capsule consisted of one or more capsular cells separated from each other by relatively afibillar ground substance.

3. *Distal region*

The receptor shown in Fig. 6 was traced distally in serial sections. The myelinated nerve fibre of the receptor terminated as an unmyelinated nerve

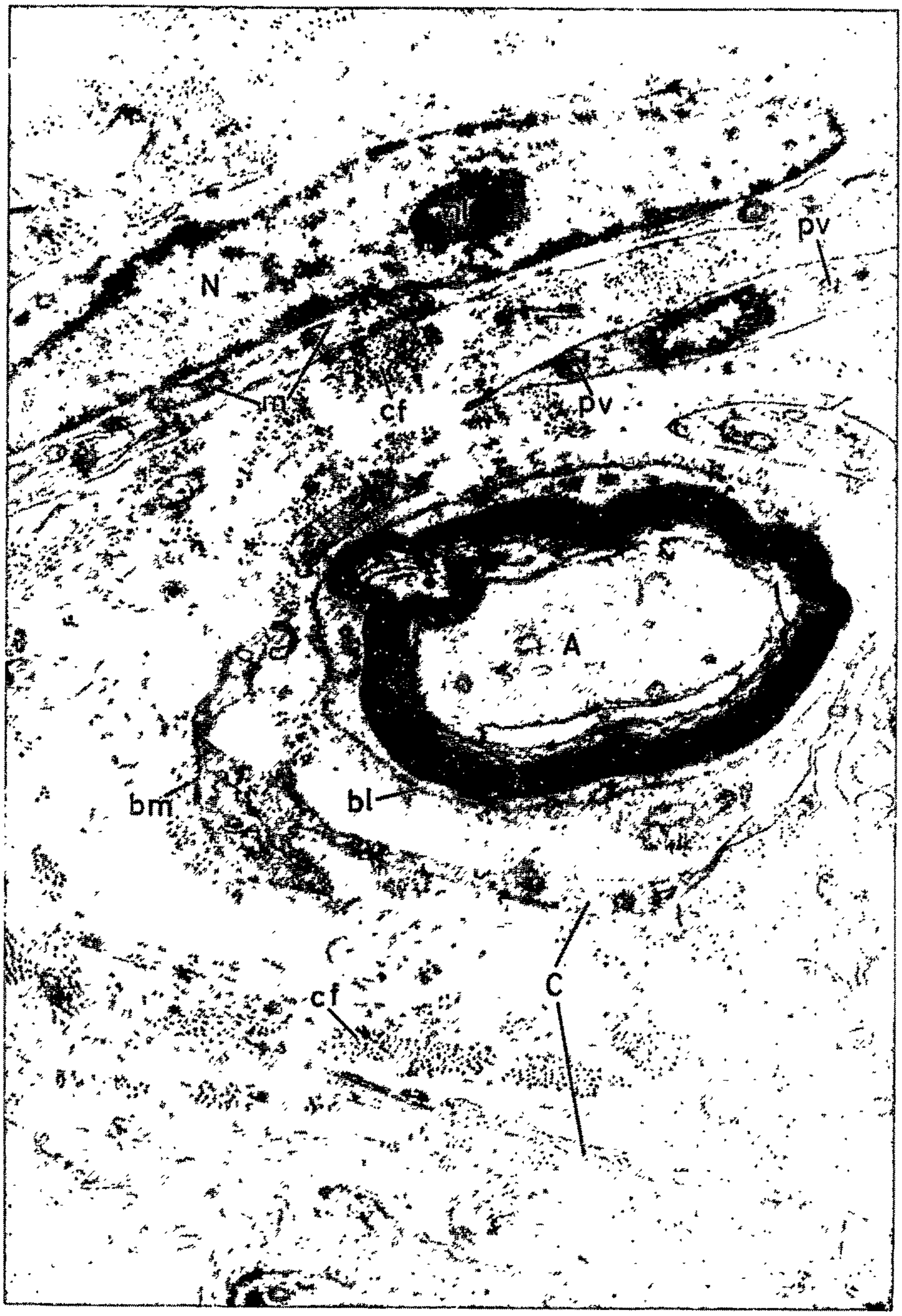

Fig. 2.—Proximal part. A, axon of myelinated nerve fibre ; bl, basal lamina of Schwann cell ; cf, small epineural and endoneural collagen fibre : N, nl, nucleus and nucleoli of capsular cell ; C, process of capsular cell ; bm, basal lamina of capsular cell ; pv, pynocytotic vesicles ; m, small mitochondria. ×15,000.

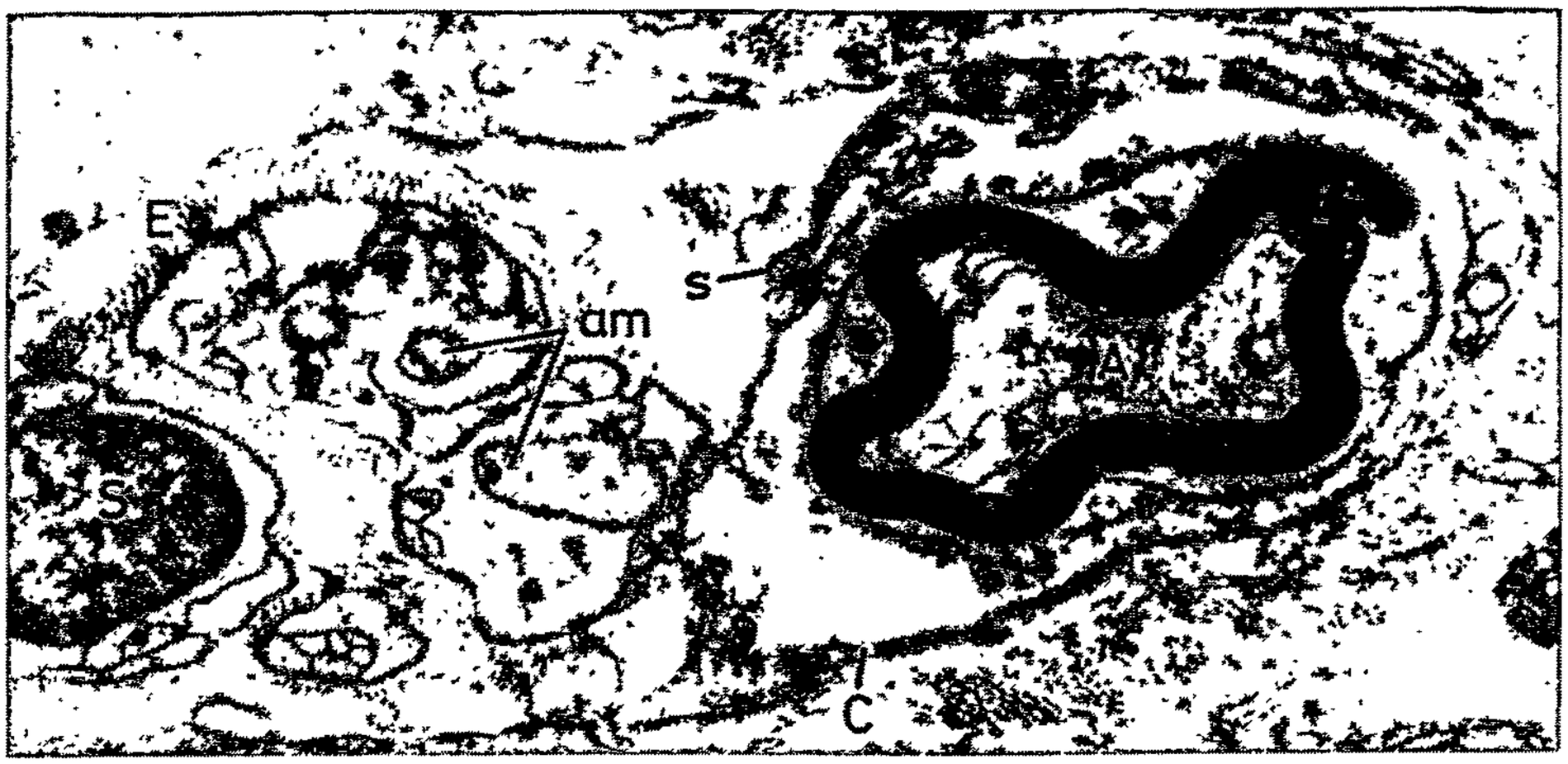

Fig. 3.—Central part. A, axon of myelinated nerve fibre; E, endoneurium; am, unmyelinated nerve fibre; C, process of capsular cell; s, septum separating myelinated from the unmyelinated nerve fibre of the neural complex; S, Schwann cell. ×10,000.

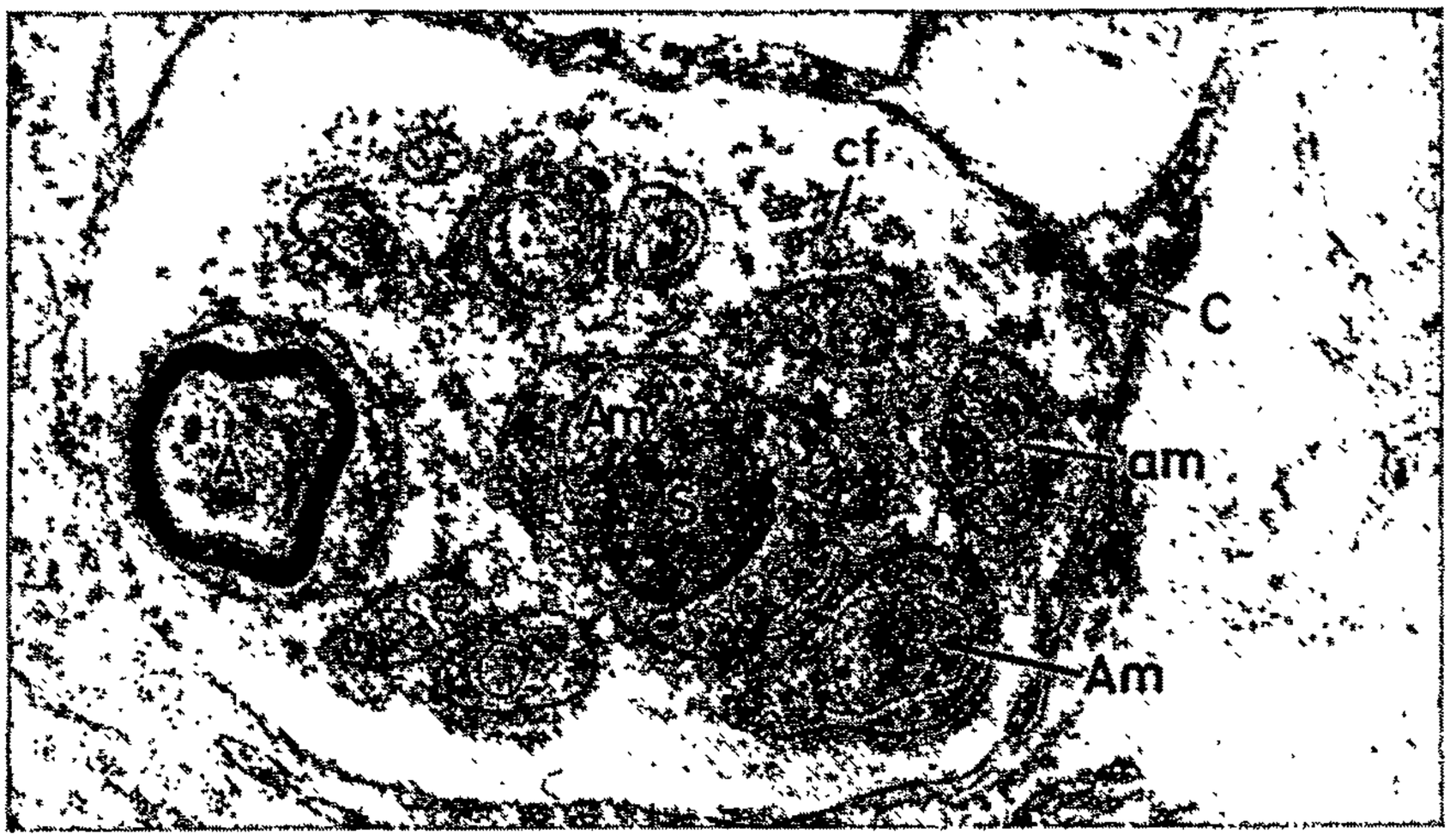

Fig. 4.—Central part. A, axon of myelinated nerve fibre; am, unmyelinated nerve fibre; C, process of capsular cell; cf, collagen fibre; S, Schwann cell; Am, large unmyelinated nerve fibre. ×7,500.

fibre (Fig. 7). The cell body of the capsular cell formed a septum separating the neural elements from each other. The unmyelinated axons derived from the myelinated axon were conspicuous for the number of mitochondria in the cytoplasm. The diameter of these large unmyelinated axons lay in the range 1–3 μm (Fig. 7, 8).

The neural complex further distally consisted of large and small unmyelinated nerve fibres surrounded by Schwann cell cytoplasm or exposed to the endoneurium. Some of the small exposed axons contained synaptic-like vesicles and small mitochondria. The intra- and extra-capsular substance was relatively afibrillar (Fig. 9). More distally the axons divided into smaller unmyelinated axons to form both lacunar and exposed nerve endings. Usually the cell bodies of the capsular cells were most conspicuous at the distal extremity. Endoneural collagen fibres were seen to lie parallel to the long axis of the unmyelinated axons.

Fig. 5.—Detail of unmyelinated nerve fibres of central part. S, cytoplasm of Schwann cell; am, small axon; m, small mitochondria; Le, lacunar nerve endings; sv, synaptic-like vesicles; bl, basal lamina; E, endoneurium; C, process of capsular cell; t, neuro tubules. ×40,000.

Fig. 6.—A, axon of myelinated nerve fibre; S, Schwann cell cytoplasm; bl, basal lamina of Schwann cell; am, unmyelinated nerve fibre; E, endoneurium; C, process of capsular cell. ×15,000.

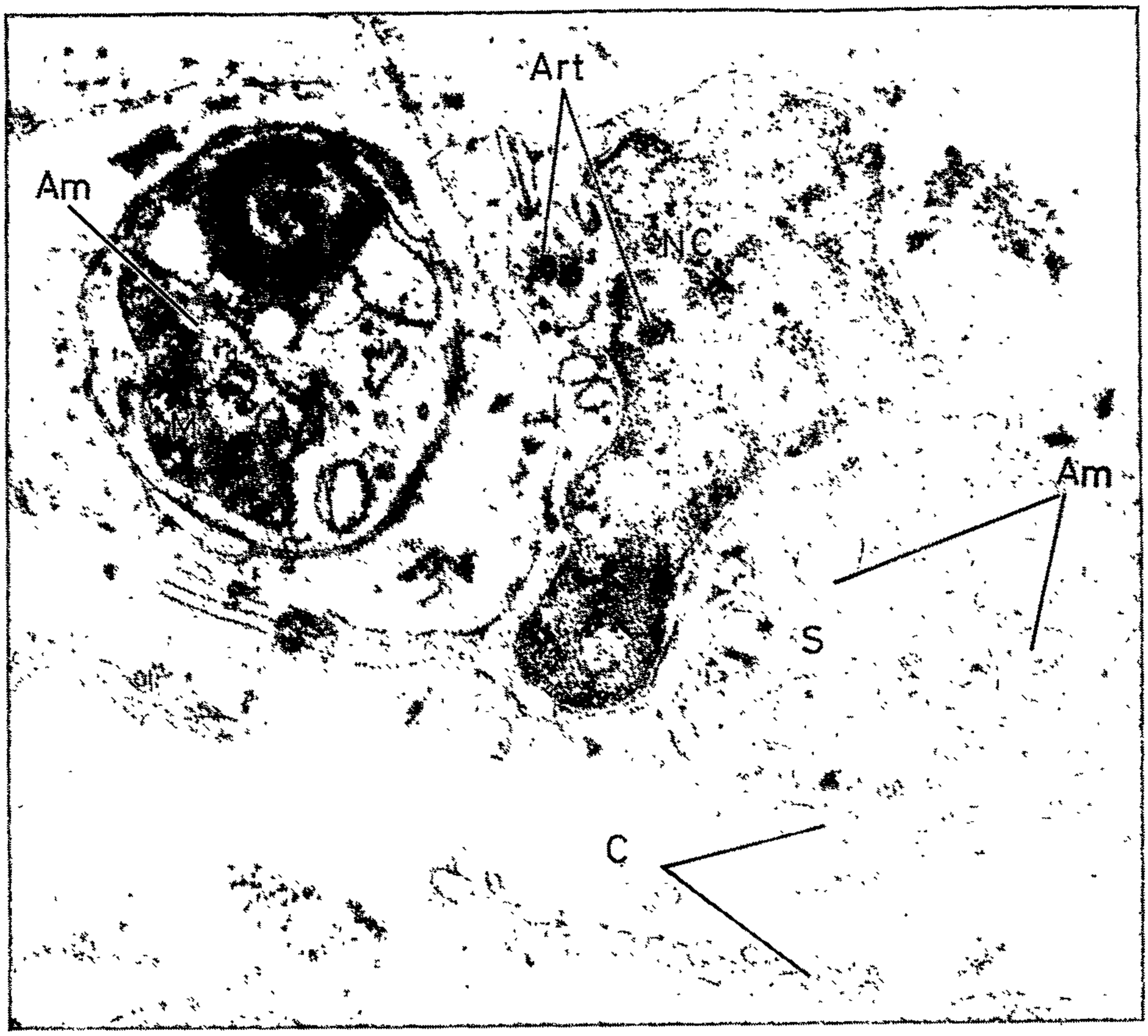

Fig. 7.—Distal part of simple mechanoreceptor shown in Fig. 6. NC, nucleus of capsular; Am, unmyelinated nerve fibres; S, cytoplasm of Schwann cell; M, mitochondrial cluster; C, process of capsular cell (Art, artefact). ×15,000.

Discussion

The simple mechanoreceptors described herein occur either in pairs or singly and presumably correspond to the end knobs described in human periodontium by Lewinsky and Stewart.[2] [3]

The receptors are derived from myelinated nerve fibres 2–3 μm in diameter, but since their velocity of conduction after appropriate stimulation is 24–80 m/sec the parent fibre, utilizing the Hursh factor[4], would have a diameter in the range of 6–12 μm.

The myelinated nerve fibre after entering the capsule retains its myelin sheath for the major part of its course and only loses its myelin as it reaches the distal regions of the receptors. It then divides into numerous unmyelinated nerve fibres which are distributed throughout the entire neural complex. Usually the myelinated nerve fibre of the complex is separated from the unmyelinated part by septa of capsular cells.

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[2] Lewinsky, W., and Stewart, D.—The innervation of the periodontal membrane. Jnl. Anat., 17: 1, 98–101 (Oct.) 1937.

[3] Lewinsky, W., and Stewart, D.—The innervation of the periodontal membrane of the cat with some observations on the functions of end organs found in that structure. Jnl. Anat., 71: 2, 232–235 (Jan.) 1938.

[4] Hannam, A. G.—The conduction velocity of nerve impulses from dental mechanoreceptors in the dog. Arch. Oral Biol., 13: 11, 1377–1383 (Nov.) 1968.

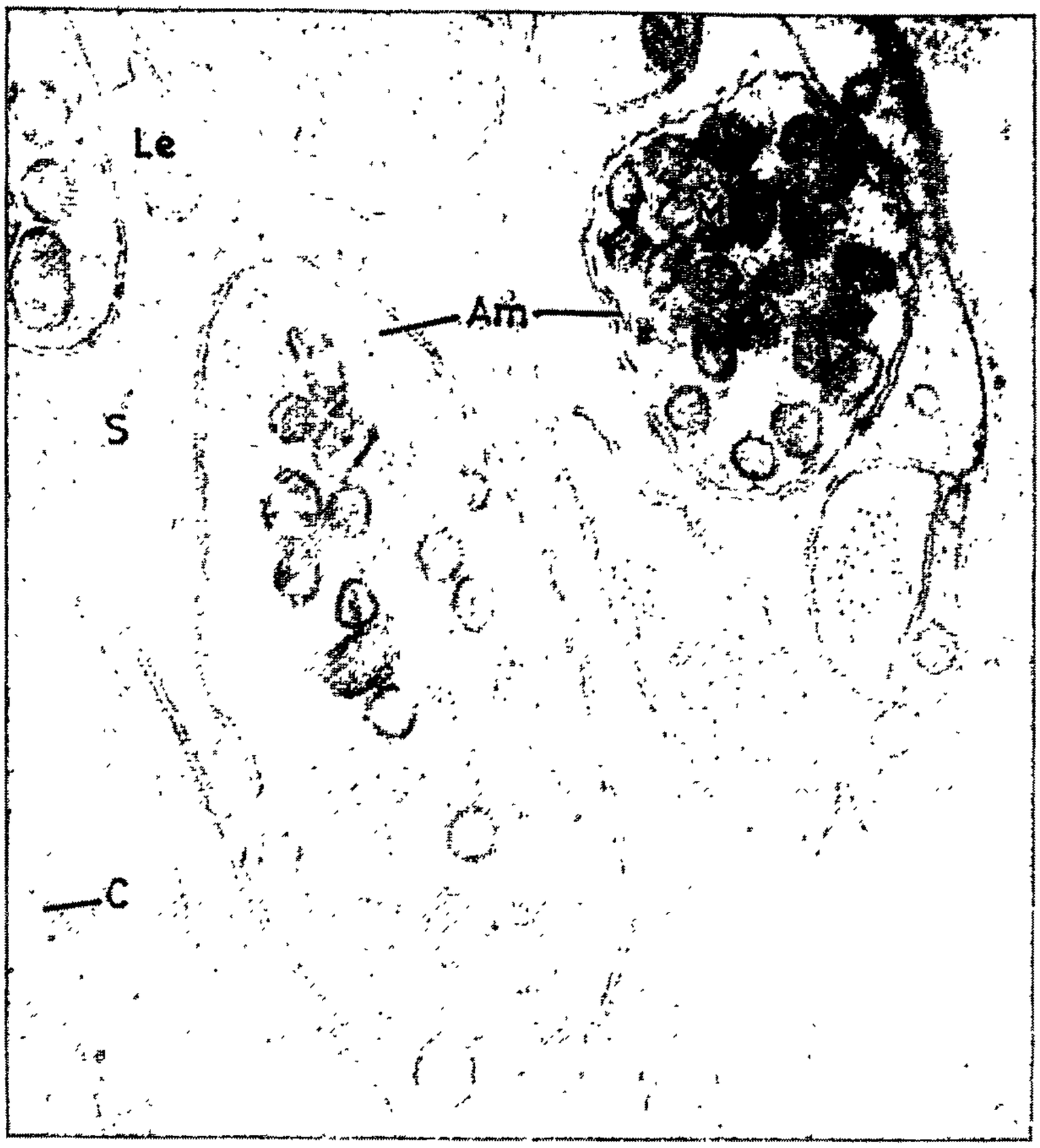

Fig. 8.—Detail of distal part. Am, unmyelinated axon; M, mitochondrial cluster; Le, lacunar nerve endings; S, Schwann cell cytoplasm; C, process of capsular cell. ×40,000.

The nerve endings in the complex contain synaptic-like vesicles, small mitochondria and neuro-tubules characteristic of nerve endings described elsewhere.[5] These synaptic-like vesicles have been noted in all nerve endings so far described.[6] [7] [8] [9]

Usually they are surrounded by afibrillar ground substance and for this reason could be classified as viscous receptors.[10] The receptor encapsulation at times was quite complex and consisted of three or more capsular cells. Because of this and because of the afibrillar ground substance these units would be rapidly adapting in as much as they could move away from an applied force. Harman[4] used physiological techniques and found periodontal mechanoreceptors to be either rapidly or slowly adapting or to discharge spontaneously. Most

[5] Biscoe, T. T., and Stephens, W. E.—Ultrastructure of the carotid body. Jnl. Cell. Biol., 30: 3, 563–578 (Sept.) 1966.

[6] Cauna, N., and Ross, L. L.—The fine structure of Meissner's touch corpuscles of human fingers. J. Biopnys. Biochem. Cytol., 8: 10, 467–482 (Oct.) 1960.

[7] Munger, B. L.—The intraepidermal innervation of the snout skin of the opossum. A light and electron microscopic study, with observations on the nature of Merkels Tastzellen. Jnl. Cell. Biol., 26: 1, 79–97 (Jan.) 1965.

[8] Griffin, C. J., and Harris, R.—Unmyelinated nerve endings in the periodontal membrane of human teeth. Arch. Oral Biol., 13: 10, 1207–1212 (Oct.) 1968.

[9] Griffin, C. J., and Spain, Helen—The fine structure of periodontal nerve plexuses in man. *In*, A symposium on the maxillo-mandibular apparatus. Proc. Int. Anat. Congr., Lenningrad, 1970. In press.

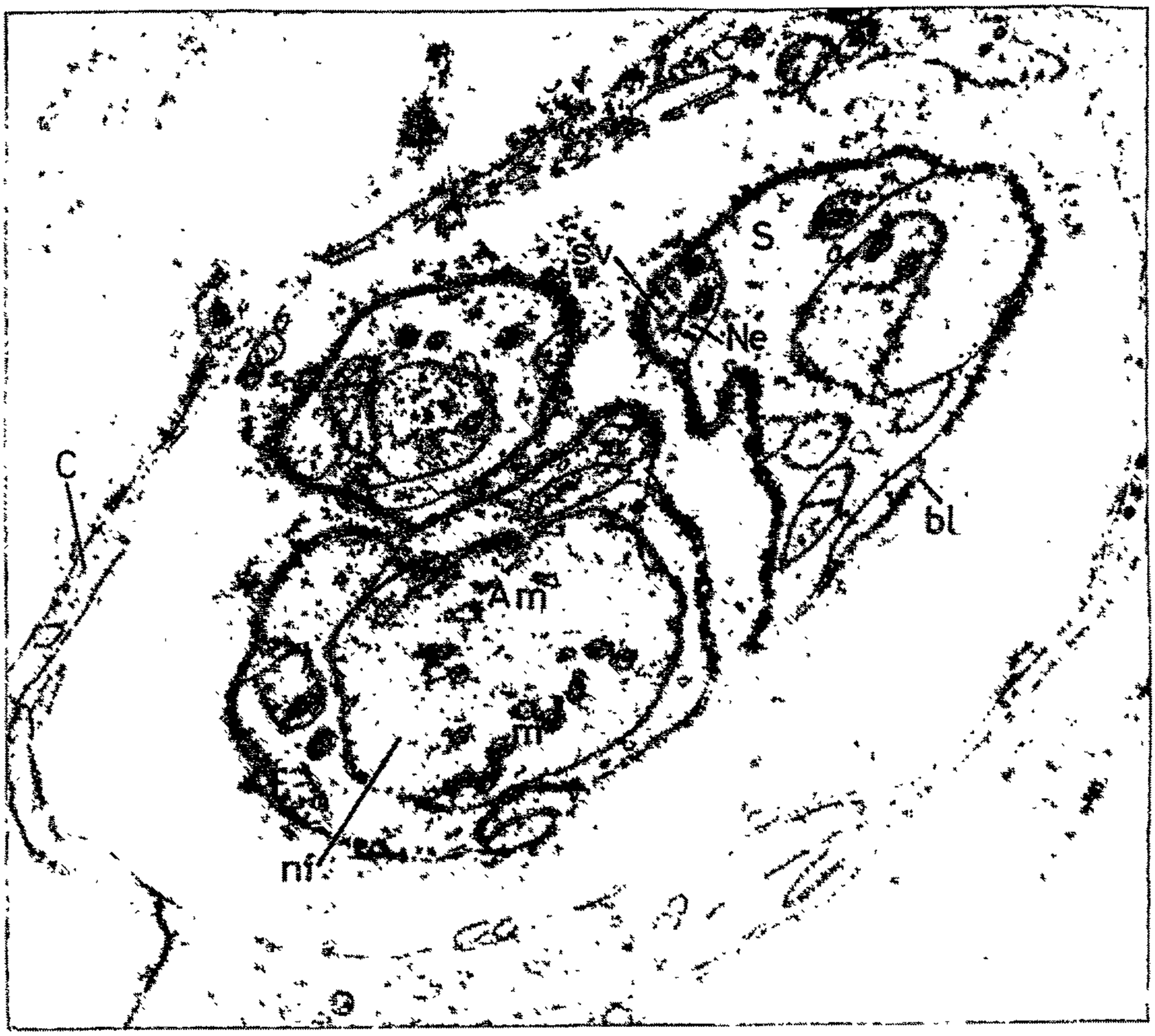

Fig. 9.—Am, unmyelinated nerve fibre; nf, neuro filaments; S, Schwann cell cytoplasm; bl, basal lamina; Ne, nerve endings; sv, synaptic-like vesicles; C, process of capsular cell; m, mitochondria. Note the loose nature of the endoneurium and surrounding ground substance. ×15,000.

authors[11] [12] [13] [14] [15] [16] agree that there is a preferred direction for the application of force to the tooth which produces the greatest response.

The lacunar endings are of particular interest. They are surrounded by Schwann cell cytoplasm and separated from the endoneural tissue by ground substance and basal lamina. Their mode of excitation would seem to be quite complex since pressure would have to be transferred through the capsular cell complex, the endoneural space and finally to the Schwann cell cytoplasm.

Nevertheless, these units have a relatively low threshold reacting to forces of 4 gm.[13] The reflexes elicited from the receptors will be discussed later in this series of papers.

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Sydney, N.S.W., 2006.

[10] Catton, W. T., and Petoe, N.—A visco-elastic theory of merchanoreceptor adaptation. J. Physiol. (Lond.), 187 : 1, 35–49 (Jan.) 1967.
[11] Pfaffmann, C.—Afferent impulses from the teeth due to pressure and noxious stimuli. J. Physiol. (Lond.), 97 : 2, 501–515 (Dec.) 1965.
[12] Kruger, L., and Michel, F.—A single neurone analysis of the buccal cavity representation in the sensory trigeminal complex. Arch. Oral Biol., 7 : 4, 157–178 (July/Aug.) 1962.
[13] Jerge, C. R.—Organization and function of the trigeminal mesencephalic nucleus. J. Neurophys., 26 : 3, 379–392 (May) 1963.
[14] Kawamura, Y., and Nishiyama, T.—Projection of dental afferents to the trigeminal nuclei of the cat. Jap. J. Physiol., 16 : 584–597, 1966.
[15] Ness, A. R.—The mechanoreceptors of the rabbit mandibular incisors. J. Physiol. (Lond.), 126 : 3, 475–493 (Dec.) 1954.
[16] Hannam, A. G.—The response of periodontal mechanoreceptors in the dog to controlled loading of the teeth. Archs. Oral Biol., 14 : 7, 781–791 (July) 1969.

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Innervation of the human periodontium
III. Fine structure of compound receptor

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Innervation of the human periodontium III. Fine structure of compound receptor

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ABSTRACT—The fine structure of the proximal and distal portions of the compound receptors and the origin of end rings and the complex encapsulation of the compound receptors has been described. The nerve endings in the end rings of the distal portions consist of exposed and lacunar endings.

(*Received for publication April, 1973*)

Light microscopy of the compound receptor showed that it was derived from a myelinated nerve which divided into three or more branches. The branches lost their myelin sheaths in a staggered fashion and formed end rings consisting of unmyelinated nerve fibres embracing an adjacent myelinated nerve fibre[1]. This is represented in the diagram in Fig. 1.

This presentation shows the myelinated nerve fibres as losing their myelin sheaths and continuing as unmyelinated nerve fibres encircling adjacent myelinated nerve fibres and terminating in either exposed endings or lacunar endings. The unmyelinated nerve fibre retains its Schwann cell which is covered by a basal lamina. The neural complex is encapsulated and collagen fibres lie parallel to the long axis of the myelinated nerve fibres. The present paper is concerned with the fine structure of these receptors and shows the arrangements in the proximal and distal regions.

The method of collecting and examining the material has been reported in the first paper of this series.

Observations

1. *Proximal region*

The proximal region of the compound receptor consists of three or more myelinated and numerous unmyelinated nerve fibres surrounded by the processes of capsular cells (Fig. 2). The unmyelinated nerve fibres were seen to encircle one of the myelinated nerve fibres to form an end ring. Capsular cell bodies and processes formed septa

[1] Griffin, C. J., and Harris, R.—Innervation of the human periodontium I. Austral. D. J., 19 : 1, 51–56 (Feb.) 1974.

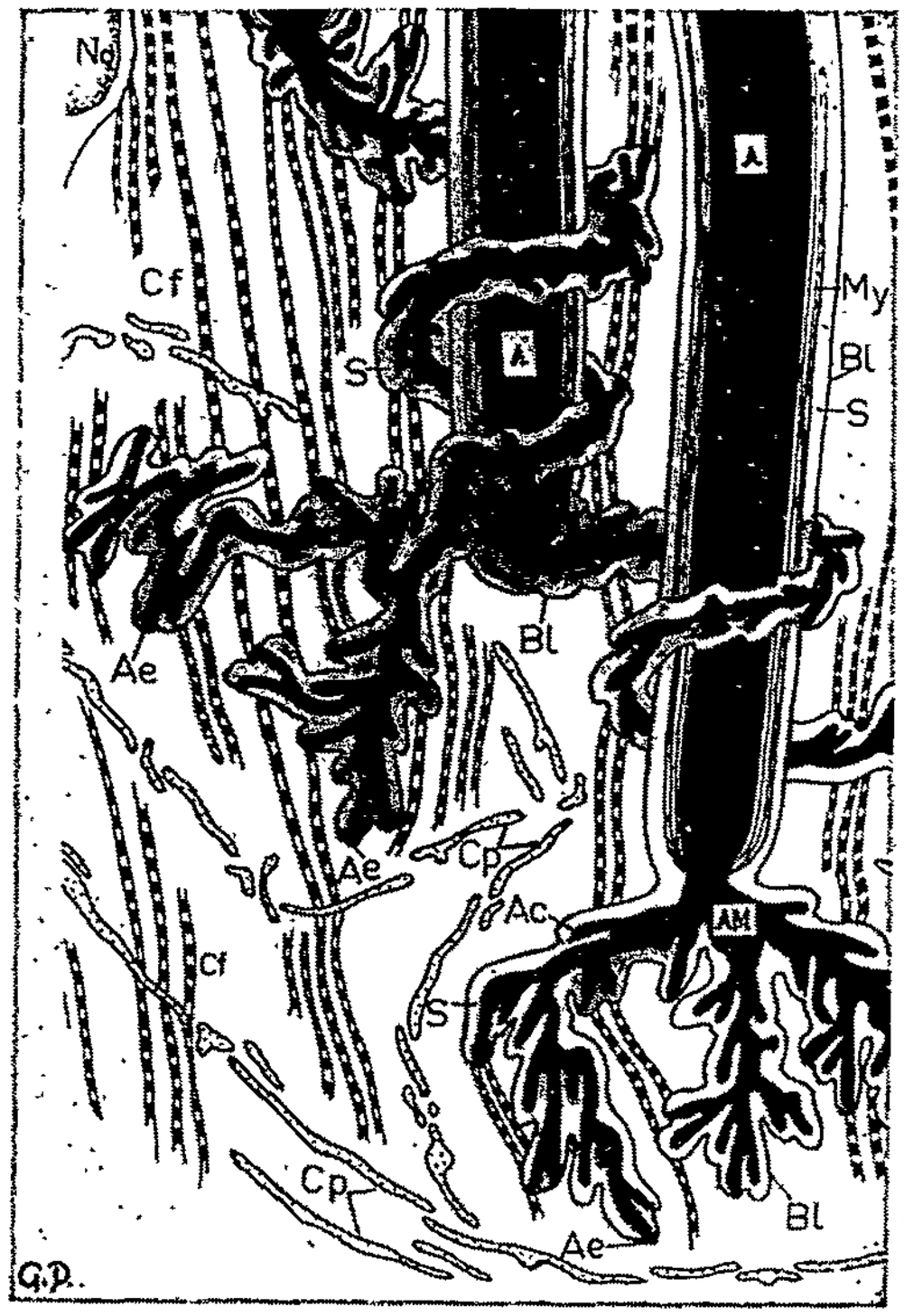

Fig. 1.—Schematic presentation of the compound receptor. A, myelinated nerve fibre ; My, myelin sheath ; S, Schwann cell cytoplasm ; Ae, exposed endings ; Ac, lacunar endings ; Cp, processes of capsular cells ; Bl, basal lamina ; Cf, collagen fibrils.

separating portions of the neural complex which was itself separated from its capsule by somewhat extensive amounts of ground substance. Endoneural collagen fibres were sparse and orientated generally parallel to the axons of the unmyelinated fibres.

Figure 3 shows that the end rings originate from large unmyelinated nerve fibres which pursue a spiral course as they divide into numerous small branches. The end ring was separated from the central myelinated nerve fibre by a few fine collagen fibres and ground substance. The diameter of the large unmyelinated nerve fibre from which the end ring originated was approximately 1·5 μm which is similar to that of the axons of the myelinated nerve fibres (Fig. 3).

Isolated compound receptors were seen to have a complex encapsulation consisting of the processes of three or more capsular cells. Interposed between the capsular cells was a large amount of afibrillar ground substance and fine collagen fibres lying parallel to the long axis of the myelinated nerve fibres. Unmyelinated nerve fibres enclosed in Schwann cell cytoplasm encircled the myelinated axons (Fig. 4).

2. *Distal region*

The distal portion of the complex was composed entirely of large and small unmyelinated nerve fibres surrounded by Schwann cell cytoplasm (Fig. 5). Endoneural collagen fibrils lay in close apposition with the basal laminae of the plasma membranes of the Schwann cells. Extensive ground substance surrounding the complex and separating it from its capsule was largely afibrillar. The capsule consisted of cell bodies and their processes.

Nerve endings in the end rings consisted of exposed endings and lacunar endings. Both types of endings contained elements common to sensory endings, *viz.* small mitochondria, neurotubules and

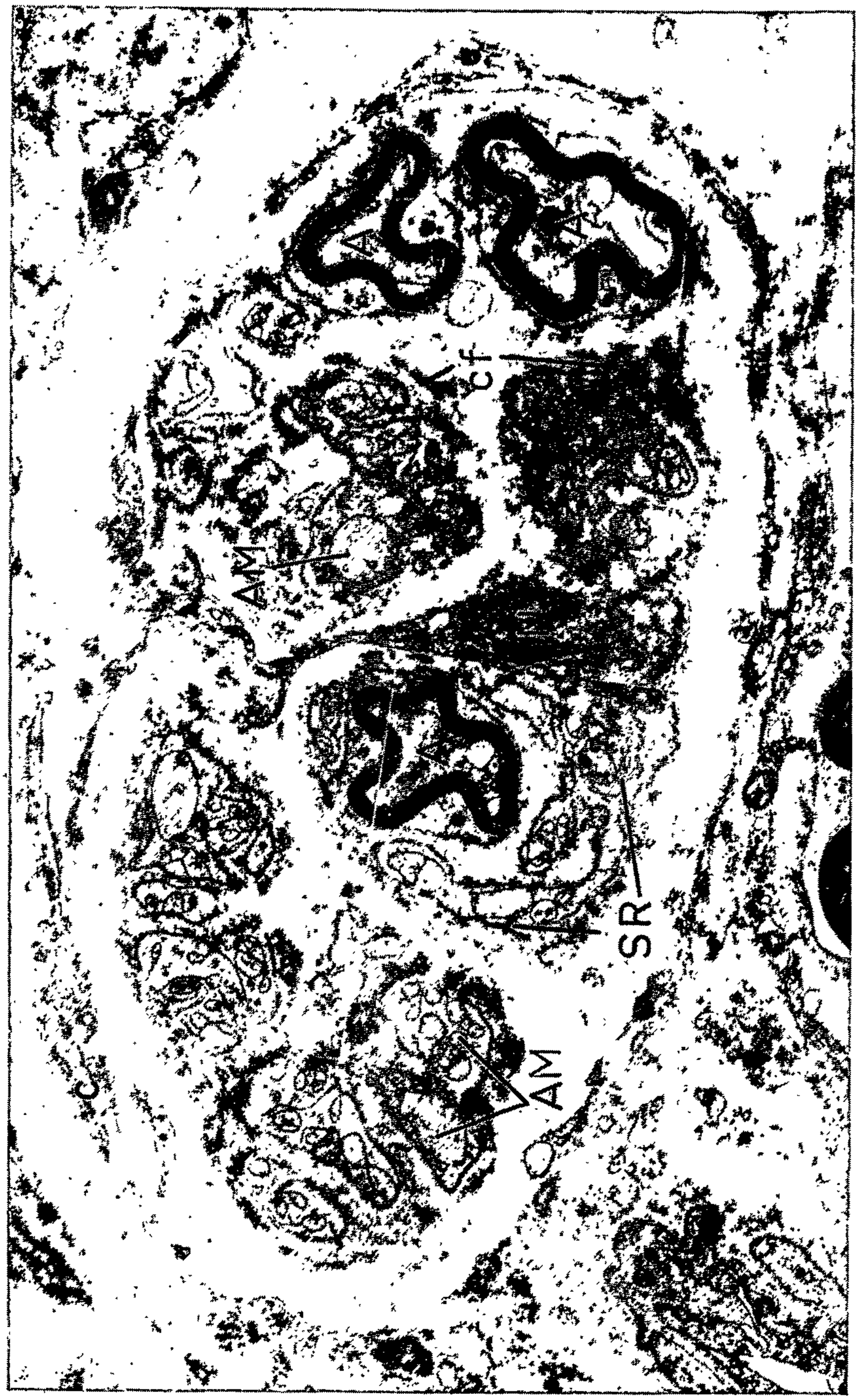

Fig. 2.—Montage of proximal region of a compound receptor. A, myelinated axons; AM, unmyelinated axons SR, end ring; N, nucleus of capsular cell c, capsule cf, collagen fibres. ×6,000.

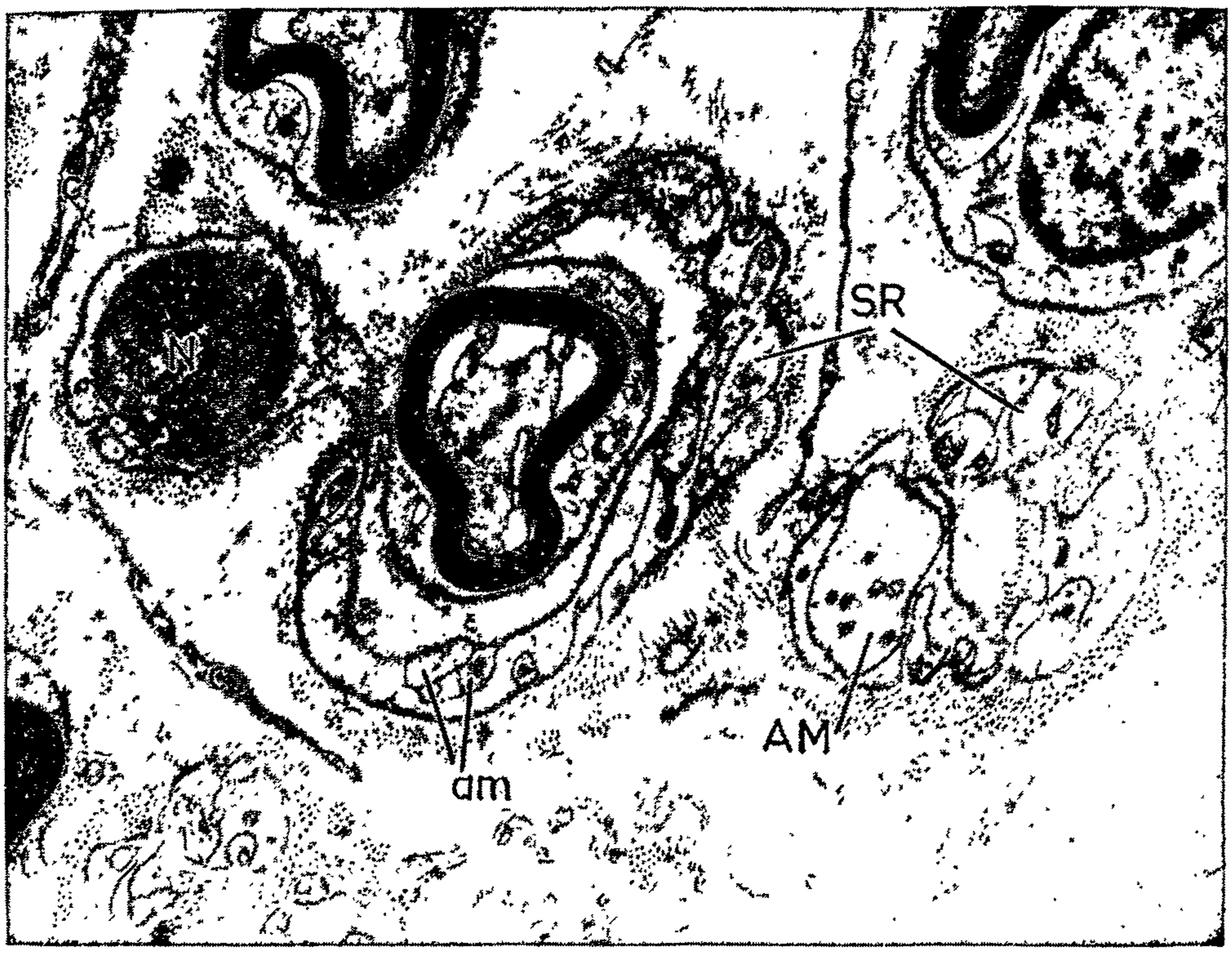

Fig. 3.—Detail of end ring formation. AM, large unmyelinated nerve fibre; SR, end rings; N, nucleus of Schwann cell; c, capsular cell process; am, small unmyelinated nerve fibres. ×12,000.

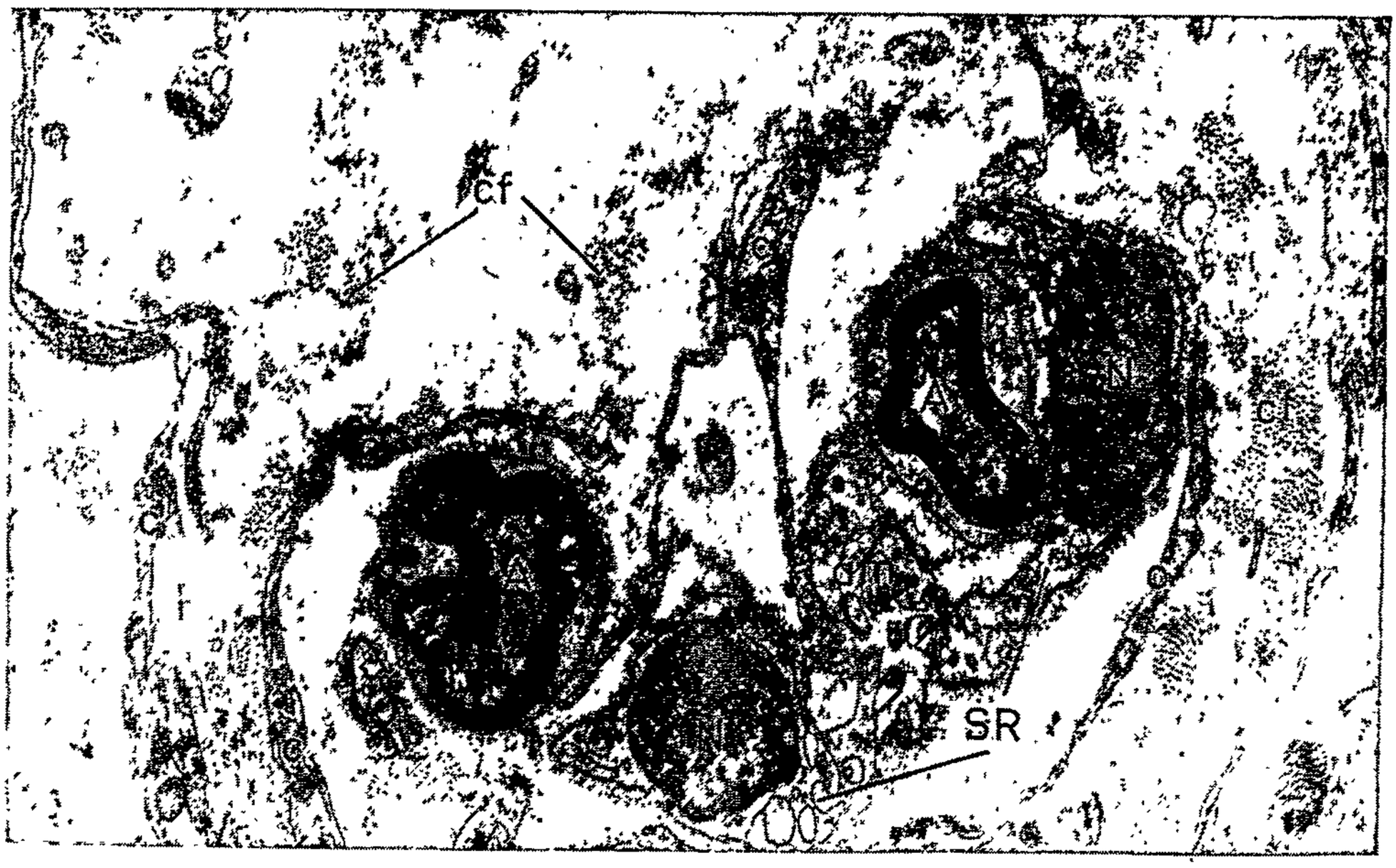

Fig. 4.—Detail of isolated compound receptor. A, myelinated axons; N, nucleus of Schwann cell; SR, end rings am, small unmyelinated nerve fibre; cf, collagen fibres; c, processes of capsular cells. ×15,000.

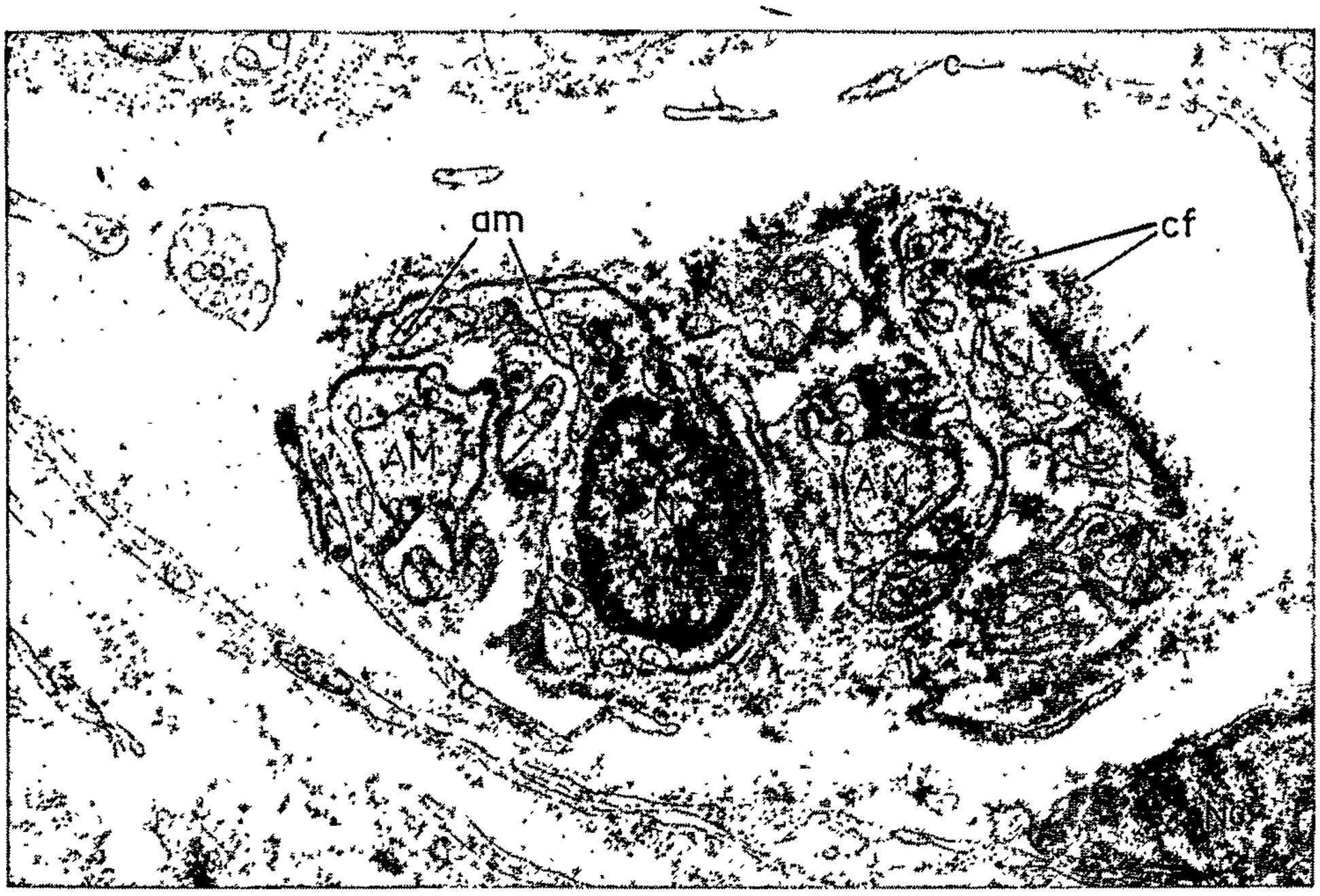

Fig. 5.—Terminal region of compound receptor. N, nucleus of Schwann cell; AM, large unmyelinated nerve fibres; am, small terminal unmyelinated nerve fibres; NC, nucleus of capsular cell; c, process of capsular cells; cf, collagen fibres. ×15,000.

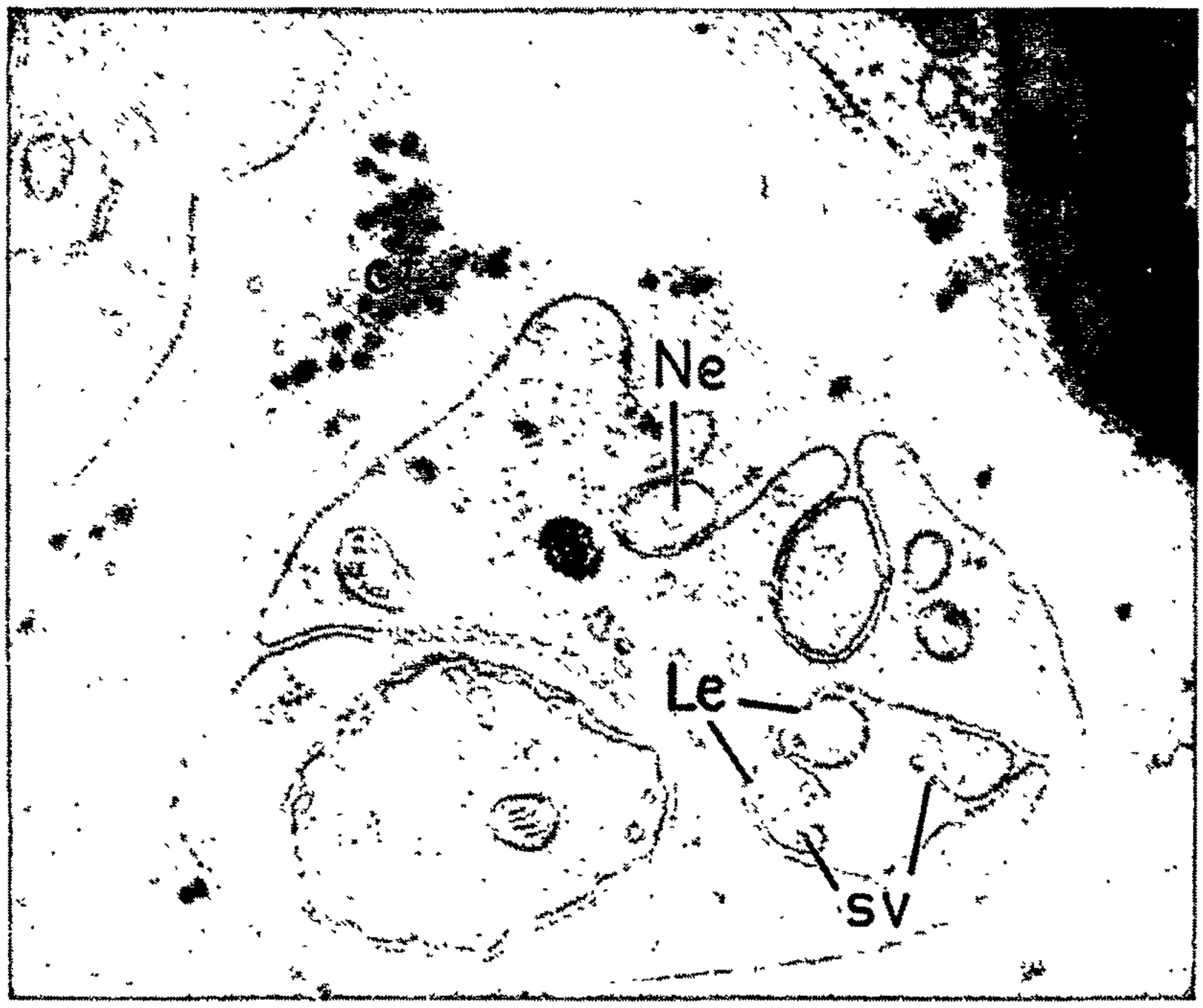

Fig. 6.—Detail of nerve ending and end rings. Ne, exposed nerve endings; Le, lacunar endings; SV, synaptic like vesicles; cf, collagen fibres; My, myelin sheath of nerve fibre. ×45,000.

neurofilaments, and synaptic-like vesicles. Some of these vesicles were contained in the minute axons of the lacunar endings and others were seen in the lacunae. Collagen fibres were orientated parallel to the long axis of the unmyelinated nerve fibres of the end rings (Fig. 6).

Discussion

The structure of the compound mechanoreceptors suggest that they would be extremely susceptible to tension changes in the periodontal ligament. In a sense they resemble the stretch receptor (muscle spindle) in skeletal muscle. In the muscle spindle the 1A afferent ending pursues a spiral course around the intrafusal muscle fibres of the spindle—the so-called annulo-spiral ending. In the periodontal ligament the afferent ending pursues a spiral course around adjacent myelinated nerve fibres and collagen fibres. In the muscle spindle, stretch of extra-fusal fibres excite the nerve endings, whereas in the periodontal ligament receptor stretch of collagen fibres or myelinated nerve fibres presumably would stimulate the receptor.

Just as the muscle spindle is surrounded by extrafusal muscle fibres and contains in its capsule intrafusal muscle fibre the periodontal ligament receptor in a similar way contains intraneural collagen fibres and extracapsular collagen fibres. Physiological investigations by Hannan[2] [3] show that there are slowly adapting periodontal units, the so-called elastic receptors described by Catton and Petoe[4]. The feature of the slowly adapting unit is that it is bound to the tissue and therefore cannot readily slip out of the way of a distorting force. Consideration of the structure of the periodontal compound receptor indicates that it could move within the intracapsular ground substance and this subsequently adapts to a distorting force. Of particular interest in the lacunar endings are the extra-cellular synaptic-like vesicles in the lacunae ; it is possible that they could be transverse sections of the terminal part of these minute axons or extra-cellular vesicles. However, in either case their presence suggests a mechanism for the mode of excitation of these mechanoreceptors. A disturbing force could displace these vesicles either into the lacunae or cause them to discharge their contents into the lacunae. These vesicles are said to contain the transmitter substance which is available to excite adjacent axons in the lacunae—an axo-axonic synapse.

Acknowledgement

Grateful acknowledgement is made to Dr Helen Spain for the montage (Fig. 2) and to Mrs. Gay Dadaur for the drawing of Fig. 1.

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[2] Hannam, A. G.—The response of periodontal mechanoreceptors in the dog to controlled loading of the teeth. Arch. Oral Biol., 14 : 7, 781–791 (July), 1969.

[3] Hannam, A. G.—Spontaneous activity in dental mechanosensitive units in the dog. Arch. Oral Biol., 14 : 7, 793–801 (July), 1969.

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Innervation of the human periodontium. IV.

Fine structure of the complex mechanoreceptors and free nerve endings

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Innervation of the human periodontium. IV. Fine structure of the complex mechanoreceptors and free nerve endings

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ABSTRACT—The complex consists of encapsulated nerve fibres and end rings, exposed and lacunar endings, and a metarteriole. The myelinated nerve fibre and metarteriole are closely associated in the capsule.

(Received for publication May 1973)

Our examination of the periodontal nerve plexuses (Part I) disclosed that when the main periodontal nerve trunk was followed in serial sections it terminated as a large encapsulated neural complex (Fig. 1a).

The fine structure of this nerve complex obtained from material prepared and reported previously[1] will be described and discussed in this paper.

Observations

The neural complex consisted of myelinated and unmyelinated nerve fibres and some of the unmyelinated nerve fibres formed end rings around the myelinated fibres (Fig. 1b, 2).

What appeared to be the distal portion of an end ring complex consisted of numerous myelinated nerve fibres (Fig. 2). Each neural complex was separated by the fine processes of capsular cells (primary capsule) and the entire complex was surrounded by a secondary cellular capsule (Fig. 1a, 2).

Exposed nerve endings and lacunar endings as described in Part III were seen (Fig. 1b, 2). The complex received its blood supply from a metarteriole (Fig. 1b) which terminated in a capillary complex (Fig. 3). Along its course the metarteriole became encapsulated (Fig. 4). The discrete encapsulation consisted of very fine processes of the capsular cells which not only enclosed the metarteriole but also included the myelinated nerve fibres. Exposed nerve endings were also present (Fig. 4).

Free nerve endings were seen located peripherally to the encapsulated neural complex and they

[1] Griffin, C. J., and Harris, R.—Innervation of the human periodontium. I. Classification of periodontal receptors. Austral. D. J., 19:1, 51-56 (Feb.) 1974.

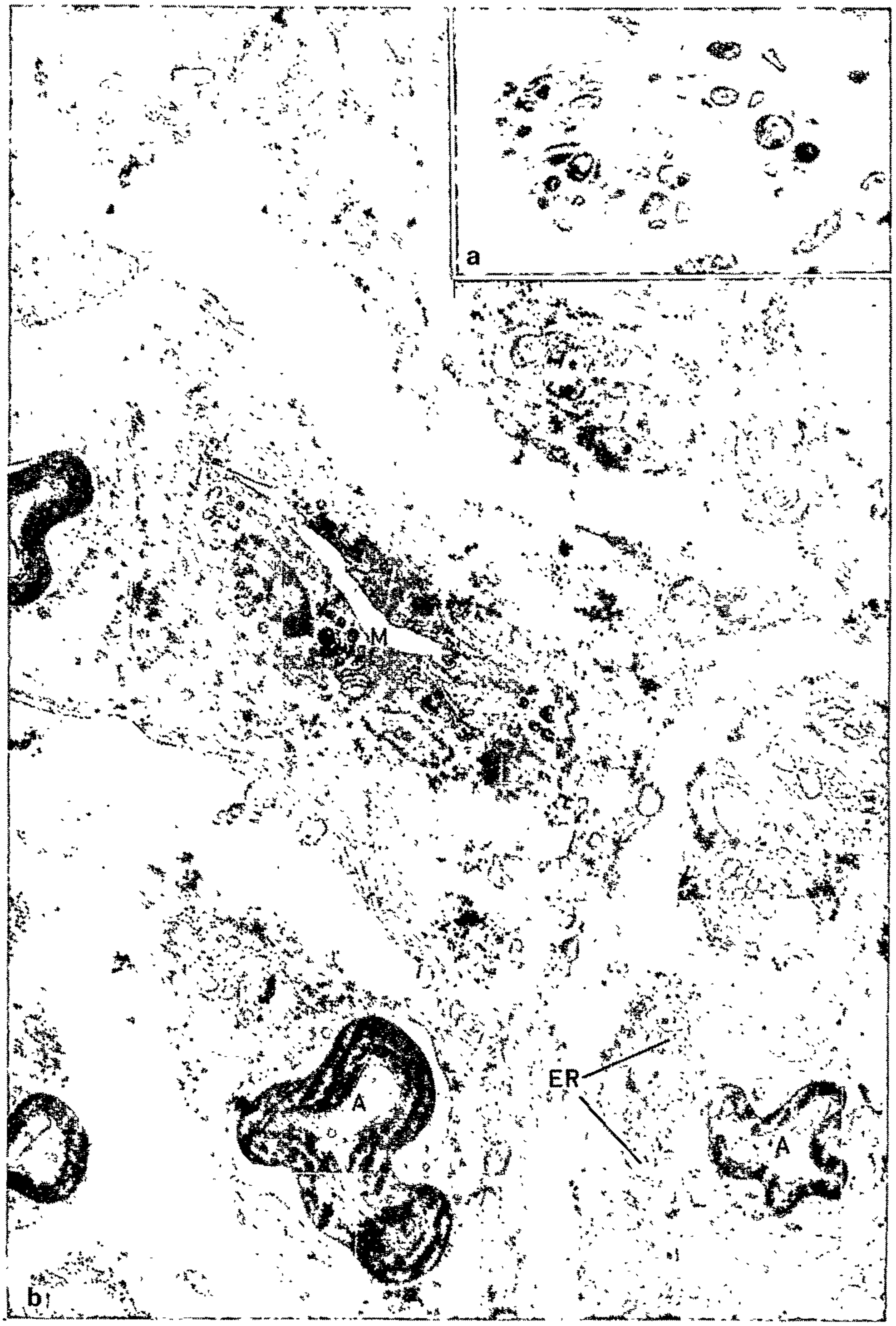

Fig. 1.—a: Complex mechanoreceptor as seen in light microscopy consisting of encapsulated myelinated and unmyelinated nerve fibres. Toluidine blue, X 1,200. b: Montage of fine structure of the complex mechanoreceptor; M, metarteriole; A, myelinated nerve fibres; ER, end ring. X 12,300.

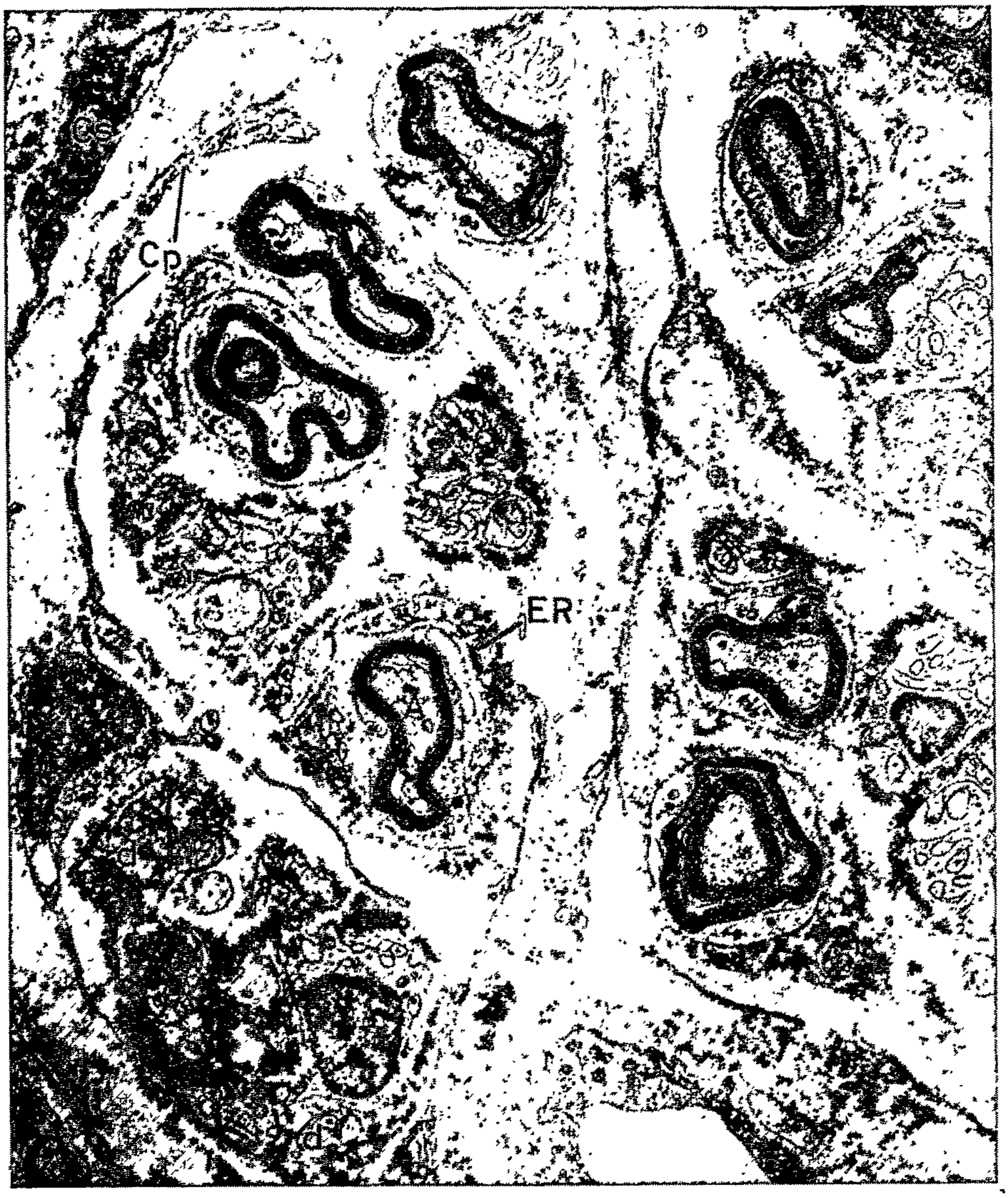

Fig. 2.—Proximal and distal parts of compound units in the complex mechanoreceptors; A, myelinated nerve fibre; ER, proximal end ring; Cp, primary capsule; Cs, secondary capsule; d, unmyelinated fibres of the distal part. X 15,000.

consisted of numerous terminal axons and minute exposed endings. Usually a discrete endoneurium was present but otherwise the endings were surrounded by loose connective tissue (Fig. 5).

Discussion

Since the complex mechanoreceptors is associated with the major periodontal nerve trunk it would seem to correspond to a spontaneously discharging unit and tension on the periodontium would cause it to discharge. Furthermore rhythmic pulsation of encapsulated metarterioles would also contribute to spontaneous discharge. This vascular mechanoreceptor seems to be responsible for spontaneous periodontal discharges in phase with the electrocardiograph as observed by

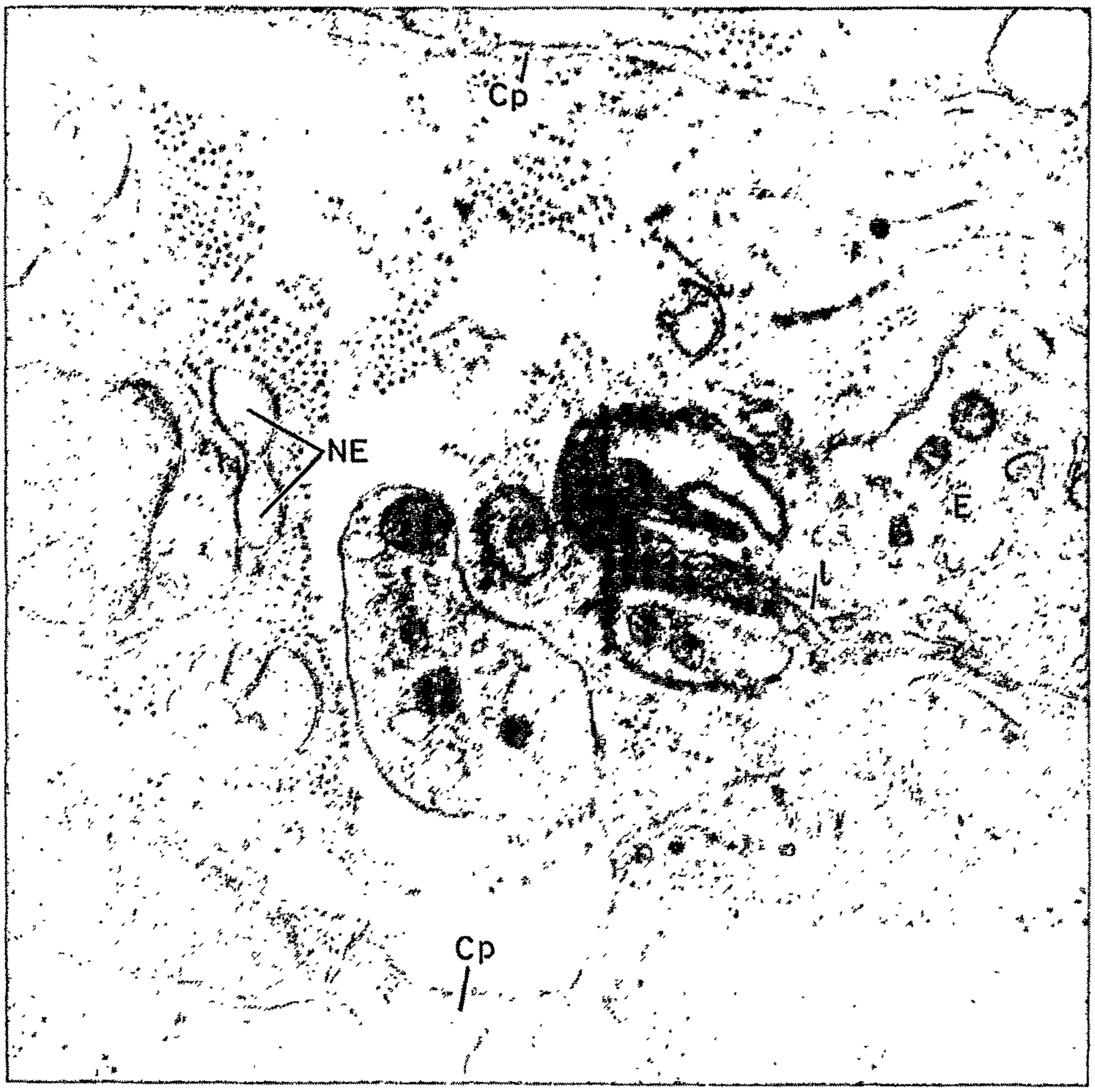

Fig. 3.—Capillary vascularization of a unit in the complex mechanoreceptor containing exposed nerve endings; E, endothelial cell; 1. lumen, NE, exposed nerve endings; Cp, primary capsules. X 15,000.

Hannam in the periodontal tissues of the dog.[2] In effect it appears to be a baroreceptor sampling periodontal blood pressure.

The free nerve endings however are either derived from Group III myelinated nerve fibres or Group IV fibres subserving pain sensibility.

The presence of periodontal neural complexes as described in this and previous papers suggests that there are discrete rapidly adapting units (Part II) slowly adapting units (Part III), and spontaneously discharging units. It would seem that the discrete unit is responsible for the jaw opening reflex which occurs after tooth contact[3]. This reflex reciprocally inhibits the mandibular elevators and excites the mandibular depressors. This is shown in Fig. 6, in which a recording is made of patient rhythmically opening, closing and clenching the jaws. The digastric contraction occurs towards the end of the inhibitory phase of the elevators (masseters).

What is the function of slowly adapting and

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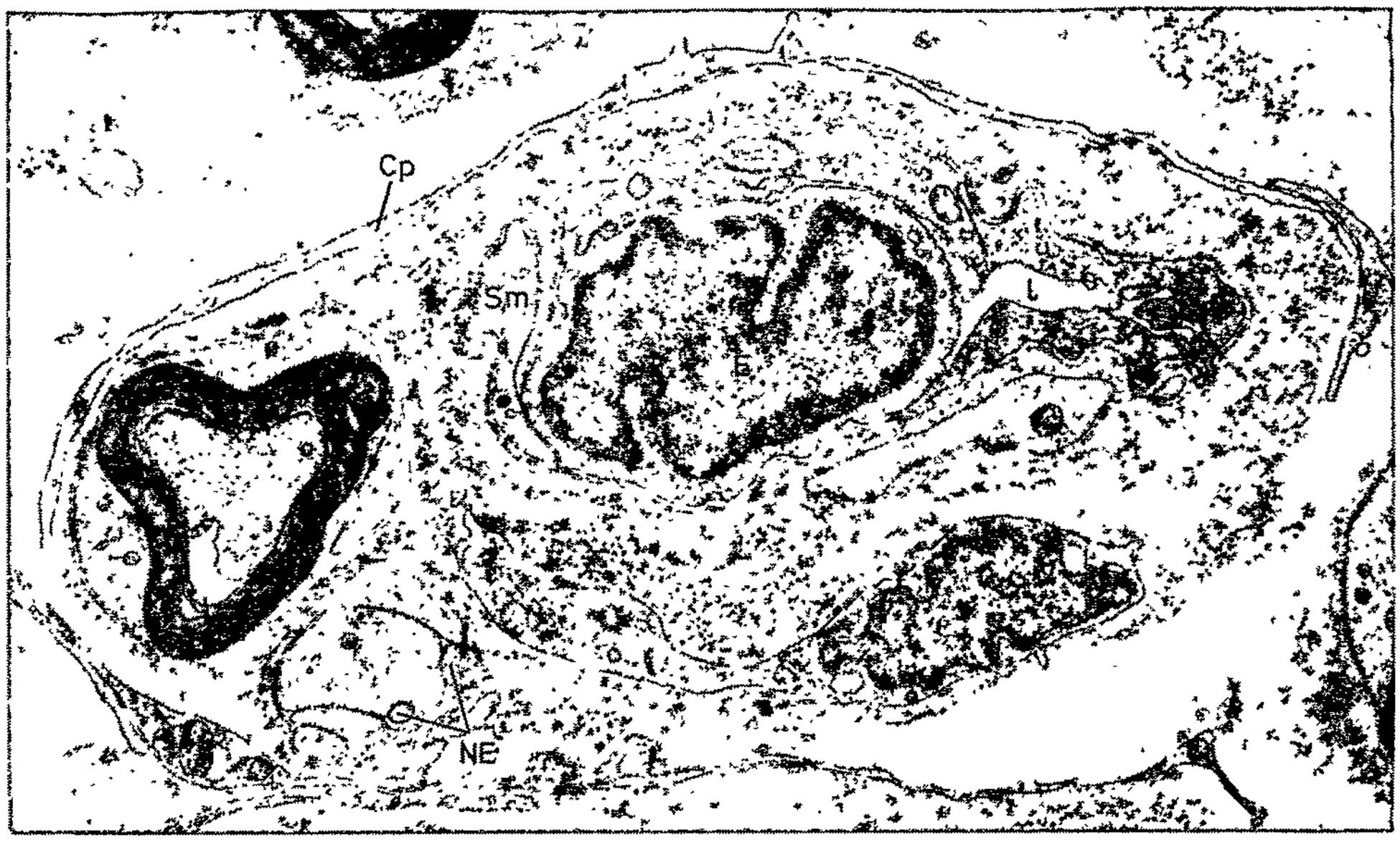

Fig. 4.—Baroreceptor unit of the complex mechanoreceptor; E, endothelial cell; l, lumen; NE, exposed nerve ending; Sm, smooth muscle cell; Cp, primary capsule. X 10,000.

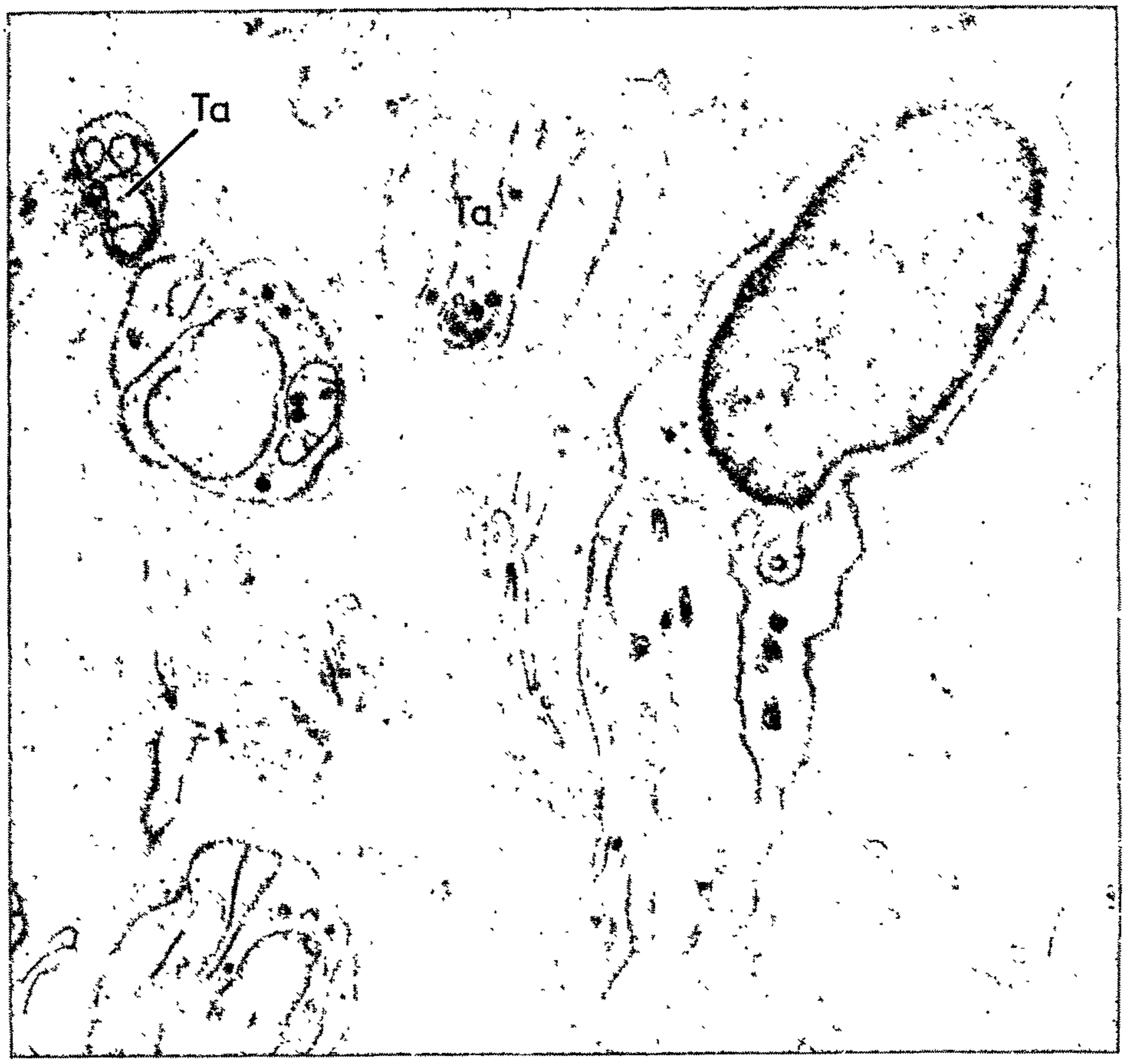

Fig. 5.—Free nerve endings peripheral to the neural complex; Ta, terminal axons (free nerve endings). X 13,100.

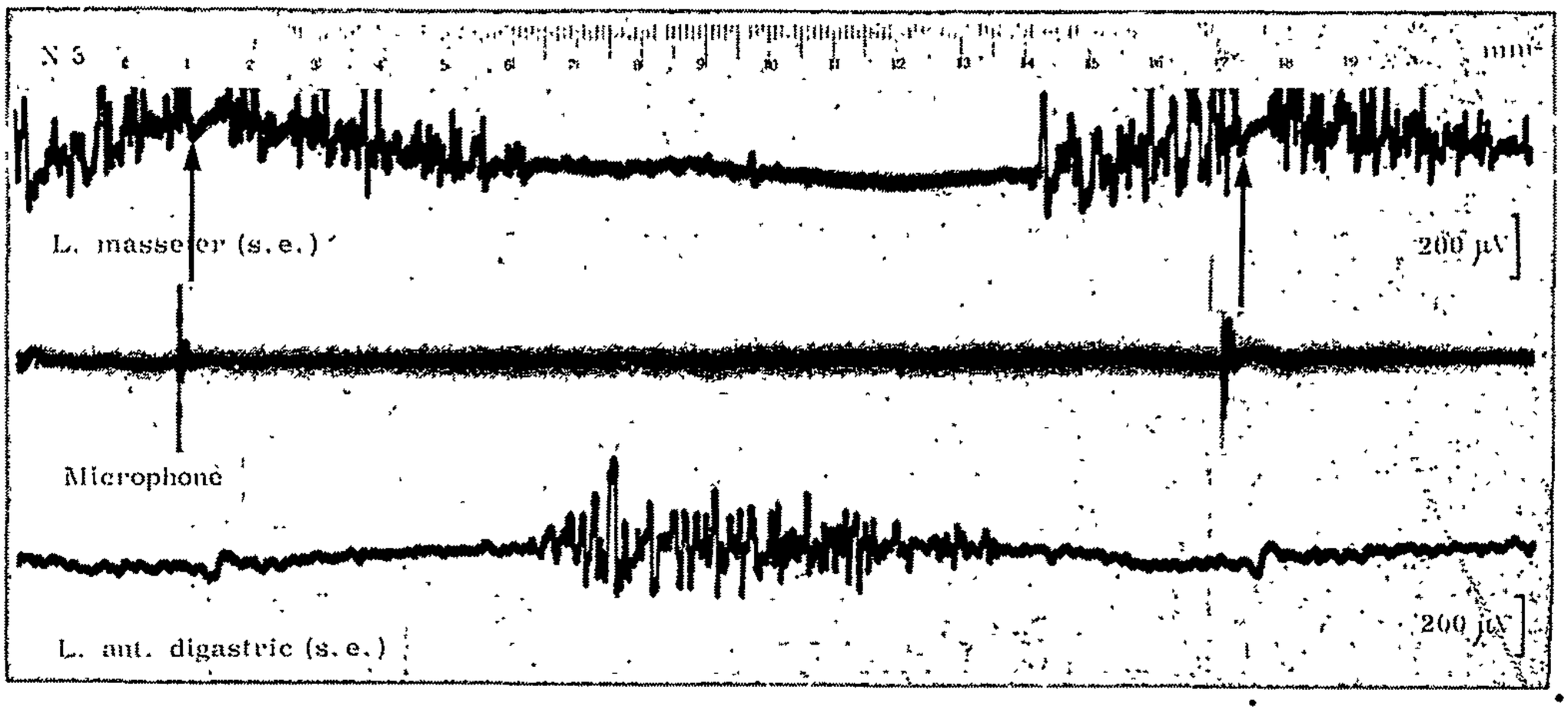

Fig. 6.—Electromyogram of jaw opening reflex recorded with a three channel Disa electromyograph. Microphone records sound of initial tooth contact; inhibition (arrows) of the masseter muscle occurs approximately 10 m sec after initial tooth contact. Duration of inhibition approx 20 m sec. Speed of trace 50 m sec/cm.

spontaneously discharging units? It is known that these units increase their rate of discharge on tooth contact[4] and that they discharge principally in the mesencephalic nucleus,[5] the principal central nucleus and the nucleus tractus spinalis oralis;[6] furthermore they relay in the reticular brain stem formation and finally project to the motor nucleus of the trigeminal nerve.[7] With the jaws at rest these units would maintain the tonicity of the motor neurones of the trigeminal nerve and with movement would direct the jaws into the occlusal position.

Anatomical evidence suggests[8] that these units play an important role in the maintenance of tonic activity of the brain stem reticular formation and it is known that this formation facilitates cortically or subcortically indirect movement.[9]

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Innervation of the Human Periodontium

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I. Introduction

Nerve fibres enter the periodontium through the base of the tooth socket and pass towards the gingival tissue in a direction more or less parallel with the long axis of the tooth. They are joined by nerve fibres which reach the periodontal ligament through minute foramina in the lamina dura.

The nerve fibres give branches to the periodontal ligament and finally terminate in the gingival mucosa surrounding the tooth.

The innervation of the periodontal membrane of the cat was studied by LEWINSKY and STEWART [1937a, b] and KEREBEL [1964] noted the richness of that innervation compared with that of the dental pulp in the kitten. SIMPSON [1966] described thick bundles of nerve fibres lying parallel to the long axis of the tooth which gave off branches to form plexuses and bundles of fibres.

II. Fibre Spectrum

A. Unmyelinated Fibres

BERNICK [1948] observed both unmyelinated and myelinated nerve fibres in the periodontium of the molar teeth of the guinea pig, and KEREBEL [1964] described unmyelinated nerve fibres in relation to blood vessels in the periodontal membrane of the kitten. In an electron microscopic study of the unmyelinated nerve fibre spectrum of the dental branches of the maxillary nerve in the cat, WILSON [1968] found that the

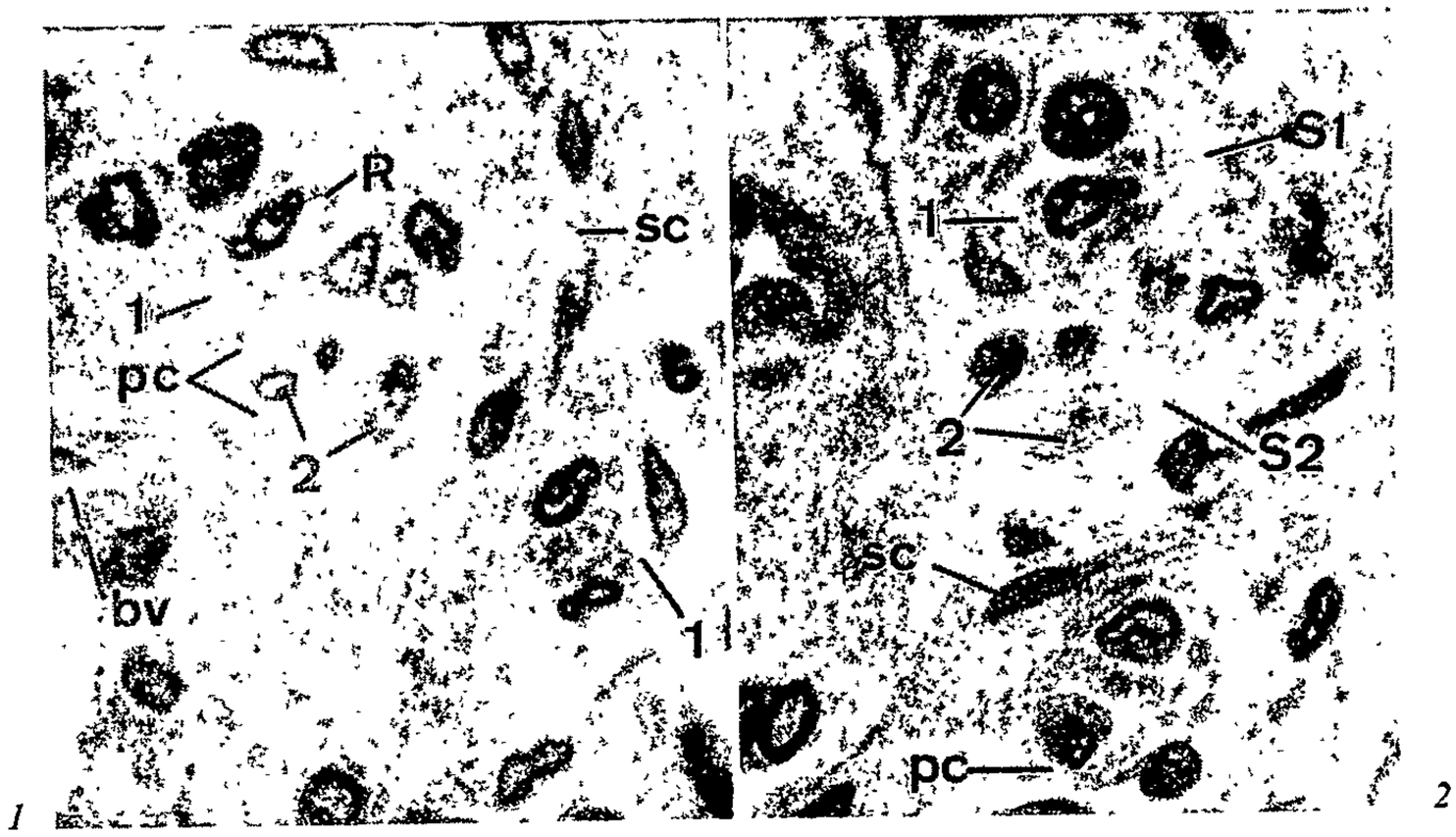
fibre size varied between 0.5 and 1.0 μm. In a study of the developing human periodontium, GRIFFIN and HARRIS [1968] found that the unmyelinated nerve fibres had a mean diameter of 0.46 μm. They considered that these fibres corresponded to vasomotor and dorsal root C fibres.

B. Myelinated Nerve Fibres

WILSON [1968] reported his histological findings and showed that the myelinated nerve fibres in the canine nerve of the cat varied in diameter between 3.0 and 8.0 μm. DE LANGE *et al.* [1969] using physiological techniques showed that the fibre diameter was between 5.0 and 8.0 μm in the periodontal membrane of the dog. PFAFFMAN [1939] and HÄNNAM [1968] had shown that periodontal nerve fibres conducted at a velocity between 24 and 83 m/sec. This indicated that their diameter [HURSH, 1939] would be between 4 and 14 μm. BRASHEAR [1936] was of the opinion that 20% of the nerve fibres entering the periodontium were over 10 μm in diameter.

III. Periodontal Nerve Plexuses

GRIFFIN and SPAIN [1972] found the mean diameter of fibres constituting the periodontal nerve plexuses to be 4.5 μm; however, 20% of these fibres were over 5.5 μm in diameter. It was thought that tapering or branching of the fibres occurred as they reached their termination. The plexus consisted of myelinated nerve fibres which formed terminal encapsulated specializations (fig. 1, 2). Two types of terminal specializations were identified. The first type consisted of a single myelinated nerve fibre and unmyelinated nerve fibres surrounded by a discrete capsule. These units usually occurred in pairs and are presumed to correspond to the end-knobs of LEWINSKY and STEWARD [1937a, b]. The second type of receptor consisted of two or more encapsulated nerve fibres and unmyelinated nerve fibres. The latter formed rings around the myelinated nerve fibres. These receptors apparently correspond to the end-rings of VAN DER SPRENKEL [1936]. Capsular cells were seen to form a rather discrete capsule around both types of end-organs and this has been called the primary capsule. However, other capsular cells formed a reticulum which encompassed the neural plexus. The plexus was associated with an afferent arteriole and a collecting vein [GRIFFIN and HARRIS, 1974]. Branches of the afferent arteriole were seen to enter the capsule of the more complex receptors [GRIFFIN and SPAIN, 1972].



1 2

Fig. 1, 2. R = End-ring; pc = primary capsule; sc = secondary capsule; bv = blood vessel; S1 = tissue associated with compound receptor; S2 = tissue associated with discrete receptor; 1 = compound receptor; 2 = discrete receptor. Toluidine blue. Oil immersion photomicrographs.

IV. The Discrete Unit

The discrete unit was approximately 10×10 μm and at its proximal part consisted of a myelinated nerve fibre about 2.5 μm in diameter and unmyelinated nerve fibres. The myelinated nerve fibre was usually separated from the unmyelinated nerve fibres by a septum consisting of a capsular cell process (fig. 3). Some of the unmyelinated nerve fibres terminated in bays in the Schwann cell and they have been called lacunar endings. More distally the myelinated nerve fibre lost its myelin sheath and branched into numerous unmyelinated nerve fibres. Some of these latter fibres terminated as exposed endings (fig. 4). The nerve endings were identified by the presence of synaptic-like vesicles and small mitochondria [BISCOE and STEPHENS, 1966]. The endoneurium of these endings was sparse and contained only a few collagen fibrils (fig. 3), and in some instances the intracapsular tissue had a microfibrillar structure and collagen fibrils were absent (fig. 4).

V. The Compound Receptor

The compound receptor, corresponding to the end-rings of VAN DER SPRENKEL [1936], contained two or more encapsulated nerve fibres (fig. 5). The nerve fibres lost their myelin sheaths in a staggered fashion and the unmyelinated fibres spiralled around the adjacent myelinated nerve fibres. A compact discrete endoneurium was associated with the myelinated and unmyelinated nerve fibres (fig. 5, 6) and the collagen fibrils constituting the endoneurium lay parallel to the myelinated nerve fibre and were closely associated with the basal laminae of the Schwann cells. The capsule of the compound receptor usually consisted of two layers of capsular cells and their processes with collagen fibrils lying close to them (fig. 5, 6).

The unmyelinated nerve fibres within the receptor terminated either as exposed or lacunar endings (fig. 6, inset). The lacunar endings consisted of three or more nerve endings containing synaptic-like vesicles and were exposed to the extracellular substance. Some of the vesicular elements appeared to have gained access to the extracellular space but it is uncertain whether they were vesicles or minute sections of the terminal axon. The dimensions of the compound receptor were about 32×25 μm.

VI. Neural Clusters

When branches of the periodontial nerves were traced to their terminations they were found to consist of clusters of the end ring type of receptor (fig. 7). Numerous myelinated nerve fibres were surrounded by unmyelinated nerve fibres. Apparently, the myelinated nerve fibres after losing their myelin sheath immediately pursued a spiral course entwining adjacent myelinated nerve fibres; the neural cluster is supplied by arteriolar and capillary blood vessels [GRIFFIN and SPAIN, 1972]. The neural cluster is presented schematically in figure 8.

VII. The Capsular Cells

The capsular cells appear to be derived from the perineurium of the periodontal nerve trunk and accompanied isolated myelinated nerve fibres as they left it (fig. 8). Usually, the nucleus of the capsular cell was elongated and had one or more nucleoli (fig. 9). The cytoplasm contained a

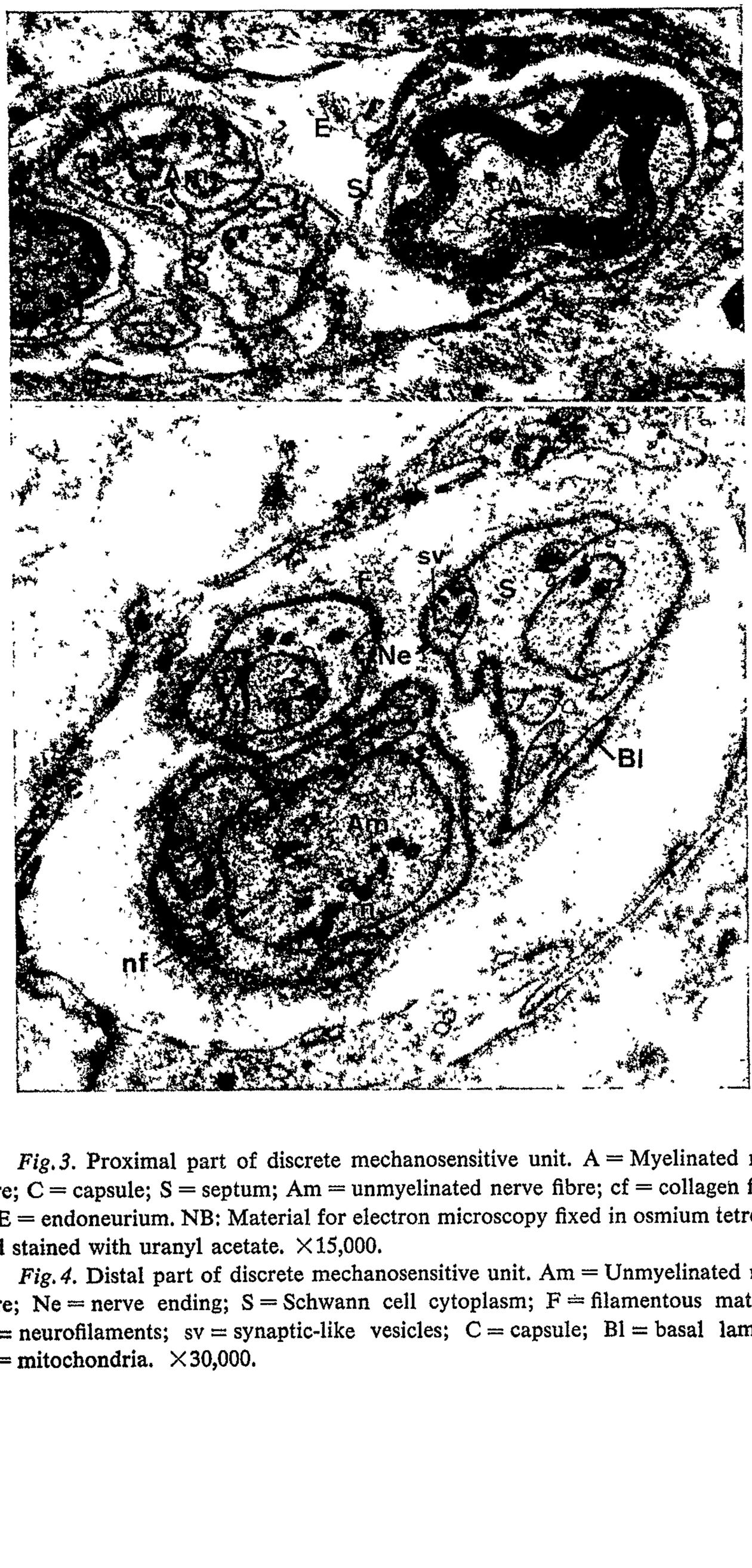


Fig. 3. Proximal part of discrete mechanosensitive unit. A = Myelinated nerve fibre; C = capsule; S = septum; Am = unmyelinated nerve fibre; cf = collagen fibrils of E = endoneurium. NB: Material for electron microscopy fixed in osmium tetroxide and stained with uranyl acetate. ×15,000.

Fig. 4. Distal part of discrete mechanosensitive unit. Am = Unmyelinated nerve fibre; Ne = nerve ending; S = Schwann cell cytoplasm; F = filamentous material; nf = neurofilaments; sv = synaptic-like vesicles; C = capsule; Bl = basal laminae; m = mitochondria. ×30,000.

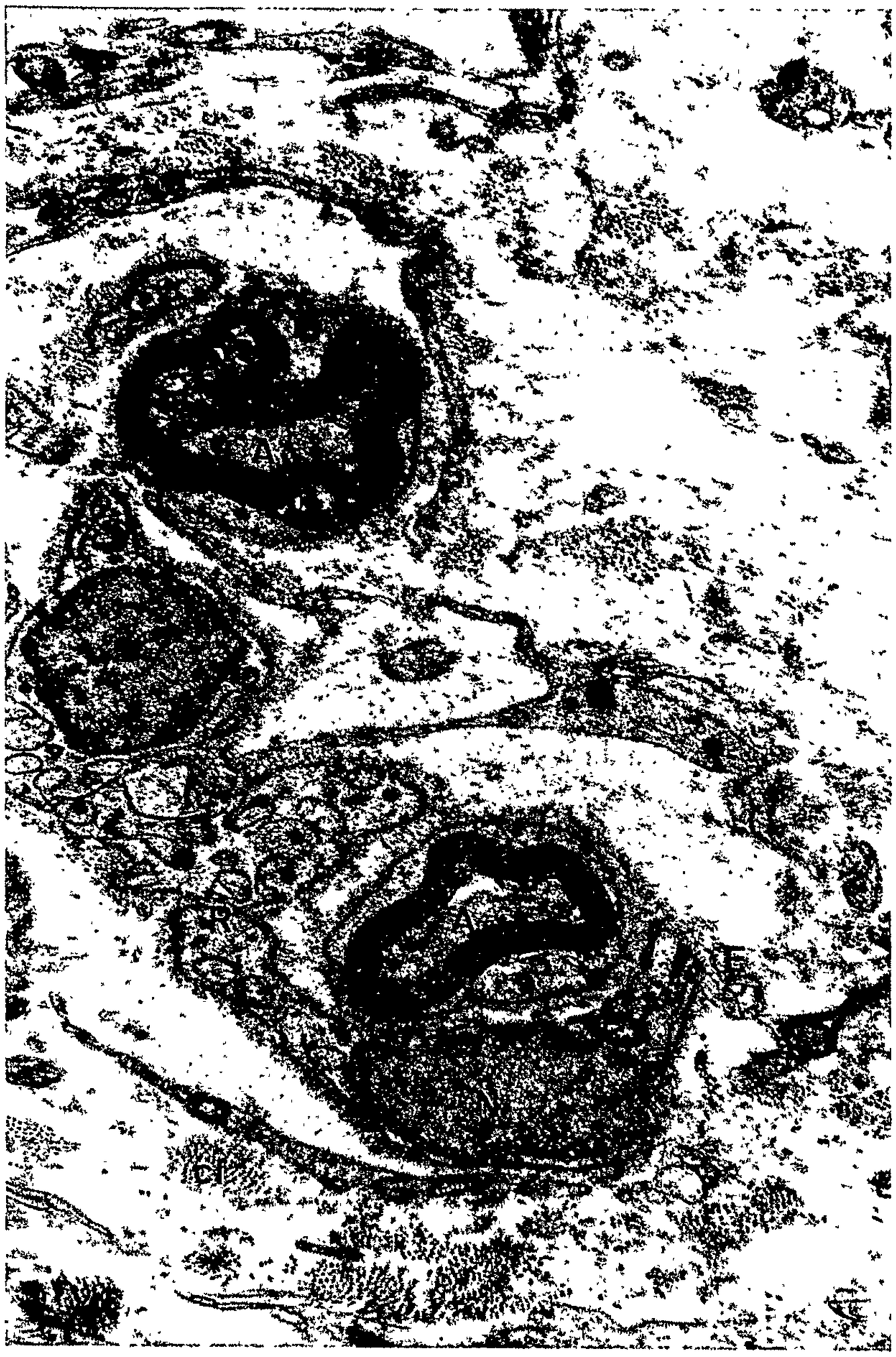


Fig. 5. Compound receptor. A = Myelinated nerve fibre; R = end rings; E = endoneurium; N = nucleus of Schwann cell; cf = collagen fibrils. ×15,000.

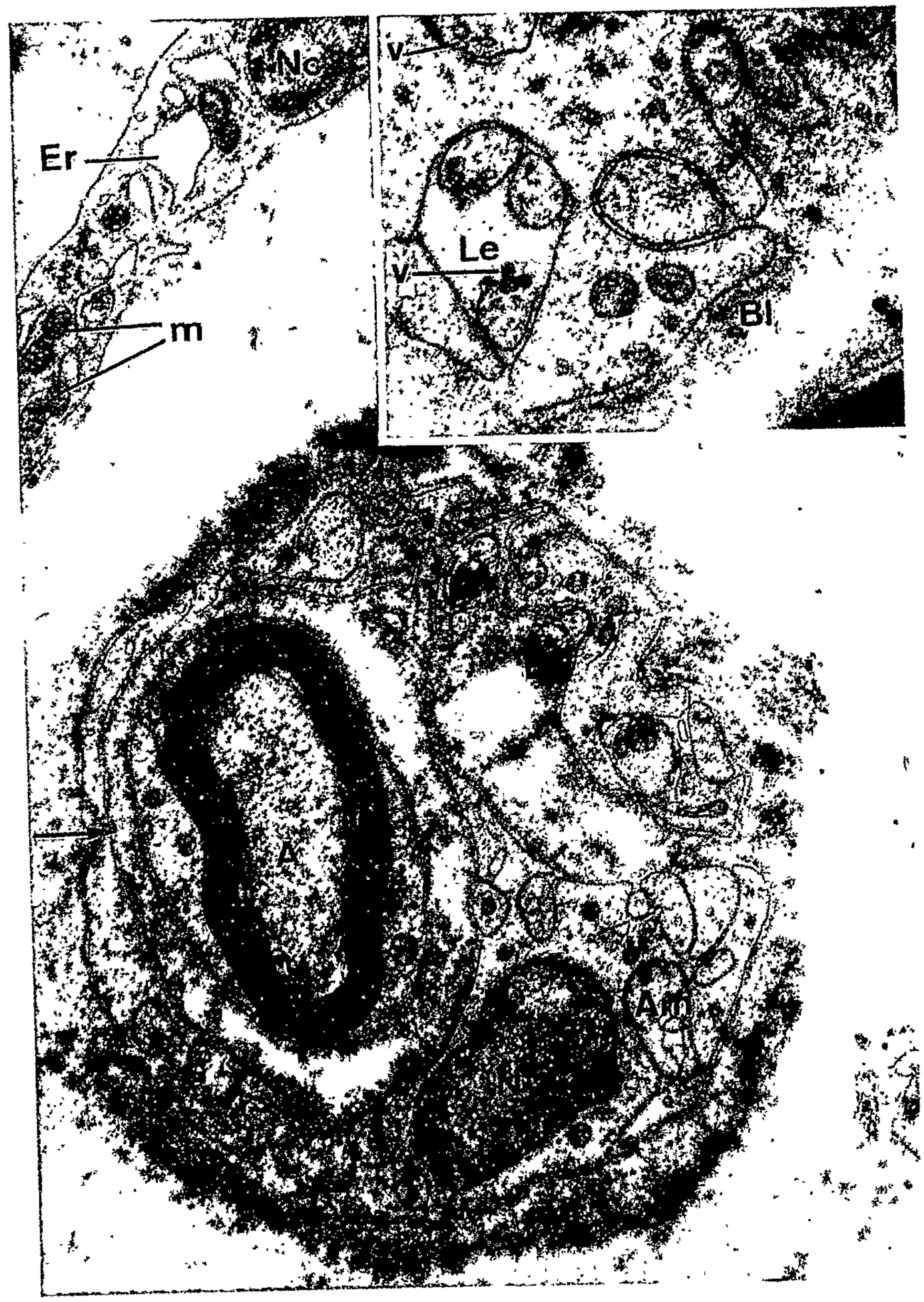


Fig. 6. Detail structure of end-ring. A = Myelinated nerve fibre; N = nucleus of Schwann cell; Am = unmyelinated fibre; arrow = tight junction; E = endoneurium; Nc = nucleus of capsular cell; Er = rough-surfaced endoplasmic reticulum; m = mitochondria. ×18,000. Inset: Le = lacunar ending; Bl = basal laminae; V = synaptic-like vesicles. ×50,000.

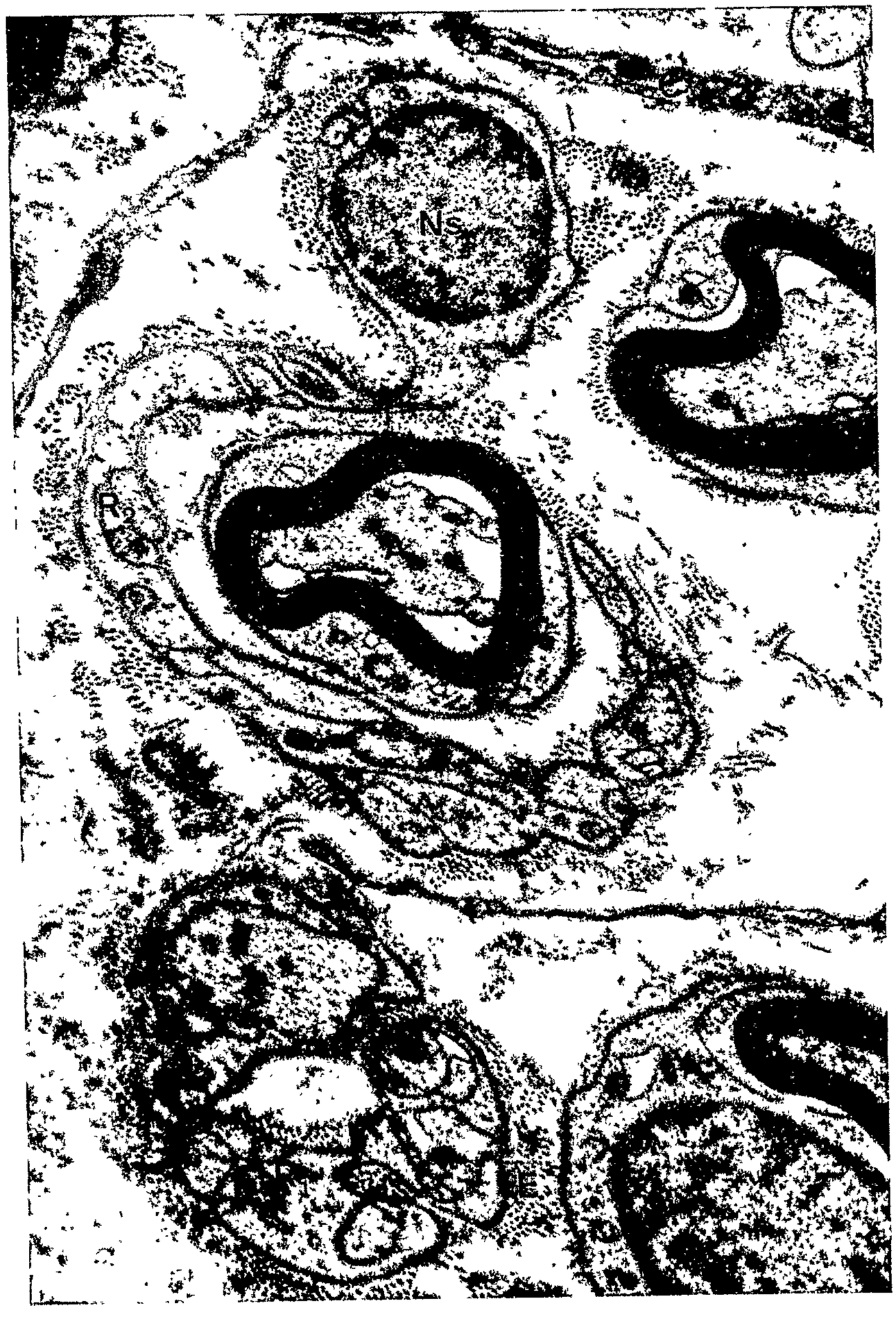


Fig.7. Neural clusters. A = Myelinated nerve fibres; C = capsule; E = endoneurium; R_1 = initiation of end-rings; R_2 = spiralling of end-rings; Ns = nucleus of Schwann cell. ×18,000.

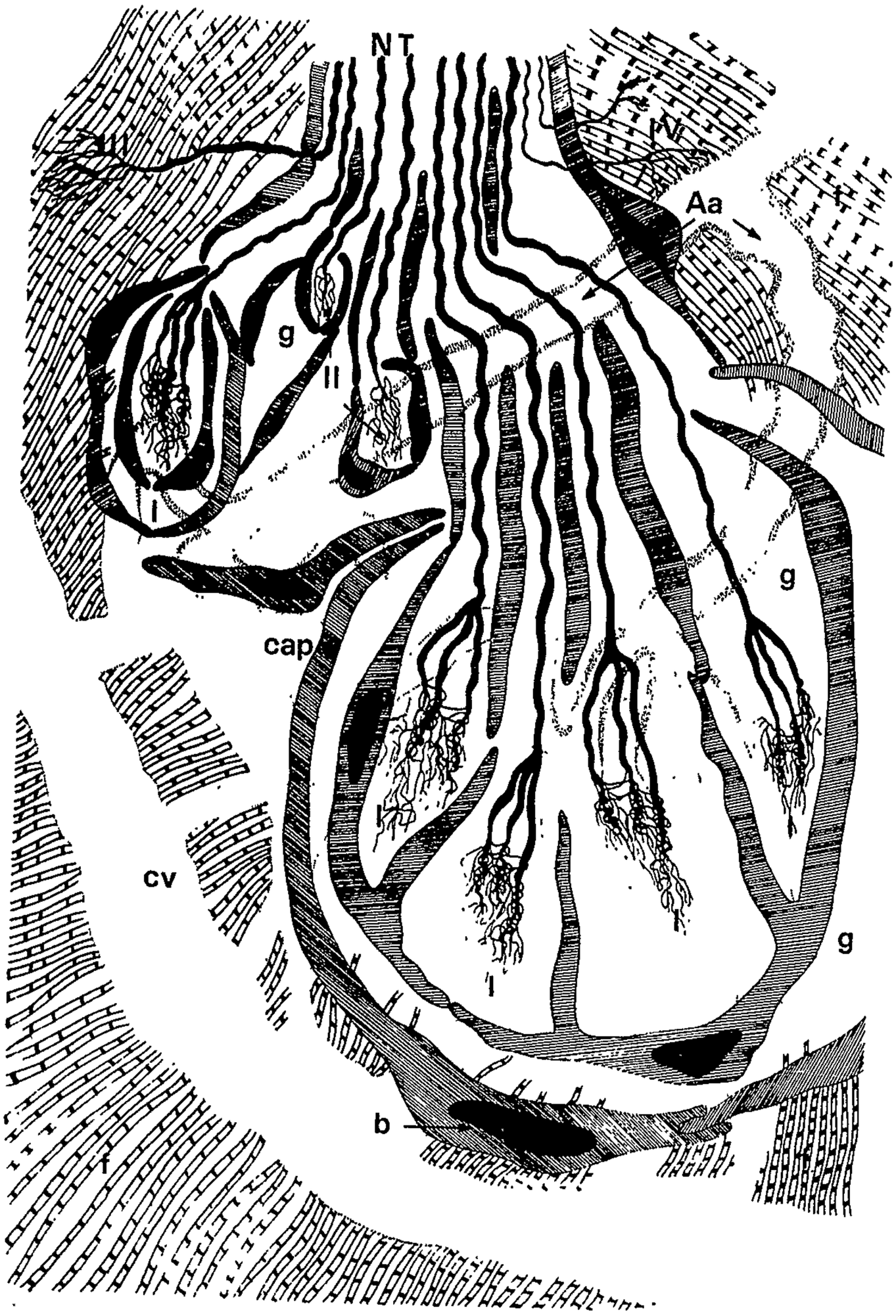


Fig. 8. Schematic representation of periodontal neural tissue I Compound mechanoreceptors derived from either group II or III nerve fibres occurring singly or forming a cluster (complex); II = simple mechanoreceptor derived from group II and III nerve fibres; IV = ending of group IV (vasomotor and DRC) fibres. NT - distal part of nerve trunk· Aa = afferent arteriole; cv = collecting vein; cap = capillary system; b = cell bodies and processes of capsular cells forming a reticulum; g = ground substance; f = dense fibrous tissue. Illustration prepared by GOLDA DADOUR.

Fig. 9. Encapsulation of proximal part of receptor. Nc = nucleus of capsular cell; C = capsule cell processes; BL = basal laminae. × 18,000.

moderately well-developed rough surfaced endoplasmic reticulum and mitochondria with regular cristae (fig. 6). Pinocytotic vesicles were frequently seen in the cytoplasm [GRIFFIN, 1972; GRIFFIN and SPAIN, 1972]. The processes were attenuated and effected tight junctions with adjacent processes of capsular cells.

The capsular cells as well as forming capsules for the various types of receptors in the neural complex also formed a syncytium throughout the neural plexus. The plasma membrane of the capsular cells was associated with a somewhat inconstant basal lamina (fig. 9). SHANTHA and BOURNE [1969] have termed epineural epithelial cells as the capsular cells constituting the epineurium surrounding nerve fasciculi and the capsule of end-organs such as the muscle spindle and Meissner's corpuscles. From examination of peridontal nerve plexuses it would seem that the cells are epineurial in origin. According to SHANTHA and BOURNE [1969] the function of these cells is to separate the respective end-organs from the surrounding fluids and the cells themselves are ectodermal in origin. However, PATRIZI and MUNGER [1965] suggested that the capsular cells of the encapsulated endings in the rat penis were modified fibroblasts. They noted that these capsular cells had very thin processes (around 0.1 μm) and that scant basal lamina-like material was associated with their plasma membranes. Nevertheless, the capsular cell of the periodontal nerve plexuses differs from fibroblasts in some respects. The mitochondria appear to be of moderate size and to have regular cristae, whereas the mitochondria of fibroblasts are swollen and have irregular cristae [ROSS and BENDITT, 1961; CASTOR and MUIRDEN, 1964; FITTON JACKSON, 1964; GOLDBERG and GREEN, 1964; GRIFFIN and HARRIS, 1966].

The development of the rough surfaced endoplasmic reticulum was not as elaborate as that in fibroblasts of the dental pulp and periodontium [GRIFFIN and HARRIS, 1967]. Perhaps the most important difference is the fact that the capsular cells effect tight junctions with adjacent fellows [GRIFFIN and SPAIN, 1972; THOMAS, 1963]. On the other hand, fibroblasts in tissue cultures move away from each other [ABERCROMBIE *et al.*, 1971].

VIII. Free Nerve Endings

Free nerve endings have been observed in the periodontal membrane [GRIFFIN and HARRIS, 1968]. One type of ending, apparently not related to blood vessels, appeared to be derived from unmyelinated nerve fibres.

It was suggested that this type of ending corresponds to the endings of dorsal root C fibres and that they mediated slow pain and subserved nociceptive reflexes. The other type of ending was more complex and was apparently derived from group III fibres [LLOYD, 1943]. The ending contained numerous synaptic-like vesicles, small mitochondria and electron-dense bodies (fig. 10). One portion of the endings was associated with Schwann cell cytoplasm whilst the other was exposed to the extracellular substance being separated from it by a basal lamina. It was suggested that this type of ending subserved fast pain sensitivity and fast nociceptive reflexes [GRIFFIN and HARRIS, 1968].

IX. Functional Considerations

A. Periodontal Receptor

The encapsulated type of end-organs in the human periodontal ligament apparently subserve proprioceptive sensibility. They exhibit their maximum activity when stimulus is applied in a certain direction [PFAFFMANN, 1939; NESS, 1954; KAWAMURA, 1964; HANNAM, 1969a]. Physiologically, four types of mechanoreceptors in the periodontal ligament have been described. These are spontaneously and slowly discharging receptors [SUZUKI, 1963; KAWAMURA and NISHIYAMA, 1966; WAGERS and SMITH, 1960; MATTHEWS, 1965; HANNAM, 1969a, b], rapidly adapting mechanoreceptors [NESS, 1954; KAWAMURA and NISHIYAMA, 1966; HANNAM, 1969a, b] and receptors in phase with the ECG [HANNAM, 1969b].

Stimulation of these receptors by the application of pressure results in the excitation of neurones in the ipsilateral mesencephalic, principal sensory, and spinal nuclei of the trigeminal nerve [JERGE, 1963; KRUGER and MICHEL, 1962; EISENMAN *et al.*, 1963; KAWAMURA and NISHIYAMA, 1966]. On the other hand, tactile stimulation is represented bilaterally in the principal sensory nucleus of the trigeminal nerve [DARIAN-SMITH *et al.*, 1963; WALL and TAUB, 1962]. Because of this, KAWAMURA and NISHIYAMA [1966] suggested that unilateral discriminatory ability for the tooth is greater than the hairy skin. Most of the neurones responding to pressure on the teeth [KAWAMURA and NISHIYAMA, 1966] were located in the principal sensory nucleus and the nucleus spinalis oralis as described by OLSZEWSKI [1950]. However, JERGE [1963] was able to record response from neurones in the mesencephalic nucleus of the trigeminal nerve after application of pressure to the teeth; he recognized two types of mesencephalic

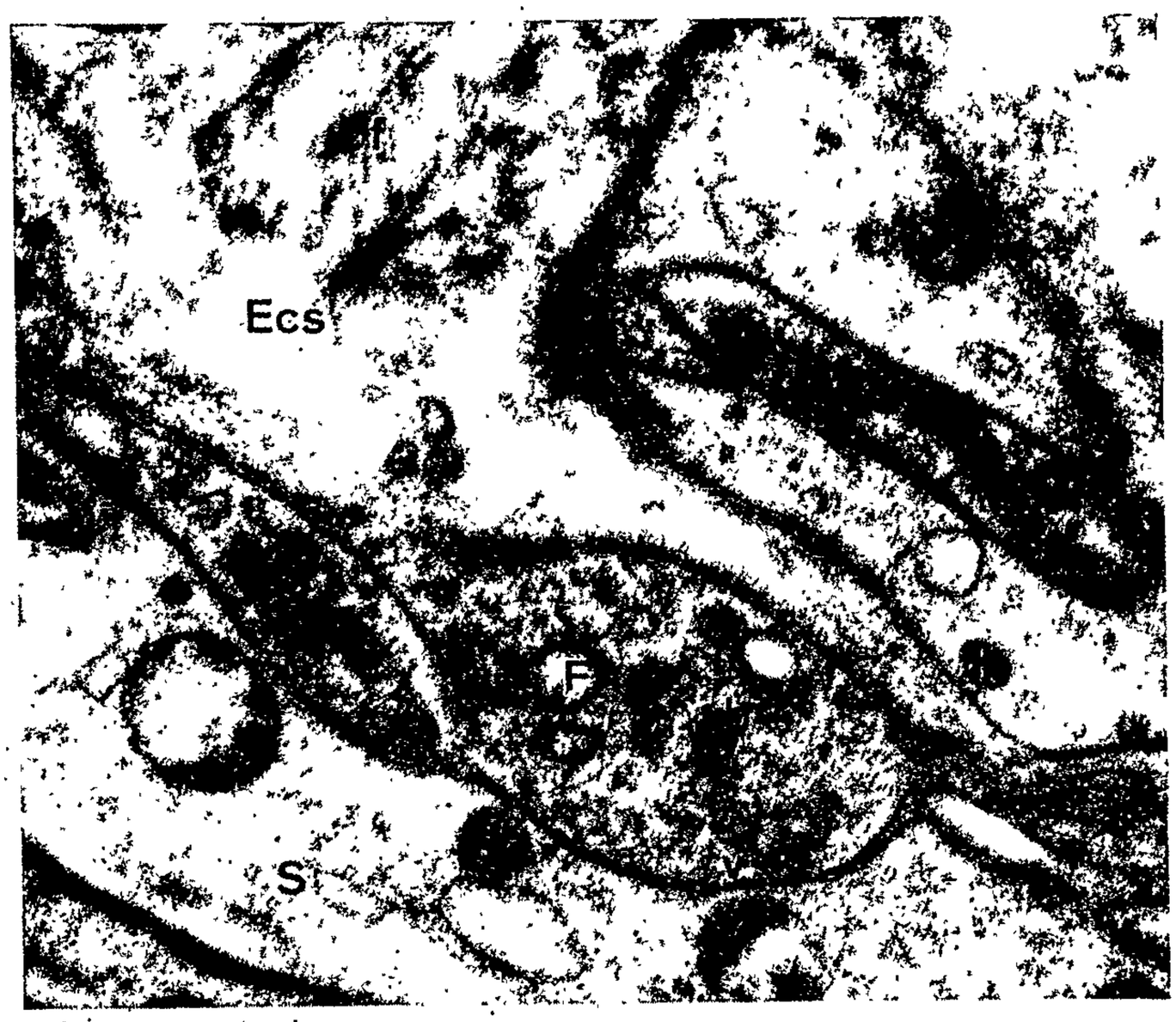


Fig. 10. F = Free nerve ending. S = Cytoplasm of Schwann cell; b = electron-dense body; v = vesicles; Ecs = extra cellular substance; cf = collagen fibrils. ×30,000.

primary neurones. The first type responded to pressure on a single tooth whilst the second type responded to pressure on a group of teeth. GRIFFIN [1962] after sectioning the maxillary nerve in the cat distal to the sphenopalatine ganglion examined the mesencephalic nucleus 10 days after surgery and found severe chromatolysis in the ipsilateral trigeminal ganglion neurones and none in the contralateral ganglion. As regards the ipsilateral mesencephalic nucleus, chromatolytic neurones were observed throughout the nucleus as far rostrally as the oculomotor nucleus but most were aggregated in the caudal part of the nucleus. Neurones in the nucleus spinalis oralis and the principle sensory nucleus of the trigeminal nerve excited by pressure on the teeth have a longitudinal arrangement [KAWAMURA and NISHIYAMA, 1966]. There is no difference between the tooth neurones from the maxillary nerve and the inferior dental nerve as regards rostro-caudal directions. Instead, neurones responding to pressure on the

molar teeth were mostly situated dorsally whilst neurones responding to pressure on the incisor teeth were mostly situated ventrally. Neurones for canine teeth were interposed between these two receptive fields. In the cat the tooth neurones for the canine teeth were most densely distributed.

Whether receptors are rapidly or slowly adapting may depend on the properties of the capsule and its intrinsic architecture. CATTON and PETOE [1966] proposed that there might be elastic and viscous coupling of mechanoreceptors to the surrounding tissues. In the case of elastic coupling the mechanoreceptor would follow the distortion of the tissue so that adaptation would be slow. If the receptor was viscously coupled to the tissues slipping would give rise to rapid adaptation. Research on the Pacinian corpuscle seems to support this concept. The capsule of that corpuscle consists of outer and inner lamellae which are structurally different. The radial deformation of the outer lamellae is much shorter than that of the inner lamellae [HUBBARD, 1958]. If the outer lamellae of the forg's Pacinian corpuscle is removed the end-organ adapted slowly. However, when an artificial outer capsule was constructed from the mesothelial layer of the mesentery the end-organ regained its rapidly adapting characteristics [LOWENSTEIN and MENDELSON, 1965].

B. Discrete Units

Consideration of the structure of periodontal mechanoreceptors suggest that basically these are rapidly adapting and slowly or spontaneously discharging units. The discrete unit has relatively small dimensions, 10×10 µm, it is usually surrounded by loose connective tissue (fig. 1, 2) and the endoneurium may be devoid of collagen fibrils (fig. 4). This suggests that the unit is relatively independent of the surrounding tissue and that it could slip out of the way of a distorting force; that is to say it would be rapidly adapting. It is probable therefore that these units are responsible for the transitory inhibitory response of the mandibular elevators that occurs after tooth contact [GRIFFIN and MUNRO, 1969] or after tooth contact during mastication [AHLGREN, 1969]. It is suggested that these units are responsible for the properties of the jaw opening reflex [GRIFFIN and MALOR, 1974].

C. Compound or Stretch Receptor

The interpretation of the probable function of the compound units is more difficult. It is possible to compare these receptors with the muscle spindle implying, on the one hand, that the collagen fibres correspond to

intrafusal muscle fibres and, on the other, recognizing that they are without a gamma innervation. Nevertheless, the nature of endings around adjacent myelinated nerve fibres corresponds to the annulospiral endings of the muscle spindle. Furthermore, the collagen fibres associated with the receptor lie in parallel relation to the myelinated nerve fibres. It would seem that any stretch of the collagen fibres would excite the receptor. The coiled nature of the ending indicates also that it would be a slowly adapting tension receptor.

It has been suggested that these receptors discharge onto the motoneurones of the mandibular elevators and direct the jaws into the intercuspal position [GRIFFIN and MALOR, 1974]. The neural end-ring clusters are presumably slowly adapting or are responsible for spontaneous discharges from the periodontium. The relationship of the afferent arteriole to these receptors [GRIFFIN and SPAIN, 1972] suggests that they could be responsible for periodontal discharges in phase with the ECG.

D. Oral Receptors

Light microscopy studies [DIXON, 1961; TOLMAN *et al.*, 1965; SCOTT and DIXON, 1972], have demonstrated coiled nerve endings in the lamina propria of the oral mucosa, gingiva and hard palate. CHOUCHKOV [1972] demonstrated two types of nerve endings in the lamina propria of the human digital skin, oral cavity, and rectum. One type consisted of free nerve endings derived from thick myelinated fibres and the other type was termed compact noncapsulated glomerular bodies. The dimensions of these end-organs were 10×30 μm. CHOUCHKOV [1972] thought that the fine structure of certain of these end-organs indicated that they were mechanoreceptors. Physiological evidence indicates that pressure on the skin of the lip, the oral mucosa, and the hard palate elicits certain reflexes [YU *et al.*, 1973; THEXTON, 1973]. Pressure stimulation of these regions may result in transient jaw opening, prolonged jaw opening, and repetitive tongue movement.

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Some observations on periodontal tissues in rats

Robert Harris
with the technical assistance of Christa Lossin

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Introduction

In 1950 Skillen reported[1] observations on histological changes in the epithelium of the gingival crevice in albino rats. He noted the degeneration of the epithelial attachment to the enamel in the 25-day-old animal and the proliferation of the mouth epithelium behind the epithelial attachment and along the root surface apically to the cemento-enamel junction in various animals up to 2 years of age. Where inflammation existed the proliferation of the mouth epithelium apparently was more rapid. He did not observe pocket formation except as a result of trauma from foreign bodies. Gupta and Shaw[2] noted a high incidence of periodontal disease in the rice rat.

Cohen in 1960 demonstrated[3] that rats normally have inflammatory gingivæ caused mainly by hair and foreign bodies having been forced into the enamel epithelium. His study showed that weanling rats on normal laboratory rat pellets had much more periodontal disease at 16 weeks than those fed a soft diet consisting of rindless cheese, soft bread, shelled hard boiled egg, raw carrot, cabbage and cooked horseflesh, for the same time. However, he noted the difference in disease was less in the older rats. He postulated enamel epithelium is not adequate protection and furthermore the eruption of contiguous teeth is likely to cause a breach in the epithelial integument which subsequently constitutes the site of initiation of a periodontal pocket. His opinion was that the reduction in differences between the amount of disease in older rats was the result of the tissue repair.

Later observations by Shaw[4] showed that the introduction of sucrose into the diet of the rice rat produced an increase in the periodontal syndrome roughly proportional to the amount of sucrose in the diet. Baer and Fitzgerald[5] noted periodontal disease was present in germ-free rats.

This paper presents some observations on the periodontal tissues in Sprague Dawley rats subject to modifications in diet and repeated trauma to the gingival sulcus.

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(1) Skillen, W. G.—The morphology of the gingivæ of the rat molar. J.A.D.A., 17: 4, 645-668 (Apr.) 1930.

(2) Gupta, O. P., and Shaw, J. H.—Periodontal disease in the rice rat. I. Anatomic and histopathologic finding. Oral Surg., Oral Med., Oral Path., 9; 6, 592-603 (June) 1956.

(3) Cohen, B.—Comparative studies in periodontal disease. Proc. Roy. Soc. Med., 53: 275-280 (Apr.) 1960.

(4) Shaw, J. H.—Further studies on the use of nutritionally adequate diets for the production of the periodontal syndrome in the rice rat. J. dent. Res., 44: 6, 1278-1284 (Nov.-Dec.) 1965.

(5) Baer, P. N., and Fitzgerald, R. J.—Periodontal disease in the 18-month-old germfree rat. J. dent. Res.. 45. 2, 406 (March-Apr.) 1966.

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Materials and methods

1. Seven groups of Sprague Dawley rats [26 females and 27 males] average weight of 306·14 g [range 221-406 g] were used. The groups (1-7) were randomly selected and divided into sub-groups so that males and females were kept in separate cages.

2. Each group was fed its own diet prepared as follows:

i. Stock rat diet cubes.
ii. Stock rat diet cubes ground to a fine powder.
iii. Same as ii plus 20 per cent sucrose.
iv. Calcium-free diet.
v. Same as iv plus 20 per cent calcium component.
vi. Same as iv plus 40 per cent calcium component.
vii. Full calcium component added to diet iv.

3. Analysis of diet programmes.

i, ii, iii. Rat diet cubes

Wheat meal	54·0
Meat meal	18·8
Lucerne meal	10·0
Coconut meal	5·6
Milk powder	8·0
Yeast	1·0
Sterilized bone flour	0·8
Salt	0·5
Cod-liver oil	1·3
	100·0

This diet provides:

Vitamin A	4000	I.U./lb
Vitamin D_3	1000	,, ,,
Vitamin E	10	,, ,,
Minimum crude protein	20·0	per cent
Minimum digestible protein	18·7	,, ,,
Maximum crude fibre	7·0	,, ,,
Ash	10·0	,, ,,
Minimum crude fat	8·75	,, ,,
Minimum calcium	2·18	,, ,,
Minimum phosphorus	1·09	,, ,,
Casein (calcium-free)	24 per cent	To make 11·35 kg
Sucrose	68 ,, ,,	
Vegetable oil	5 ,, ,,	
Salt mixture(s)	3 ,, ,,	
Vitamin mixture*	250 g	

Basic salt mixture(s)

Calcium carbonate	54·3	per cent
Magnesium carbonate	2·5	,, ,,
Magnesium sulphate ($7H_2O$)	1·6	,, ,,
Sodium chloride	6·9	,, ,,
Potassium chloride	11·2	,, ,,
Potassium phosphate	21·2	,, ,,
Ferric phosphate	2·05	,, ,,
Potassium iodide	0·008	,, ,,
Sodium fluoride	0·010	,, ,,
Aluminium potassium phosphate	0·017	,, ,,
Copper sulphate ($5H_2O$)	0·090	,, ,,

* Vitamin fortification mixture in dextrose. Nutritional Biochemicals Corp., Ohio.

Calcium carbonate was replaced in diets iv-vi by the appropriate amount of magnesium chloride.

4. Feeding programme.

A trial feeding of the rats indicated an average daily consumption for each animal of 30 g would suffice for Groups 2-7 and 50 g for Group 1. Changes of food and drinking water were made at fixed times each day and each animal was weighed at regular weekly intervals, and the upper and lower incisors of all animals in Groups 2-7 were shortened 2-3 mm each week in order to compensate for the absence of wear.

5. Each week a wound was made by probing the gingival sulcus of the mesial and distal of all first molars with a sharpened **Ash Universal** probe No. 48. The excision of the incisors and probing were carried out under ether anæsthesia.

6. Recovery of the material commenced at 17 weeks and was completed at 23 weeks. The material was immediately fixed in 10 per cent buffered neutral formalin 2-4 days, decalcified in 5 per cent nitric acid, dehydrated and embedded in paraffin. Sections cut at 7μ were stained in hæmatoxylin and eosin.

Observations

1. *Weight*

A steady weight increase occurred for the groups as a whole but the female Sub-group 1 showed no change in average weight. Table 1 shows the average gain in weight up to the 17th week.

2. *Clinical observations*

On recovery oral debris in varying amounts was present in all of the rats from Groups 2-7. It was of a soft flocculent type not adherent to the tooth surfaces and more frequently found around the lower molars.

The first signs of gingivitis and ulceration were noted around the traumatized tooth at approximately 9 and 18 weeks and were judged to be more severe in the mandible. Whilst gingivitis was apparent in all traumatized sulci ulceration was not observed in Groups 1 and 2. Mobility of the first molars could be demonstrated in Groups 3-7 at about 13 weeks.

3. *Histologic observations*

The tissues were examined for the presence of seven changes in the gingival sulcus and the adjacent hard structures and the findings

TABLE 1

Average weight gain of 26 female and 27 male Sprague Dawley rats after 17 weeks of the experiment

Weight gain in gm

	Group							
	1	2	3	4	5	6	7	All groups
Female	—	33·67	47·25	37·25	28·00	39·00	58·40	34·79
Male ..	75·00	37·75	67·00	59·34	87·75	71·25	67·75	65·83
Mean	37·50	35·71	57·12	48·29	56·87	55·12	63·07	50·31

TABLE 2

Distribution of changes in periodontal tissues of 53 rats

	Group							Total
	1	2	3	4	5	6	7	
Calculus								
F	3	2	4	9	9	16	11	54 } 93
M	1	7	5	7	1	10	8	39 }
Inflammation								
F	20	13	22	28	27	28	32	170 } 317
M	19	21	21	22	18	24	22	147 }
Proliferation of epithelium								
F	14	14	16	28	20	29	30	151 } 268
M	11	16	16	20	15	18	21	117 }
Cementum damage								
F	11	10	23	11	9	19	30	113 } 216
M	10	19	16	14	10	12	21	103 }
Bone resorption								
F	15	6	13	11	9	27	8	89 } 165
M	4	7	16	11	11	13	14	76 }
Disruption of periodontal ligament								
F	6	4	8	4	9	19	8	58 } 114
M	2	9	9	5	6	11	14	56 }
Cystic formation								
F	—	1	4	6	3	6	2	26 } 50
M	5	1	4	3	2	5	4	24 }
Number of animals	7	7	8	7	9	7	8	53

are recorded in Table 2. The observations are restricted to the 53 animals that survived 17 or more weeks of the experiment and record the changes in 342 surfaces. It will be noted that more reactions are recorded in specimens from female rats.

It will be noted that calculus was limited to less than 25 per cent of the regions and the greatest number of observations was recorded for inflammatory reaction (317), proliferation of epithelium (268) and damage to cementum (216). The periodontal ligament appeared to act as a strong barrier to disruption (Fig. 1) but on examining serial sections it was apparent that where inflammation was severe and epithelial proliferation extensive (Fig. 2) the ligament was disrupted. The damage to the cementum occurred in all of the interproximal lesions and in about 10 per cent of the mesial of the first molars. In some instances epithelium was attached to the cementum (Fig. 3). Bone resorption of the alveolar crest (Fig. 4) was present in 165 instances. The presence of large vacuoles (Fig. 2) (which have been called cystic) in the interproximal soft tissues in 50 instances was associated with inflammation and epithelial proliferation. Foreign bodies were observed in the perio-

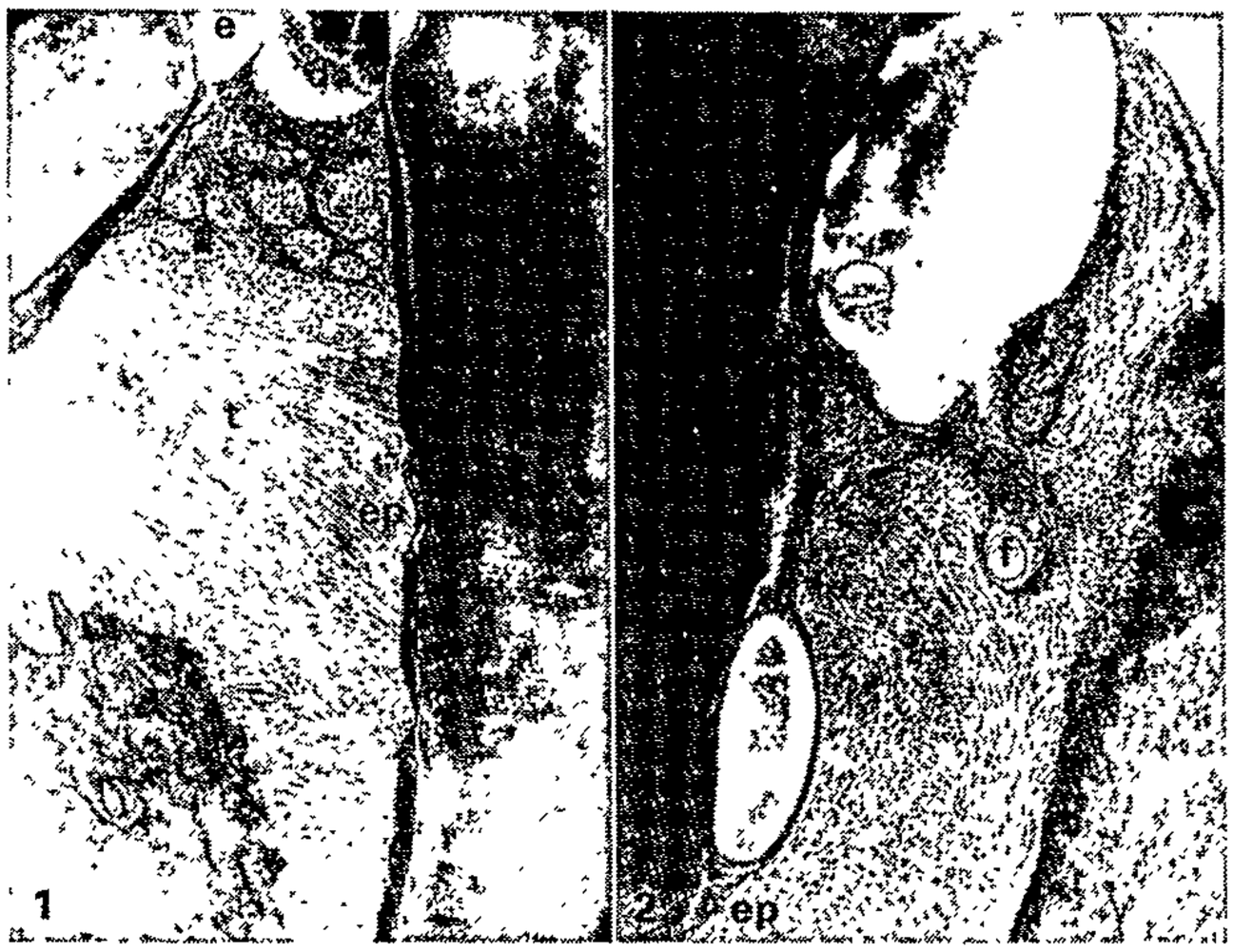

Fig. 1.—Interproximal tissues in lower right molar region of male rat [476 g, 148 days] Diet iii. Enamel, e; debris, d; transverse fibres of periodontal ligament, t; epithelium, ep. H & E × 80.

Fig. 2.—Interproximal tissues in upper right molar region in same animal as in Fig. 1. Epithelium, ep; foreign body, f; note cavity along root. H & E × 80.

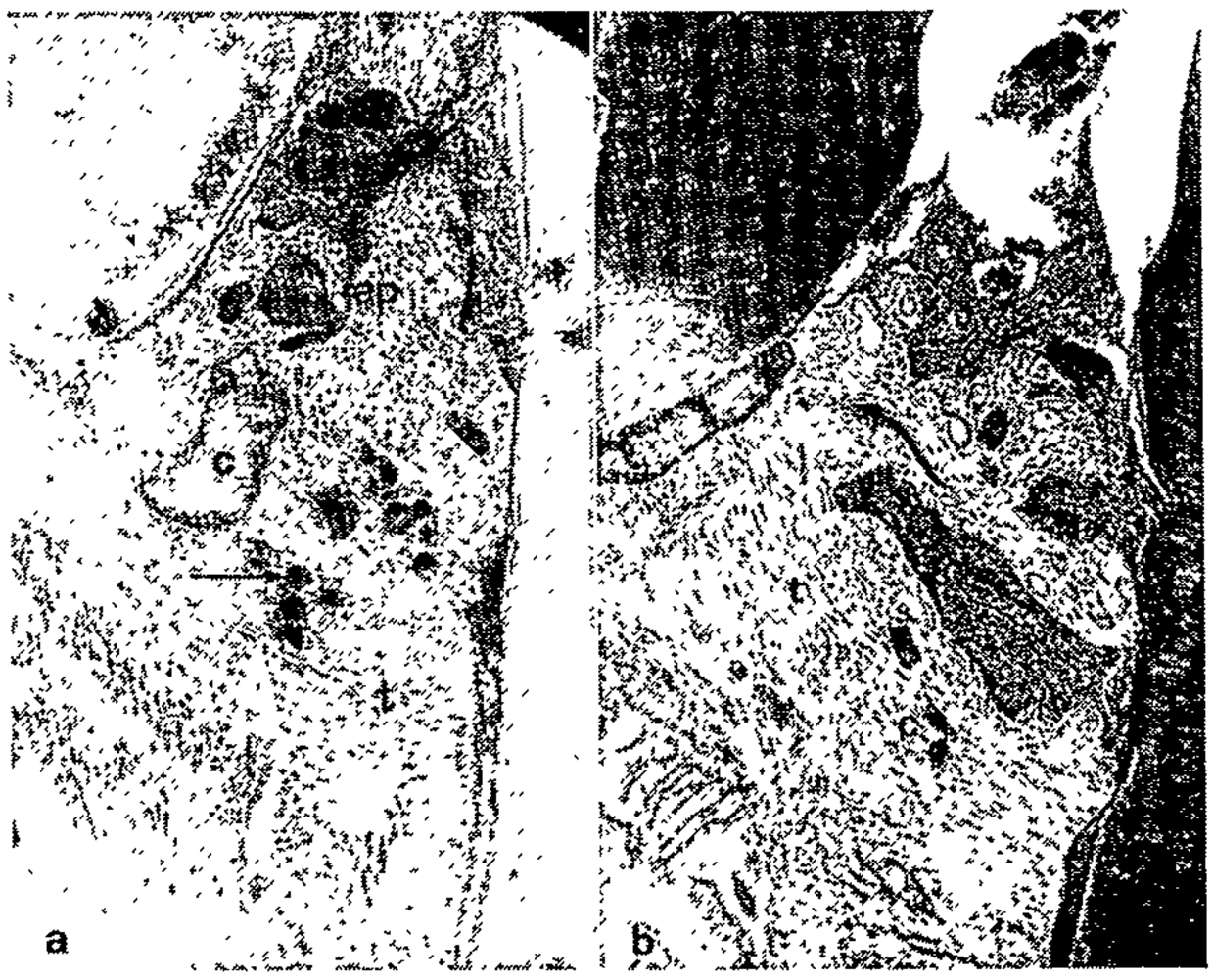

Fig. 3.

(a) Interproximal tissues in lower right molar region of male rat [418 g, 135 days] Diet ii. Cementum, c; transverse fibres of periodontal ligament, t; epithelium, ep; calcific bodies (arrow). H & E × 80.

(b) Interproximal tissues in lower right molar region of female rat [247 g, 107 days] Diet v. Transverse fibres of periodontal ligament, t; cementum, c. H & E × 80.

dontal tissues in 36 instances and in 2 of these were associated with a cyst-like cavity.

The relation between the 4 conditions—inflammation, epithelial proliferation, bone resorption and disruption of the periodontal ligament is shown in descending order of frequency in Table 3.

It will be noted that there is a predominance of the relation between the 3 conditions—inflammation, epithelial proliferation and bone

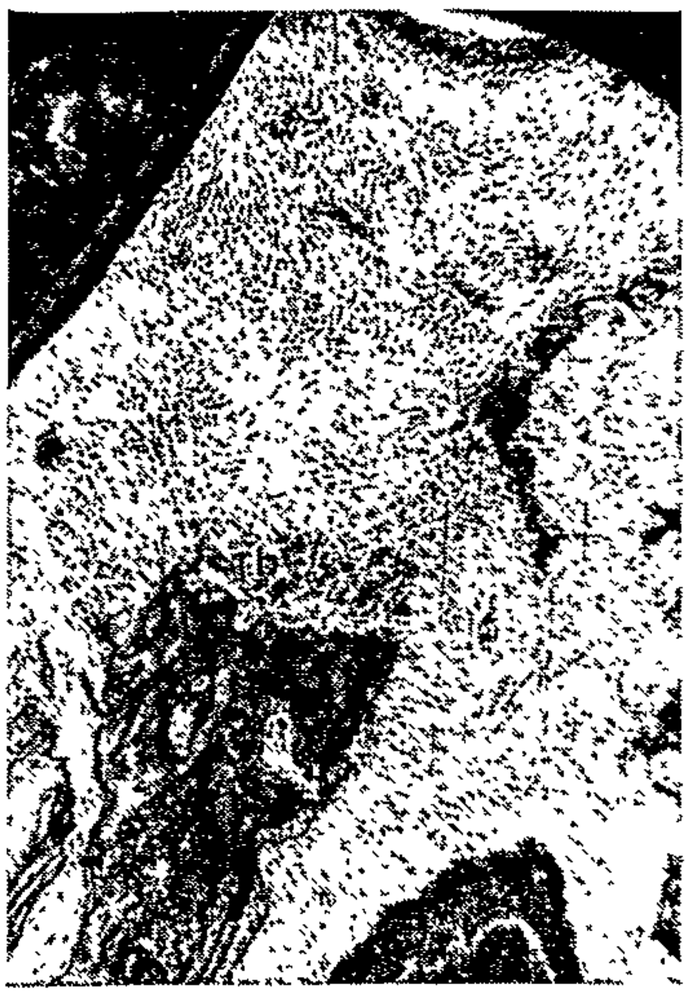

Fig. 4.—Interproximal tissues in lower left molar region in female rat [299 g, 107 days] Diet vii. Note extent of inflammatory reaction and resorption of bone at rb. H & E × 80.

TABLE 3

Frequency of association of the four conditions (1) inflammation, (2) epithelial proliferation, (3) bone resorption, and (4) disruption of the periodontal ligament in the periodontium of 53 Sprague Dawley rats

Relation	Frequency
1+2	193
1+2+3	123
1+2+3+4	59
1+3	23

resorption; and that of the 165 examples of bone resorption 123 were related to inflammation and epithelial proliferation.

The dislodgement of cementum occurred in 216 situations but in only 8 of these was inflammatory reaction to the cementum observed; multinucleated cells were present on the surface of the fragments of cementum in 3 specimens.

Animals in Groups 4, 5, 6 receiving diets of varying degrees of calcium deficiency may be compared and the relation of the 4 conditions is shown in descending order of frequency in Table 4. The relation between inflammation, epithelial proliferation and bone resorption appears to be somewhat more positive in the case of the animals on the calcium deficient and reduced diets. The correlation was of the order $P < 0{\cdot}0027$.

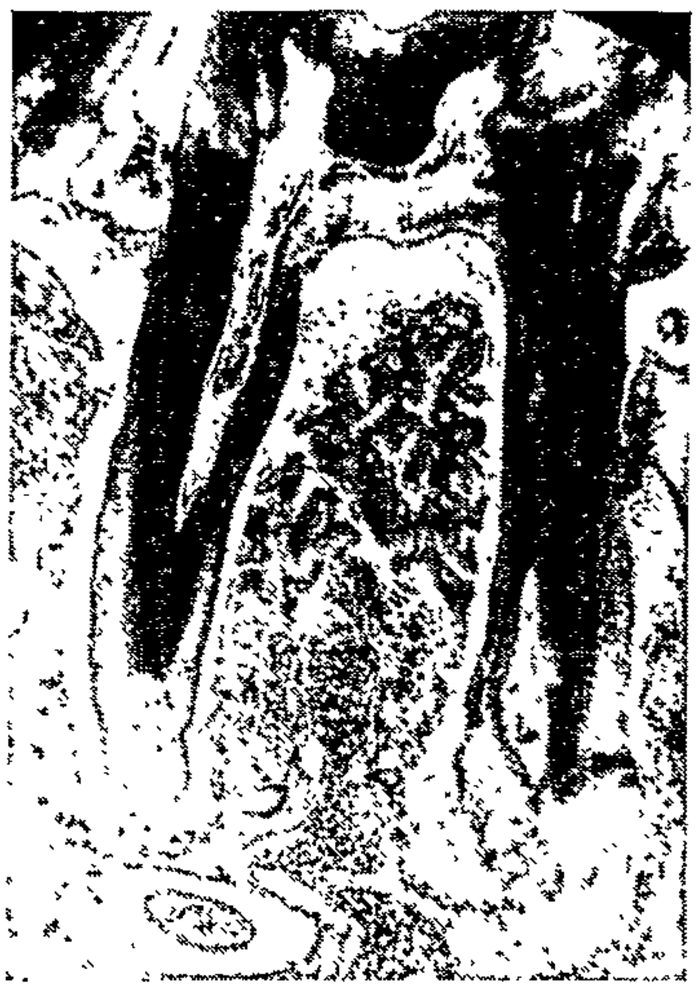

Fig. 5.—Interradicular alveolus in lower left molar region of male rat [376 g, 107 days] Diet iv. Note the width of the periodontal space is approximately normal and the resorption of cementum in some areas. H & E × 20.

TABLE 4

Frequency of association of the four conditions (1) inflammation, (2) epithelial proliferation, (3) bone resorption, and (4) disruption of the periodontal ligament in the periodontium of 23 Sprague Dawley rats on varying degrees of calcium deficiency

Relation	Frequency
1+2+3	48
1+2	35
1+2+3+4	22
1+3	14

Of the 7 animals in Group 4 all specimens showed evidence of osteoporosis (Fig. 5) in which two could be classed as mild. In Group 5 (9 animals) 8 animals showed evidence of osteoporosis (2 mild) and in Group 6 (7 animals) 5 showed evidence of mild osteoporosis.

The gingival papilla and its relation to the adjoining teeth are shown in Fig. 1 [male rat Diet iii]. The dense periodontal ligament with its transverse fibres and the epithelial papilla showing inflammation can be seen. The extent of epithelial proliferation in an isolated segment of the cementum of the lower right molar is shown (Fig. 1 ep). Extensive damage to the tissues with epithelial proliferation, cyst-like cavity formation and foreign body in the interproximal region between upper first

and second molars is shown in Fig. 2 [male rat Diet iii]. Interproximal tissues showing dislodgement of cementum [male rat Diet ii] (Fig. 3a) and cementum with epithelium attached lying in the periodontal ligament [female rat Diet v] (Fig. 3b). The inflammatory reaction is mild and appears to be limited to the epithelial zone. Some isolated spherical calcified bodies darkly stained with hæmatoxylin and eosin lie in the transverse fibres. Similar stained bodies were observed in various periodontal tissues not associated with the traumatized regions.

Figure 4 shows extension of inflammatory reaction and resorption of alveolar bone [female rat Diet vii].

Figure 5 is an example of interradicular alveolar septum in the lower right molar of a male rat on Diet iv. The general contour of the bone remains with normal periodontal membrane width, except at the bifurcation of the roots, but osteoporosis is present. Not all of the specimens show this picture, and in some animals very much less bone structure remained. Resorption of cementum is seen but this was also noted in some animals in Groups 1-3.

Discussion

The study was designed to determine the effect of repeated trauma to the gingival sulcus and the possible influence of dietary factors on the progress of the disintegration of the periodontal tissues.

The work of Skillen,[1] Gupta and Shaw[2] and Cohen[3] indicated that proliferation of epithelium in the rat periodontium could be expected. This apparently is mainly the result of damage to the enamel epithelium from intrusion of foreign bodies contained in the usual laboratory type diet. Shaw also noted[4] that the addition of sucrose increased the extent of periodontal disease. Henriksen[6] noted that progressive loss of bone sufficient to cause detachment of the incisor teeth in dogs occurred after 12 months on a calcium-deficient diet. He also noted that calculus did not play any role in the production of periodontal disease since it was present in the mouths of animals in both control and experimental groups. Baer and Fitzgerald[5] had demonstrated periodontal disease in Sprague Dawley rats living on a nutritionally adequate diet in a germ-free environment. The lesions were characterized by the apical migration of the epithelial attachment and loss of alveolar bone. König and Mühlemann[7] observed pocket-like gingival lesions in Sprague Dawley rats fed a soft diet and plain drinking water.

In this study the presence of calculus was noted but it was associated with proliferation of the epithelium and bone resorption in only 37 teeth and its presence was detected histologically in 93 teeth (54 female, 39 male animals). The inflammatory reaction and proliferation of epithelium appear to be more frequently noted in Groups 4-7 (Table 2). These animals had a finely powdered purified diet and the presence of food debris around the teeth could be a contributing factor. Bone resorption was also more prevalent in Groups 3-7.

The calcium deficient diet does appear to have had some effect on the frequency of association between inflammation, epithelial proliferation and bone resorption. Oliver[8] noted that calcium deficiency produced a reduction in the amount of bone present and that the changes resembled osteoporosis, which is confirmed in this study. Ferguson and Hartles[9] [10] have also noted similar changes. Oliver[8] also reported that rats taking calcium deficient diets containing blood albumen gained weight less rapidly than the controls. The differences were greatly increased when blood albumen was replaced by egg albumen.

Diets iv-vii in this study were based on calcium-free casein and animals in Groups 5-7 showed weight gains progressively greater when calcium was introduced into the diet (Table 1), being comparable with those noted where sucrose was added.

Damage to cementum was extensive (Table 2) and mostly confined to the interproximal regions (mesial of the first molars showing

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[6] Henriksen, P.—Periodontal disease and calcium deficiency. An experimental study in the dog. Acta odont. Scand., 26: 1-132, 1968. Supp. 50.

[7] König, K. G., and Mühlemann, H. R.—Alterations in rat gingivæ due to plaque accumulations. Helv. odont. Acta, 3: 2, 44-48 (Oct.) 1959.

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[10] Ferguson, H. W., and Hartles, R. L.—Effects of diets deficient in calcium or phosphorus in the presence and absence of vitamin D on the secondary cementum and alveolar bone of young rats. Archs. oral Biol., 9: 6, 647-658 (Nov.-Dec.) 1964.

less than 10 per cent) but did not appear to play any major part in the production of periodontal lesions. Foreign bodies were noted sometimes in association with cyst-like lesions but were not as frequent as suggested by Cohen.[3]

The association between inflammatory reaction, epithelial proliferation and bone resorption (Table 3) in 342 sulci on 123 occasions (36 per cent) was greater if the calcium deficient animals are taken separately (Table 4). In these instances it was observed in 48 subjects (5·2 per cent).

King and Martin[11] maintain that the influence of the oral microflora is secondary to irritation and injury to the gum surfaces, and that in the absence of nutritional deficiencies, retention of food debris about the teeth and deposits of salivary calculus comprise the main causative agencies of periodontal disease. It cannot be overlooked, however, that inflammatory changes may render the gingival tissues less resistant to bacterial invasion; nevertheless Baer and Fitzgerald[5] have demonstrated periodontal lesions in germ-free rats. Rovin, Costich and Gordon,[12] however, found in germ-free animals that inflammation did not occur when the tissues had been traumatized for periods up to 10 weeks with rubber ligatures around the molars.

Smith, Baer, King and White[13] studied the effect of diet on calculus formation in the rat and found a high fat diet to be as effective as a high carbohydrate diet in producing oral calculus. They used 5 per cent or less sucrose in drinking water in combination with diets known to produce calculus.

In this experiment only one diet (Diet iii) had an addition of sucrose. Table 2 shows greater prevalence of calculus in the animals of Groups 4-7 in which the diet was a finely ground mixture of casein and mineral salts. The least calculus was noted in Group 1 on whole rat cubes and the addition of sucrose appears to cause no increase in calculus formation.

Rushton[14] noted in golden hamsters the epithelial proliferation in certain regions of some teeth and that plaque was markedly reduced by incorporating ground animal charcoal in the diet and as a result the epithelial proliferation was diminished.

The observations from this study suggest that (1) repeated trauma not only produces inflammatory changes in the soft tissues but increases epithelial proliferation leading to bone resorption; (2) this association is greater with diets deficient in calcium; (3) the presence of fragments of cementum in the periodontium appears to have little deleterious effect; (4) excessive trauma which disrupts the epithelium of the gingival papilla and sulcus may produce cyst-like cavities.

Finally, the question posed by Leung[15] is important. "To what extent are the conditions observed in animals comparable to human periodontal disease?"

Summary

The study covering 23 weeks of the effect of repeated trauma associated with modifications in the physical nature and in the calcium content of the diet of Sprague Dawley rats indicates:

(1) repeated trauma leads to bone resorption;

(2) the addition of sucrose to finely prepared diet does not appear to influence the production of calculus, inflammatory reaction or epithelial proliferation;

(3) calcium deficiency is associated with an increased frequency in bone resorption.

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Glomus tumour of the periodontal tissues

R. Harris and C. J. Griffin

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Glomus tumour of the periodontal tissues

R. Harris* and C. J. Griffin†

Case report

Introduction

In the corium of the skin of the finger tips, particularly in the nail beds, around the joints of the extremities, over the scapula and coccyx, and in other regions there are normally arteriovenous shunts or glomera. Tumours of these structures are known as glomus tumours. They are common in the nail bed appearing as purplish red spots several millimetres in diameter, and are often clinically diagnosable by a characteristically lancinating, often severe, pain.

Histologically the tumour may be identified by the presence of several rows of peritheliomatously arranged glomus cells in which mitotic figures are rare or absent. These cells may be so numerous as to obliterate vascular lumina and may resemble a basal cell tumour.

Griffin[1] described a glomus tumour in the human temporomandibular meniscus. King[2] described the nucleus of the epithelioid cells and the presence of collagen fibres between the cells. He referred to three types of glomus tumours, namely: cellular, vascular and fibrous. In the cellular type the tumour is recognized by the presence of numerous epithelioid cells, and in the vascular type by dilated blood vessels filled with blood clot and a few epithelioid cells in the walls of vessels. The fibrous type has epithelioid cells and a large amount of fibrous tissue in the walls of the vessels.

Shafer, Hine and Levy[3] referred to glomus tumours and appeared to prefer to list them as hæmangiopericytomas. Of these only about 5 per cent were said to occur in the oral cavity and pharynx. They suggested that histological variations are found and hence there is a difficulty in diagnosis. However, there is a characteristic concentric layering of cells about the capillaries. Allen,[4] however, stated a hæmangiopericytoma lacks the pain symptom and the organoid structure of the glomus tumour. Small and Bloom[5] reported the occurrence of an example of hæmangiopericytoma in the floor of the mouth and Thoma[6] quoted the case of Guilmote, Molaret and Capdeville in which the tumour was found in the tongue of a 21-year-old male. More recently a glomus tumour of the hard palate has been reported by Grande and D'Angelo.[7]

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(1) Griffin, C. J.—Glomus tumour in the bilaminar zone of the human temporomandibular meniscus. Austral. D. J., 7: 5, 377-380 (Oct.) 1962.

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(3) Shafer, W. G., Hine, M. K., and Levy, B. M.—A textbook of oral pathology. Philadelphia, W. B. Saunders Co., 2nd ed., 1963 (p. 142).

(4) Allen, A. C.—Pathology, Ed. W. A. D. Anderson. St. Louis, The C. V. Mosby Co., 2nd ed., 1953 (p. 1175).

(5) Small, I. A., and Bloom, H. J.—Hemangiopericytoma of the sublingual fossa: report of a case. J. Oral Surg., Anest. Hosp. D. Serv., 17: 4, 65-69 (July) 1959.

(6) Thoma, K. H.—Oral Surgery. St. Louis, The C. V. Mosby Co., 4th ed., 1963 (p. 940).

(7) Grande, F., and D'Angelo, E.—A glomus tumour of the hard palate. Arch. Ital. Laryng., 70: Suppl. 6, 89-99, 1962.

Apart from the difficulty of accurate diagnosis and the variability of the presence of pain, the possibility of a glomus tumour or an hæmangiopericytoma being disclosed in the early stages of its development in the alveolar tissues can be considered remote. The case history here reported supports this suggestion and indicates a need for the closest scrutiny of all intra-oral roentgenograms of patients with pain symptoms. In this instance the fact that gross caries existed in many teeth provided an obvious reason for pain so other factors were overlooked. The disclosure of a tumour on the root of the upper left second bicuspid after its extraction under general anæsthesia—a lesion which at subsequent histological examination was found to be a glomus tumour—indicates the necessity for careful scrutiny of all dental roentgenograms.

Case report

A married woman, aged 35 years, attended for the relief of pain from what her physician had stated was an "antral abscess" of three weeks' duration. On examination many gross carious lesions were found and a full mouth roentgenographic examination disclosed radiolucent areas at the apices of the upper left first premolar, lateral and central incisors, the upper right first and second premolars, the first and second molars and the lower first and second molars. A number of other teeth had carious lesions, not involving the pulp. No restorative treatment had been received. Arrangements were made for the removal of all carious teeth under general anæsthesia. The appointment for this was cancelled and she did not return to the United Dental Hospital for two years when the carious teeth were then removed under general anæsthesia.

Roentgenographic examination:

A study of the periapical films shows an alteration in the roentgenographic image of the alveolar septum between the upper left second premolar and first molar (Fig. 1). The roentgenographic appearance of the lesion shows an irregular but clearly defined radiolucent area extending from the periodontal membrane of the distal surface of the second premolar across the mesial buccal root of the first molar. This radiolucent zone extends from the cervical third of the root to the floor of the maxillary sinus (Fig. 1). It appears to be located buccally to the mesiobuccal root of the molar. There are some small areas of greater radiolucency suggesting the invasive nature of the lesion. The outline of the molar root and its lamina dura are obscured.

A similar appearance is noted on the mesial surface in the apical region of the upper left canine and in the alveolar septa between the upper right lateral and canine, and between the lower right premolar and first premolar. The bone in the area of the lesions has an osteoporotic appearance (Fig. 1). King[2] referred to osteoporosis as one of the changes associated with a glomus tumour.

Histological examination:

On examination of the upper second premolar after its extraction, a firm reddish mass ($0{\cdot}5 \times 0{\cdot}25$ cm.) was seen to be attached to the cementum on the distal surface. The tooth was cut through the cervical region with a fissure bur and air rotor and the two pieces were immediately placed in Bouin's fixative; decalcification was carried out in 5 per cent nitric acid; the tissue was embedded in paraffin and sections were cut at six microns thickness and stained with hæmatoxylin and eosin.

The overall appearance of the section suggests that the tumour was of a mixed type, resembling in some areas a fibrous type of glomus tumour and in other areas that of the cellular variety (Figs. 2, 3, 4).

The supporting alveolar bone has been grossly destroyed. In some of the fibrous parts there appears to have been an attempt at encapsulation. There the central part of the encapsulated zone consists of the lumen of a blood vessel with a very thick wall (Figs. 2, 3).

The vessels have no internal elastic lamina and their lumina have a corrugated appearance. The media consists of smooth muscle cells and epithelioid type cells. The outstanding feature is the thickness of the adventitia and the numerous capillary vessels therein. The general appearance of these partially encapsulated vessels is that of a glomus body.

The other prominent feature of the tumour is the predominance in certain areas of epithelioid cells (Fig. 4). The central regions consist of blood vessels with characteristically thick media with epithelioid cells (Fig. 4), while from the surrounding tissue numerous epithelioid type cells in well defined patterns are demarcated. The cytoplasm of the epithelioid cell has no affinity for ordinary histo-

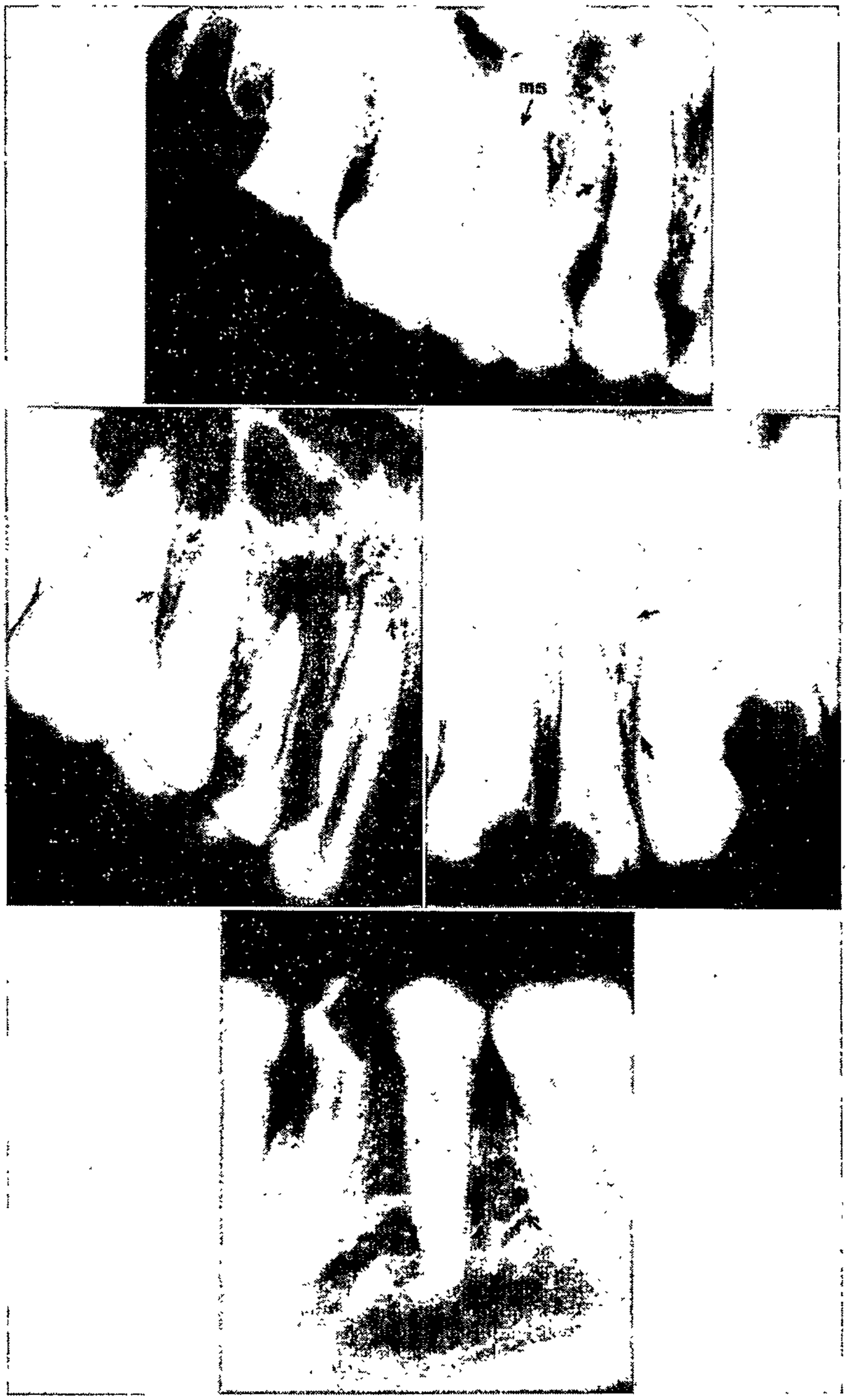

Fig. 1.—Four intraoral roentgenograms showing the area where the tumour was located between the upper left second premolar and first molar (arrows). The floor of the maxillary sinus, ms. Radiolucent zones appear in the apical region of the upper left canine and in the alveolar septa between the upper lateral and canine and the lower right second premolar and first molar.

Fig. 2.—Vascular portion of the tumour. Encapsulated glomus bodies, E; remnants of supporting alveolar bone, A; and dentine, D. Original × 150.

logical stains and this gives the oval nucleus a characteristic halo. Fine collagen fibres are found between the cells (Fig. 5). A great increase in the amount of fibrous tissue has destroyed the periodontal membrane (Fig. 4).

Discussion

The ætiology of glomus tumours is obscure, although trauma may be a factor.[8][9] They are not restricted to areas where glomus bodies

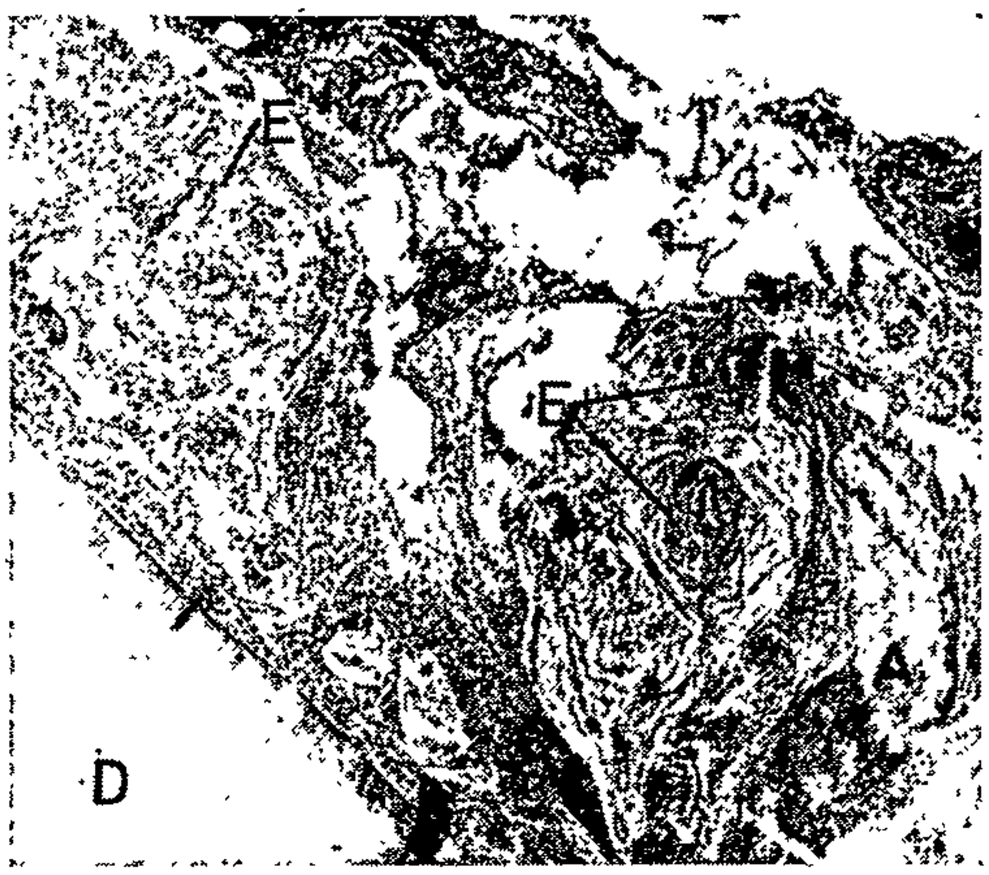

Fig. 3.—Fibrous portion of the tumour, adjacent to cementum and dentine, D; remnants of alveolar bone, A; and epithelial cell type blood vessels, E. Original × 150.

normally occur: King[2] reported finding a tumour of the cellular type in the subgingival tissue in the maxilla of a 32-year-old male

[8] Stout, A. P.—Tumors of neuromyoarterial glomus. Am. J. Can., 24: 6, 255-272 (June) 1935.

[9] Grauer, R. C., and Burt, C.—Unusual location of glomus tumor. J.A.M.A., 112: 1806-1810 (May 6) 1939.

and one was also found[6] in the hard palate. They are found most commonly in persons in the fourth to the seventh decades of life.

It would appear that glomus bodies are normally present in the periodontal membrane[10] and they are found in peridontosis,[11] presumably as a result of arterial occlusion[12] and by their elaboration destroy the supporting alveolar bone. Further growth of these bodies could constitute a glomus tumour. The roentgenographic appearance of these tumours in the jaw bones has not previously been described.

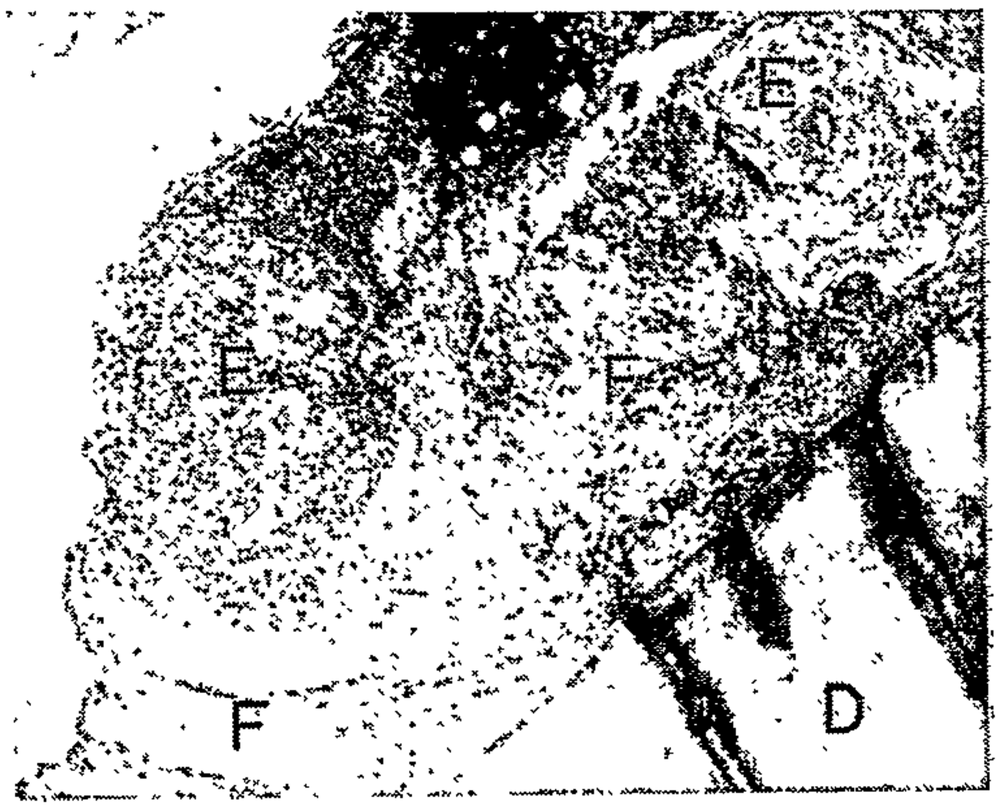

Fig. 4.—Fibrous, F, and cellular, E, portions of the tumour. Note the demarcation of the cellular from fibrous portion. Dentine, D. Original × 150.

This example suggests an irregular circumscribed lesion with extension into the surrounding bone.

It was not possible to assess the degree of pain attributable to the tumour since the patient did not return for further examination and advice. Despite the extensive destruction of the crowns and the presence of periapical pathosis on a number of teeth, the patient showed little desire for treatment. The diagnosis by her physician of an "antral abscess" suggests that severe pain may have been present at the time she attended for the extraction of teeth under general anæsthesia.

[10] Ishimitsu, K.—Beitrag zur keratosis der morphologie und entwicklungsgeschichte der glomeruli periodontii. Yokohoma Med. Bull., 11: 5, 415-432 (Oct.) 1960.

[11] Provenza, D. V., Biddix, J. C., and Cheng, T. C.—Studies on the etiology of periodontosis. II. Glomera as vascular components in the periodontal membrane. Oral Surg., Oral Med. & Oral Path., 13: 2, 157-164 (Feb.) 1960.

[12] Dorman, H. L., and Bishop, J.—Changes in vascular resistance following induction of chronic unilateral peridodontitis in dogs. J. D. Res., 41: 2, 453-458 (March-Apl.) 1962.

Glomus tumours are known to give rise to local, referred and remote pain of variable intensity. Descriptions, such as burning, dull, diffuse, excruciating and paroxysmal have been given to the pain suffered but in some instances the tumour is asymptomatic. In other individuals the pain is elicited only by pressure over the region of the tumour, this being the only indication of the tumour's presence.

Fig. 5.—Detail of cellular portion shown in Fig. 4. The lumen, L, of the blood vessel is surrounded by an intima having epithelioid cells, E. Epithelioid cells are also seen between the blood vessels; the non-staining cytoplasm gives a halo effect to the nucleus. Collagen fibres, C. Original × 700.

Sometimes the pain may be spontaneous and in King's[2] series of twenty-eight cases, four patients were regarded as having a neurosis. King quotes an observation made by Masson of a Horner's syndrome on the same side of the body as a sublingual tumour which subsided on its removal.

It should be noted in the case now reported that, because of the presence of gross dental caries with much periapical pathosis, the existence of the tumour was apparently overlooked. Its presence was established on histological examination. Subsequent study of the intraoral films revealed the roentgenographic image in the upper premolar-molar area. On careful inspection of the periapical roentgenograms the presence of radiolucent areas on other teeth strongly suggested the possibility of multiple glomus tumours in the maxilla of this patient.

Recognition of these tumours requires a meticulous study of intraoral films and the assessment of the significance of radiolucent areas and the degree of osteoporosis. Where painful symptoms occur pressure may elicit pain in the suspected area; or, alternatively, pain, either local or referred, will be eliminated by anæsthetization of the area. If these criteria are satisfied, a biopsy examination of the area should be made.

The destruction of alveolar bone would account for the variation in radiolucency seen in Figure 1. The fact, that at extraction a portion of the tumour came away attached to the tooth and that the fibrous zone near the dentine was thickened (Fig. 4) suggests the tumour originated in the periodontal membrane or the supporting bone. The presence of glomus bodies in the periodontal membrane makes it not unreasonable to propose that they may give rise to the glomus tumour, although the exact mechanism is not known.

The incidence of these tumours may therefore be more common than previously recognized and, because of the frequent occurrence of associated reflex disturbances, greater care in diagnosis is imperative. In some instances diagnosis of neurosis may be justified but it is wrong to accept this without a thorough and painstaking investigation.

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Implantation of chrome cobalt alloy tooth forms in the rabbit's mandible

R. Harris
with the technical assistance of Christa Lossin

Implantation of chrome cobalt alloy tooth forms in the rabbit's mandible

R. Harris*

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Metal appliances have been used in the body for various purposes for some hundreds of years but the degree of success has been variable, and in those instances where it appeared to have been achieved success was usually transitory. The major problem associated with the procedure lies in the corrosion of the metal by galvanic action.

Venables, Stuck and Beach[1] demonstrated that Vitallium was the only metal in which electrolytic action was absent and the bone tolerated its presence. Campbell and Speed,[2] who had observed the use of Vitallium for dentures, had suggested its use as a dependable material for the fixation of fractures even in the presence of gross infection, and it had been used by Smith-Petersen[3] for arthroplasty. Venables and Stuck[4] reported on their experience with the alloy for the fixation of fractures in 1941. A variety of materials, such as porcelain, ivory, gold, iridioplatinum and acrylic resins in many forms, have all been used for restoring isolated teeth or acting as abutments to which prosthetic appliances could be attached.[5] Most if not all of these oral implants resulted in failures because the materials were incompatible with the tissues as a result of infection, or because the implant was placed into alveolar bone which eventually resorbed.

Gershkoff and Goldberg[5] have developed a procedure for the construction and insertion of a full denture supported by four projections into the oral cavity from a subperiosteal mesh frame of Vitallium. An essential feature for the procedure is an accurate fit of the frame to the bone and this is obtained by using a direct impression of the bone for the model on which the casting is made.[6] Early investigations on the tissue reactions to the implants were made by Herschfus.[7] More recently, Held and Spirgi[8] reported on the osteoperiosteal reaction to various implants in rabbits' tibia and found the most favourable reaction to occur in the case of acrylic and tantalum, although in the latter the implants were on average in place only half the length of time of Vitallium implants. Schmidt[9] developed a "saddle" implant and his reports indicated that provided proper diagnosis is made of the existing condition and the resorption of alveolar bone is complete, it can be expected that saddle type implants supporting a prosthesis with fixed abutment at one end could be successfully retained from 6-10 years.

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* Director, Institute of Dental Research, Sydney.

Received for publication, July, 1969.

(1) Venables, C. S., Stuck, W. G., and Beach, Ann—The effects on bone of the presence of metals based upon electrolysis. Ann. Surg., 105 : 6, 917-938 (June) 1937.

(2) Campbell, W. C., and Speed, J. S.—The use of vitallium as a material for internal fixation of fractures. Ann. Surg., 110 : 1, 119-130 (July) 1939.

(3) Smith-Petersen, M. N.—Arthroplasty of the hip—a new method. J. Bone and Joint Surg., 21 : 2, 269-288 (Apr.) 1939.

(4) Venables, C. S., and Stuck, W. G.—Three years' experience with vitallium in bone surgery. Ann. Surg., 114 : 2. 309-315 (Aug.) 1941.

(5) Gershkoff, A., and Goldberg, N. I.—Implant dentures. Philadelphia, J. B. Lippincott Co., 1957 (pp. 11-16).

(6) Lew, I.—Progress report on full implant dentures. J. Pros. Den., 3 : 4, 571-575 (July) 1953.

(7) Herschfus, L.—Histopathologic findings on vitallium implants in dogs. J. Pros. Den., 4 : 3, 413-419 (May) 1954.

(8) Held, A. J., and Spirgi, M.—Osteoperiosteal response to various implants in rabbits. Helv. Odont. Acta, 12 : 1, 1-14 (Apr.) 1968.

(9) Schmidt, H. J.—Langzeiterfahrung mit dem Sattelimplantat. Deut. Zahn. Zeitschrift, 23 : 9, 944-956 (Sept.) 1968.

Gershkoff and Goldberg in 1957 devoted a chapter of their book to the unilateral subperiosteal implant, and have set down requirements on a similar basis to those of Schmidt, but nevertheless their opinion was that such implants can only be regarded as experimental.

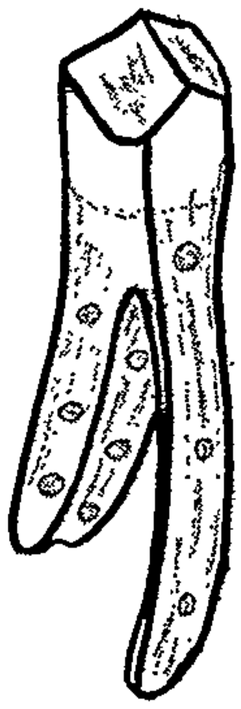

Fig. 1a.—Form of the chrome cobalt implant.

It should be noted that Weinberg[10] had previously reported the use of implants for abutments.

Linkow[11] also reported a reappraisal of the unilateral subperiosteal implant after a period of twelve years. He emphasized the need for the selection of the right conditions for its use and an improved design in which both buccal and lingual grooves are cut for the reception of chrome cobalt extensions. He concludes that "a subperiosteal implant is contraindicated when residual alveolar bone is present." Fitzpatrick[12] has evaluated various materials which can be tolerated as implants.

More recently, Linkow has presented information on the use of prefabricated intraosseous implants of a screw[13] or blade vent[14] type which form distal support in fixed units, and Izikowitz[15] used a posterior extension into the subperiosteal region for unilateral or bilateral fixed prostheses.

It is realized that chrome cobalt alloy implants have been successfully used in a variety of situations including restoration of the body and ascending ramus of the mandible, where they have been completely embedded in soft tissues.

This investigation was undertaken in order to assess the procedures currently practised.

Materials and methods

1. Fully grown albino rabbits weighing 3·75—4·5 kg were selected for the surgical implants.

2. Chrome cobalt castings* were made to match a number of shapes and dimensions of the lower first and second molars. Initially, these castings were simple replicas of the molar teeth, hollow and perforated in the root portion

Fig. 1b.—Two buccolingual sections showing implants (11A, 11B, 90 and 120 days) and the position of a retaining pin at "x".

and subsequently with a buccal extension which fitted over the cortical bone of the mandible providing a support through which pins could be driven into the cortical bone (Fig. 1a, 1b).

3. Anæsthesia was attained intravenously using pentobarbitone sodium 0·62 ml/kg body weight of animal, supplemented by inferior mandibular nerve block (lignocaine) 60 mg/ml.

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[10] Weinberg, B. D.—Subperiosteal implantation of a vitallium (cobalt-chromium alloy) artificial abutment. J.A.D.A., 40 : 11, 549-554 (May) 1950.

[11] Linkow, L. I.—Re-evaluation of mandibular unilateral subperiosteal implants: a twelve year report. J. Pros. Den., 17 : 5, 509-514 (May) 1967.

[12] Fitzpatrick, B.—A comparative study of some implant materials. II. Austral. D. J., 13 : 6, 422-434 (Dec.) 1968.

[13] Linkow, L. I.—Prefabricated mandibular prostheses for intraosseous implants. J. Pros. Den., 20 : 4, 367-375 (Oct.) 1968.

[14] Linkow, L. I.—Alloplastic endosseous implants. In *Current therapy in dentistry. III.* Ed. H. M. Goldman, S. P. Forrest, D. L. Byrd and R. E. McDonald. St. Louis, C. V. Mosby Co., 1968 (pp. 335-356).

* **Vitallium surgical,** prepared by courtesy of Professor C. H. Graham, Department of Prosthetic Dentistry, University of Sydney.

[15] Izikowitz, L.—Superplants. Acta Odont. Scandinavica, 23 : 1, 1-70 (Feb.) 1965.

TABLE 1

Results of the 24 implants inserted in the occlusal arch of the mandibles of rabbits (aged 3–20 months) for varying periods of 14–280 days

Implant No.	Rabbit age (mths.)	Region	Implant	Time (days)	Clinical result	Histological result	
0	3·0	M1	Tw	157	F	Superficial inflammation¶	Deep bone growth
1	5·0	M1	Tw	43	F	,, ,,	,, ,, ,,
2	5·0	M1	Tw	180	F	No reaction	,, ,, ,,
3	5·0	M1	Tw	180	F	Inflammation¶	,, ,, ,,
4	5·0	M2	Tw	29	F	No reaction	,, ,, ,,
5	5·0	M2†	Tw	56	NF	Inflammation	Slight bone growth
6	4·5	M1	Tw*	28	U	Extensive areas of granulation tissue and bone resorption	
7	4·5	M1	Tw(1)	14	U	Extensive inflammation	
8	4·5	M1§	Tw	90	NF	No reaction	Bone growth
9A	5·5	M1	Tw	240	F	Inflammation	,, ,,
9B	5·5	M1	Tw(2)	180	F	,,	,, ,,
10A	18·0	M1	Tp(1)	90	NF	,,	,, ,,
10B	18·0	M2	Tp	60	NF	No reaction	,, ,,
11A	8·0	M2	Tp	90	F	Inflammation	,, ,, around bar
11B	8·0	M2†	Tp	120	NF	,,	,, ,,
12A	6·0	M2	Tp	180	NF	,,¶	Apical abscess. Bone growth around bar
12B	6·0	M2‡	Tp	280	U	Extensive inflammation on lingual	Bone growth (buccally)
13A	6·0	M2	Tp	180	U	Inflammation	Apical cyst and abscess
13B	6·0	M2	Tp	210	F	Epithelium with inflammation	Some necrotic bone
14A	10·0	M2†	Tp	90	U	Extensive inflammation¶	Little bone growth
14B	10·0	M2	Tp	120	F	Inflammation	Bone growth
15	20·0	M2	Tp	37	U	Abscess at alveolar border¶	,, ,,
16A	10·0	M2	Tp	30	F	Abscess at alveolar border¶	,, ,,
16B	10·0	M2	Tp	60	F	Inflammation	,, ,,

Total		M1	M2	Tw	Tp	
24	M 7·3	10	14	11	13	M 110·4

Tw Implant wired.
Tp Implant pinned through buccal bar.
F Functional.
NF Non-functional: displaced buccally or anteriorly.
U Failure.
(1) Implant placed in four-weeks-old socket.
(2) Implant placed in eight-weeks-old socket.
* Mandible fractured at time of operation.
† Implant displaced buccally.
‡ Molar 2 not completely removed and tooth developed and erupted lingually.
§ This implant was extended through lingual plate and therefore not in occlusal function.
¶ Inflammation around foreign body.

4. Implantation was carried out through an external approach by an incision along the inferior border of the mandible, reflection of soft tissue and periosteum. Removal of the upper third of buccal alveolus over the tooth by round bur perforation and chisel enabled the tooth to be cut in half, elevated buccally and drawn down. A small elevator was then used to raise the apical half clear of the alveolus and then drawn down from the socket. An implant was chosen to match the size of the tooth. The chrome cobalt implant was first passed from below through the gingival cuff until the radicular portion could be placed into the remaining alveolar socket and then pushed apically. The animal's mandible was brought into centric occlusion and, if satisfactory, pins were driven through the attachment bar into the cortical bone. The soft tissues were replaced, periosteum and muscle layers sutured with catgut No. 4/0, and finally the skin sutured with black silk.

5. Postoperative treatment: Intraperitoneal injection of 200,000 I.U. penicillin daily for three days and soft mashed diet for ten days supplemented with milk.

6. In a number of instances right and left sides of the mandible were used. The implants were recovered at intervals from 1-9 months.

7. All animals were examined daily during the first postoperative week and then at weekly intervals. Each experiment was terminated on schedule or, if some postoperative condition warranted this, at an earlier stage.

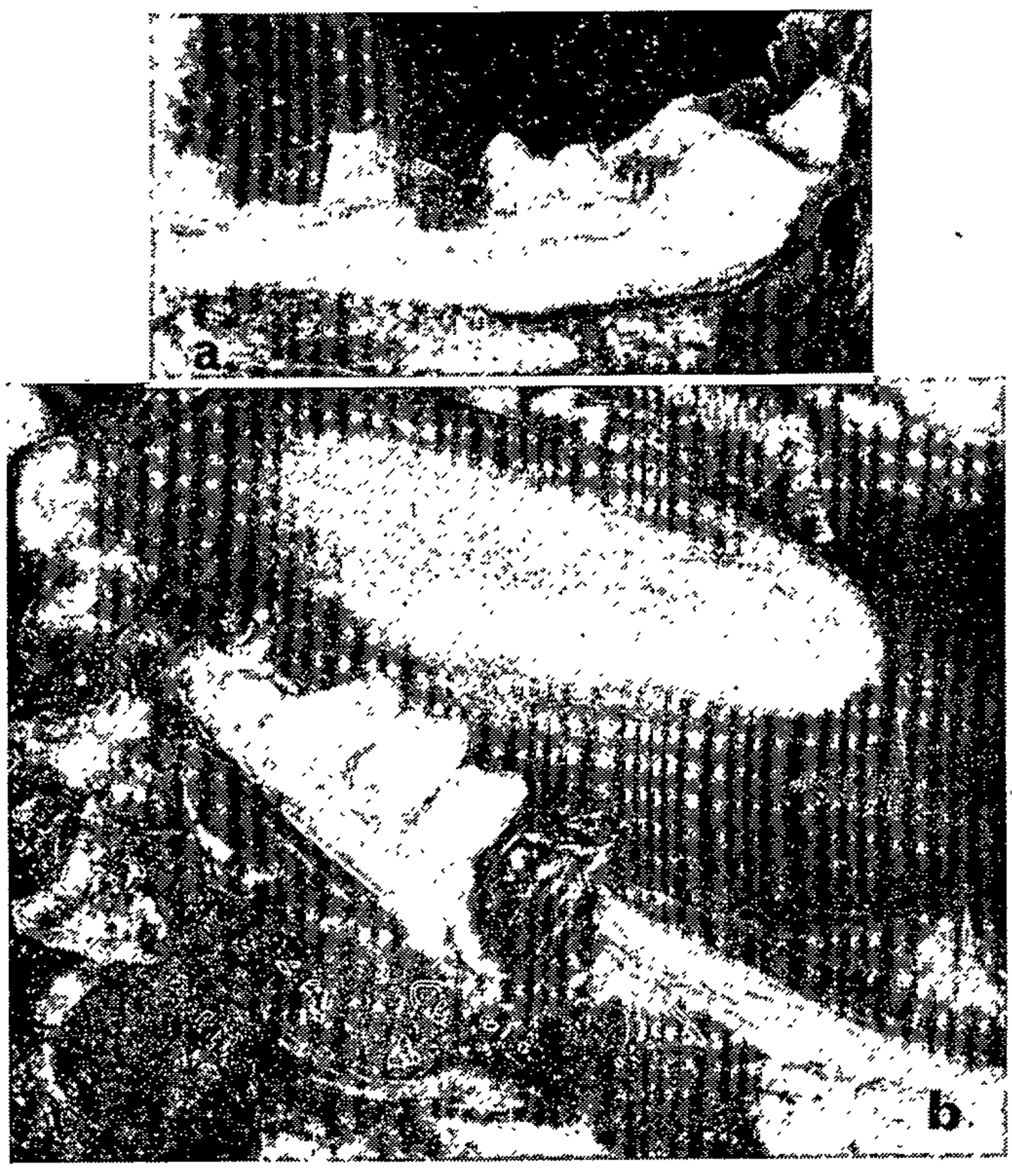

Fig. 2.—(a) Implant (16B, 60 days); (b) implant (9A, 240 days).

Observations

The record of each experiment is shown in Table 1.

Clinical

In all cases where there was no sign of infection, whether the implant was in correct alignment or lying buccally it was held firmly in position and was only dislodged after decalcification.

Twenty-four implants were inserted in the occlusal arch of the mandibles of 17 rabbits aged 3-20 months. Of these twelve were in functional occlusion with the opposing molars; six were in a buccal position arising from incorrect alignment. In two instances the implant was smaller than the original tooth and the space between the first and second molars was eliminated by movement of the first and third molars. In the other four the implant was pinned out of alignment buccally in two cases and below the occlusal plane in two cases. In all six of these cases the tooth was firmly held in the jaws.

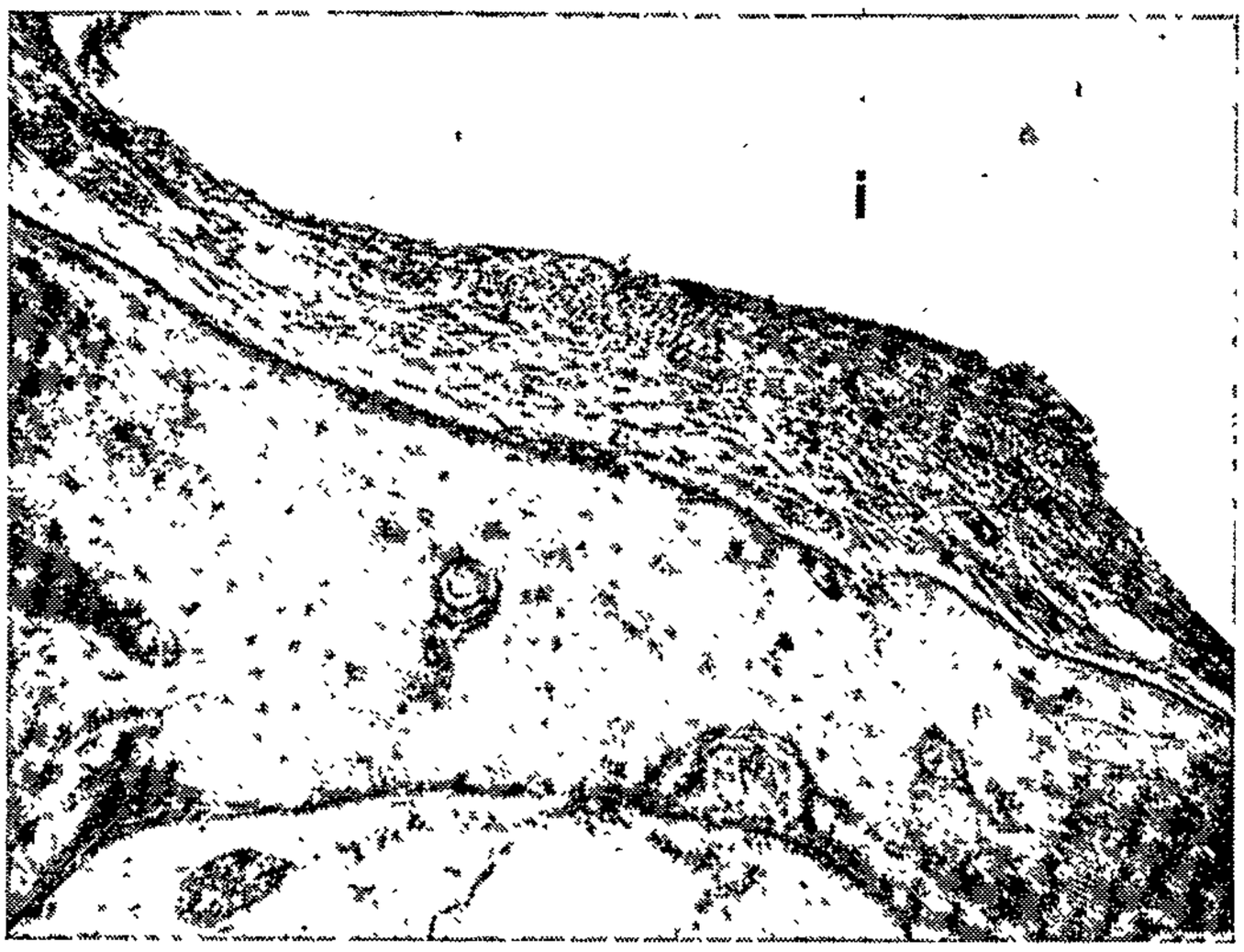

Fig. 3.—Fibrous layer covering bone of socket for implant (i) (2, 180 days). H & E × 18.

The remaining six implants were not firmly placed in the bone. There were obvious clinical signs of infection and they were unsatisfactory.

Two examples of the implants in position are shown in Fig. 2. It will be seen that the occlusal plane of the implant conforms to the general occlusal pattern of the arch and the soft tissues are in close apposition to the chrome cobalt alloy at the gingival margin.

Histological

In four cases no inflammatory reaction was observed in the gingival tissues. In two cases the implant was functional and in two non-functional, and the time interval ranged from 29-180 days.

In the remaining 10 functional cases some inflammatory reaction was present in the lingual soft tissues along the alveolar border in which a foreign body appeared to be the cause in three cases.

Inflammatory reaction of the lingual gingival tissues was present in four cases of the non-functional implants and in one of these it was associated with a foreign body. In 17 cases (functional 12, non-functional 5) bone deposition had occurred during the period of the implant, which ranged from 29-240 days, and the surface of the bone in apposition with the implant was covered with a layer of fibrous tissue (Fig. 3). The deeper portions of the supporting bar were surrounded by bone depositions in two cases (90 and 180 days) (Fig. 4). Bone depositions occurred around the retaining pins but did not cover the head of the pin in the subperiosteal region except in the two cases where bone was deposited around the retaining bar.

The six failures showed evidence of extensive inflammatory reaction in the gingival and deep tissues and in two of these a foreign body appeared to be associated with the reaction. A deep alveolar abscess (in the apical region of the original tooth) was present in one of the non-functional and one of the unsuccessful

implants; and extensive granulation tissue surrounded one of the unsuccessful implants.

The extent of the epithelial covering of the soft tissues of the gingiva and the penetration between the fibrous covering of the bone and the implant was noted (Table 2).

A more detailed examination of the fibrous tissue "membrane" covering the bone showed that in some instances purple staining fibres (Halmi) were present, and the tissue was well supplied with blood vessels (Fig. 5a, 5b).

A comparison between tooth and implant is shown in Fig. 7a, b, where the extent of epithelial covering is indicated by the arrow.

Discussion

The solution of the problems faced by the dental prosthetist and the patient for whom extensive surgery has been undertaken is formidable. Whether it can be solved or ameliorated rests upon so many factors that it is easy to accept the philosophy that nothing

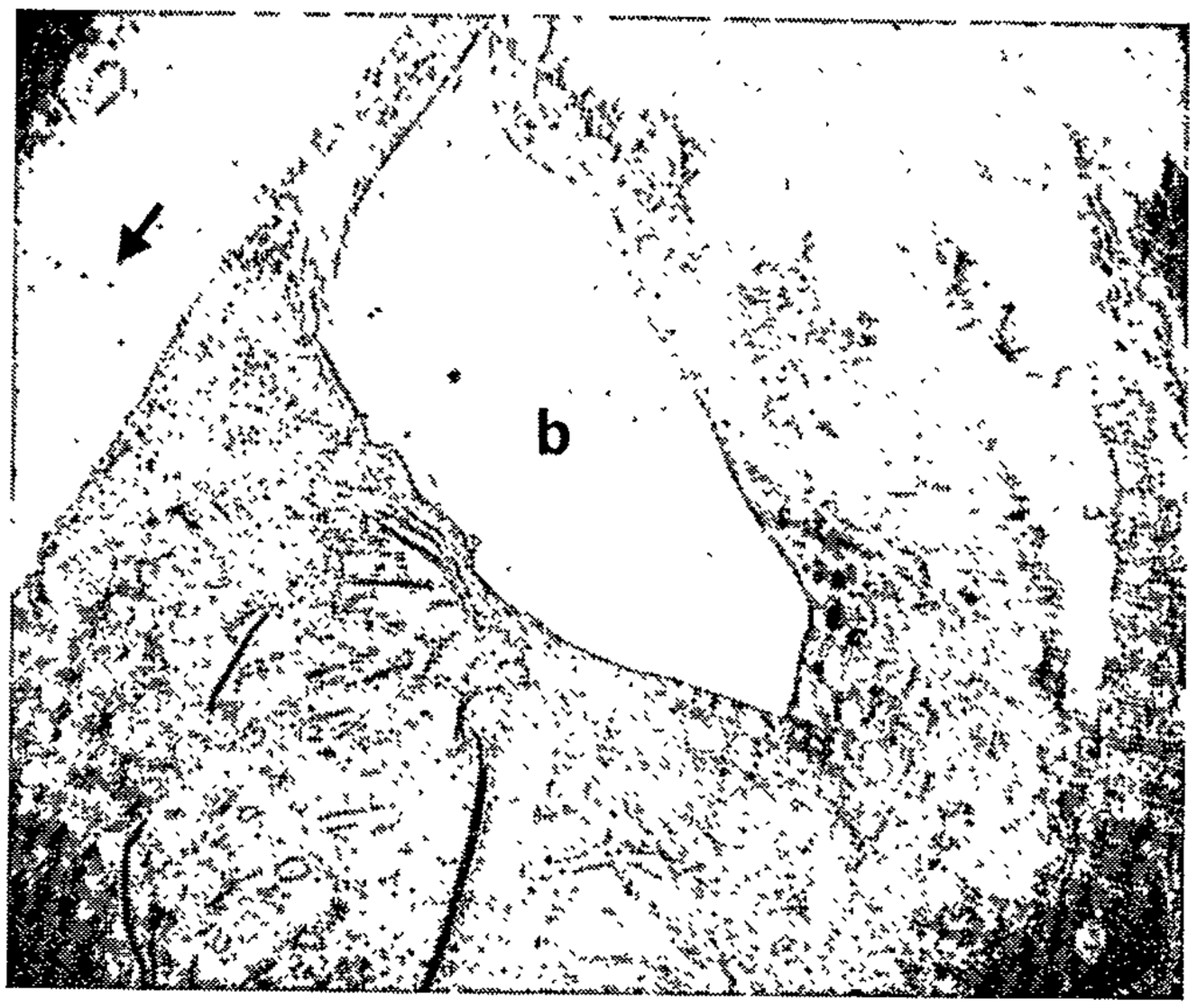

Fig. 4.—Bone deposition around retaining bar (b); direction of the retaining pin (arrow) (implant 16B, 60 days). H & E × 18.

The presence of an epithelial covering to the soft tissues in apposition to the implant was noted and there was a variation in the gingival apical length in relation to the time (Fig. 6a, b). Generally, the longer the implant was in place the greater penetration of the epithelium occurred (Table 2). It will be noted that the epithelium penetrated to a lesser degree on the lingual tissue. [It should be recalled that about one-third of the buccal bone had been removed.] The depth of penetration on the buccal was readily determined in those implants wired into place [marked "w" in Table 1], but where pinned through a buccal supporting bar the soft tissue covered the bar and the epithelium descended beneath it to lie between the connective tissue and the implant in the superficial regions.

can be done for such patients. Some patients have extreme difficulties in the wearing of full dentures and the implant, if it could be successfully used, would help in the solution of their problems. Metal implants can be fabricated for insertion and attachment to the mandible within the remaining soft tissues and are used occasionally.

Early attempts to use metallic implants in the alveolar bone have failed mainly because the tissues rejected the metal. Strock[16] reviewed some of the early work in this field [Maggiolo, 1809, Rogers, 1845, Harris, 1887, Edmunds, 1889, Bonwell, 1895, all of which failed because the metals were incompatible

[16] Strock, A. E.—Experimental work on a method for the replacement of missing teeth by direct implantation of a metal support into the alveolus. Am. J. Orth. Oral Surg., 25:5, 467-472 (May) 1939.

with the tissues; Greenfield, 1913, used iridioplatinum in a light mesh-like structure but it was not strong enough to withstand masticatory stress], and following the work of Venables, Stuck and Beach[1] used Vitallium screws in fresh sockets of human and dog

TABLE 2

*Presence of epithelium in apposition with the implant in relation to socket depth and time in 20 specimens**

Implant No.	Time (days)	Depth	
		Buccal	Lingual
7	14	L	Q
16A	30	S	Q
15	37	Q	S
5	56	Q	L
10B	60	L(M)	S(D)‡
16B	60	Q	Q
11A	90	Q	Q
8	90	L	Q
10A†	90	S	S
14A	90	S	S
14B	120	S	P
11B	120	S	S
0†	157	S	P
2	180	L(M)	L(D)‡
3†	180	S	P
9B†	180	S	L
12A	180	S	P
13A†	180	S	>P
13B	210	P	>P
9A†	240	S	Q

L=level with the alveolar bone.
Q=one-quarter length of the socket.
S=one-third length of the socket.
P=one-half length of the socket.

* Two specimens were cut in cross-section and two specimens had extensive inflammatory reaction with destruction of epithelial tissue. These have been deleted from the table.

† Implants had a transverse hole just below alveolar border level and bone covered with soft tissue and epithelium had grown into it.

‡ Cut mesiodistally.

jaws which remained in place and were accepted by the tissues for six months. Since then other metals and substances have been used.[17][18][19][20][21]

Metal implants of two main types have been and are currently used:

(1) The subperiosteal casting[5] which accurately fits the bone of the mandible or maxilla (in some instances it may be attached by screws to the bone) from which a number of carefully designed projections emerge through the periosteum;

(2) the intraosseous screw, and the blade vent.[13][14] These two are similar in principle but differ in implementation. The former is screwed into the bone exposed by surgical reflection of the mucoperiosteum and requires proper instruments for cutting the bone and inserting the implant. The latter is inserted into a slot cut into the bone and is retained in place by the deposition of bone into perforations in the metal.

Most protagonists for implants have reported satisfactory service in a high proportion of cases provided the method is carried out in carefully selected cases with the greatest care at all stages, including the construction of the denture. Knowlton[22] demonstrated an increase of about seven times in biting pressure with full upper and lower dentures following the insertion of the chrome cobalt implants. Herschfus[23] in a ten-year programme claimed 95 per cent success based on clinical evidence. Similar support is given by Trainin,[24] Lew,[25] Killebrew,[26] and Bodine[27] for the subperiosteal implant inserted and observed for 7-11 years.

The critics of the method base their rejection on the technical difficulties of the procedure, although the actual surgery is relatively mild and insertion of screws should occasion no trauma or shock; possibility of infection around the projecting parts,[28] unfavourable tissue reaction — no tight approximation

(17) Marziani, L.—The use of tantalum in reconstructive surgery with special regard to oral subperiosteal implants. Internat. D. J., 3 : 1, 12-13 (Sept.) 1952.

(18) Holland, D. J.—Alveoplasty with tantalum mesh. J. Pros. Den., 3 : 3, 354-357 (May) 1953.

(19) Bienstock, J. S.—Implants. A review of research, as regards tissue reaction to metal, plastic and dental implants. Oral Surg., Oral Med., Oral Path., 8, 4, 430-437 (Apr.) 1955.

(20) Budge, C. T.—Closure of an antraoral opening by the use of the tantalum plate. J. Oral Surg. 10 : 1, 32-34 (Jan.) 1952.

(21) Beder, O. E., and Ploger, W. J.—Intraoral titanium implants. Oral Surg., Oral Med., Oral Path., 12 : 7, 787-799 (July) 1959.

(22) Knowlton, J. P.—Masticatory pressures exerted with implant dentures as compared with soft-tissue-borne dentures. J. Pros. Den., 3 : 5, 721-726 (Sept.) 1953.

(23) Herschfus, L.—An evaluation of the present status of implantodontics. Oral Surg., Oral Med., Oral Path., 12 : 7, 800-813 (July) 1959.

(24) Trainin, B.—Dental implants in theory and practice. Brit. D. J., 102 : 10, 389-398 (May 21) 1957.

(25) Lew, I.—Progress in implant dentistry—an evaluation. J.A.D.A., 59 : 3, 478-492 (Sept.) 1959.

(26) Killebrew, R. H.—A decade of implant dentures. J. Pros. Den., 11 : 6, 1156-1165 (Nov.-Dec.) 1961.

(27) Bodine, R. L.—Implant dentures—follow up after seven to ten years. J.A.D.A., 67 : 3, 352-363 (Sept.) 1963.

(28) Sullivan, E. J.—Fundamentals of the implant denture. Discussion of paper by Goldberg, N. I. and Gershkoff, A. J. Pros. Den., 2 : 1, 40-50 (Jan.) 1952.

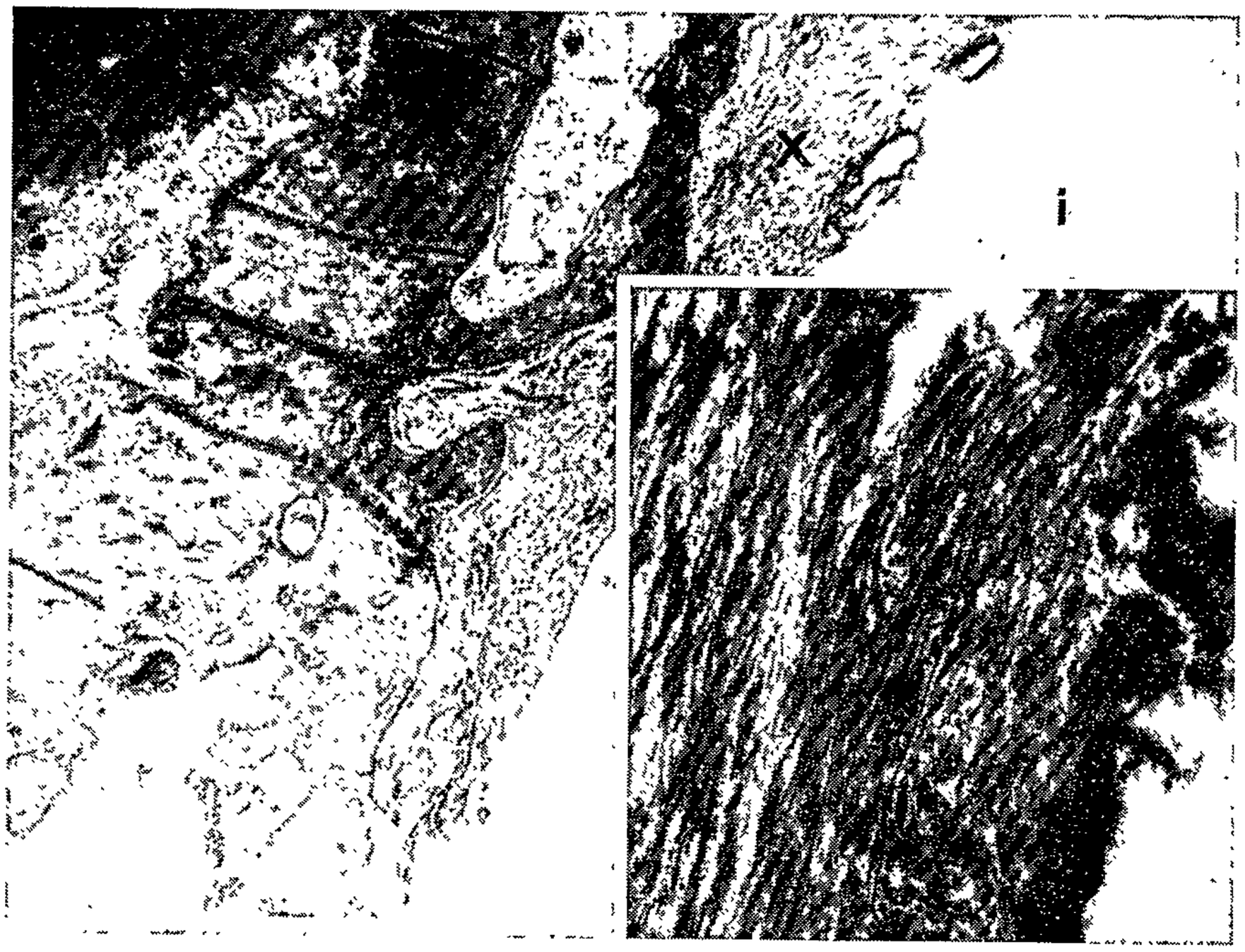

Fig. 5 (a).—Transverse section through implant socket (i) (implant 10B, 60 days). H & E × 15. *Inset*: Detail of "x". H & E × 250.

Fig. 5 (b).—*Inset*: Transverse section through implant socket (i) showing fibrous tissue covering bone (implant 10B, 60 days). × 18. Detail area of "x". Halmi × 250.

between the implant and tissue at the gingival margin, migration of epithelial cells between metal and tissue without evidence of attachment, inflammation of epithelium and cells adjacent to implant, metal is separated by a connective tissue layer from bone.[29] Obwegeser[30] had success in nine out of thirty-two cases and carefully assessed and listed the reasons for failure. He further emphasized that if the implant itself is successful, and he

Histological evidence is generally slender and has been largely provided from observations made on implants in animals living under laboratory conditions. Bernier and Canby[32] in 1943 observed the results when chrome cobalt screws were inserted into the sockets of freshly extracted monkeys' teeth. They reported little or no inflammatory reaction in tissues after 6-10 months. Lew[6] noted a thick type of compressed fibrous tissue resembling that of

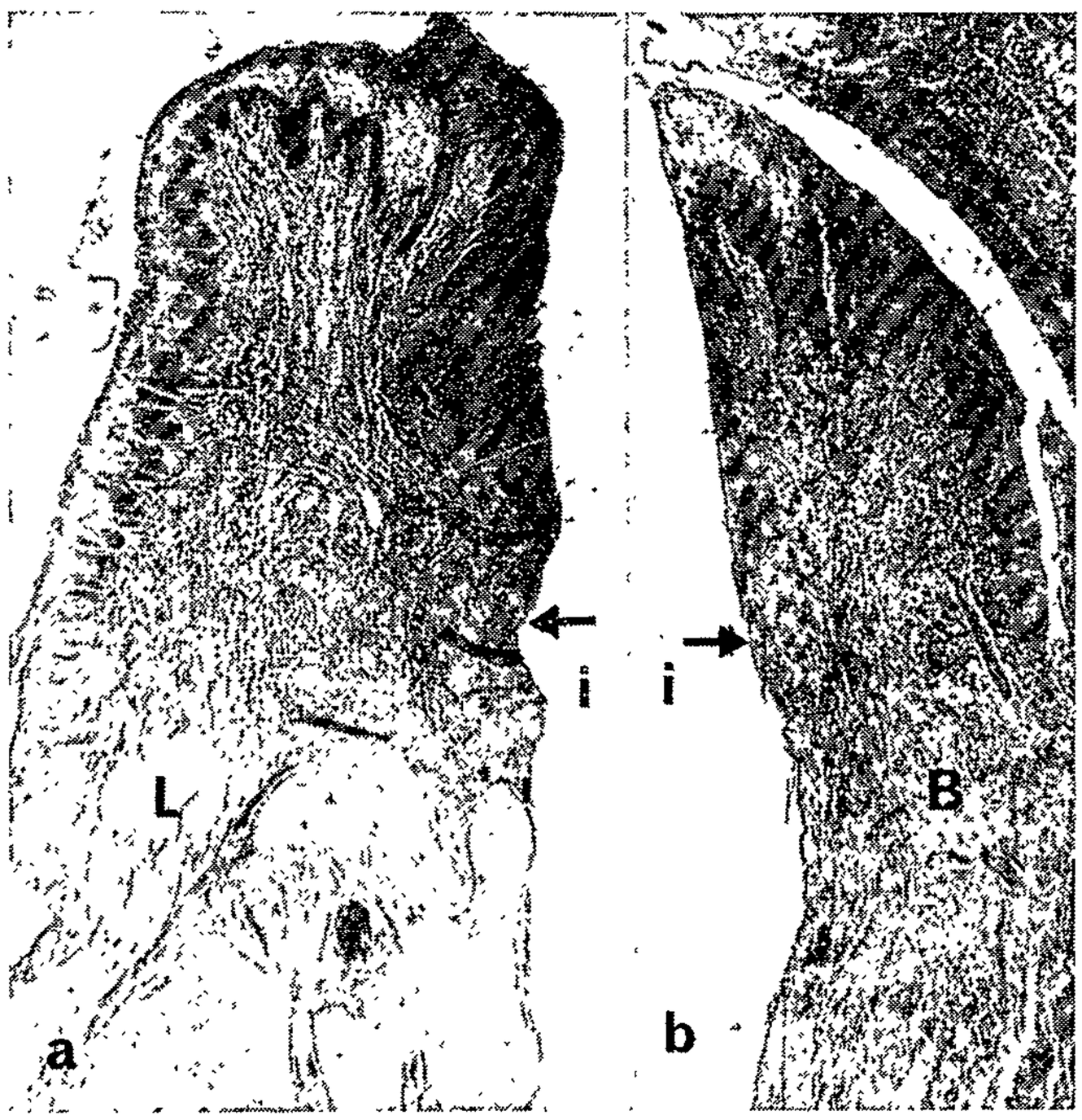

Fig. 6.—(a) Lingual gingival margin and alveolar crest (L); epithelial penetration (arrow) (implant 16B, 60 days). H. & E × 18. (b) Buccal gingival margin (B); epithelial penetration (arrow) (implant 2A, 180 days). H & E × 18.

is unable to explain the reason for success, the dentures must be constructed with the utmost care and skill. Supervision of the patient and oral hygiene must be regular and frequent. Coffin[31] gives only limited support for the method and says the implant is exfoliated ultimately but admits some patients have used implants for a number of years.

early hyaline cartilage formation around the implant which appeared clinically successful. Herschfus[7] observed the reaction to **Vitallium** implants bearing coronal superstructures placed in alveolar sockets of dogs and found no foreign body reaction and no pocket formation or accumulation of foreign material between implant and tissues. The epithelium was normal; in deeper areas of the socket calcification occurred and there were small zones of proliferating fibroblasts. Gross and

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[29] Nicholls, F. G.—Semiburied denture implants: review of the literature and an experimental study. J. Oral Surg., 12:3, 217-231 (July) 1954.

[30] Obwegeser, H. L.—Experience with subperiosteal implants. Oral Surg., Oral Med., Oral Path., 12:7, 777-786 (July) 1959.

[31] Coffin, F.—Surgery for prosthetics. Brit. J. Oral Surg., 2:1, 9-19 (July) 1964.

[32] Bernier, J. L., and Canby, C. P.—Histologic studies on the reaction of alveolar bone to vitallium implants. J.A.D.A., 30:2, 188-197 (Feb.) 1943.

Gold[33] observed the effects in dogs of completely buried implants and found no untoward tissue reactions. There was no fibrous tissue barrier between the screw and the bone except where the screws penetrated the inner cortex or the periosteum or muscle, although in the medullary cavity of the mandible a fibrous capsule was present between the apex of the screw and the medullary space. Mack[34] observed in monkeys that the implant lies in

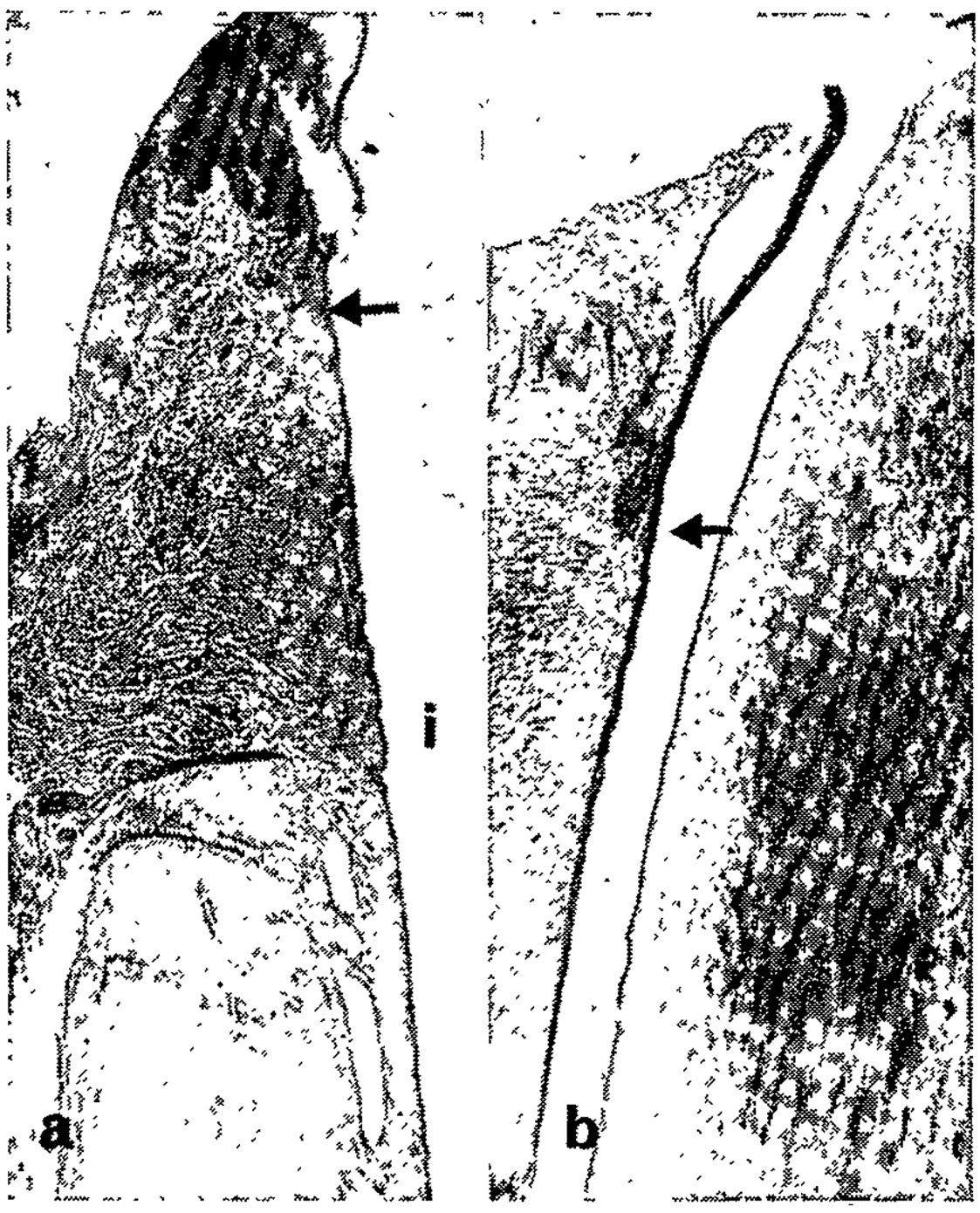

Fig. 7.—(a) Lingual gingival margin and alveolar crest; epithelial penetration (arrow); implant socket (i) (9A, 240 days). H & E x 18. (b) Relation of tooth to soft tissues from specimen 2A; epithelial penetration (arrow). H & E x 15.

a fibrous bed with an epithelial lining (probably a protective mechanism). There was little inflammation where the epithelium lies between implant and tissue.

Fitzpatrick[12] noted some inflammatory response of the tissues to Vitallium but suggested that this could be attributed to mechanical movement of the implant. Cobb,[35] observing the effect in dogs of subperiosteal implants, reported no clinical changes at the end of three months. The implants were firmly in place and the dogs were apparently able to chew without difficulty. There were areas of slight to moderate chronic inflammatory reaction and some fibrous tissue formation; no foreign body reaction, although there was fibrous replacement of bone marrow in some isolated areas. There was no notable new bone formation. Cranin and Cranin[36] reported the tissue reaction around one of the tissue inserts in a multiple insert supporting an upper denture and found no abnormalities, although there was an increased epithelial layer consistent with tissues found beneath a denture.

The studies reported in this paper can be compared with those discussed above. The difficulties of having ready access to the site

[33] Gross, P. P., and Gold, L.—The compatibility of vitallium and austanium in completely buried implants in dogs. Oral Surg., Oral Med. and Oral Path., 10:7, 769-780 (July) 1957.

[34] Mack, A.—Histological investigation of the effects of subperiosteal dental implants in monkeys. Brit. D. J., 108:6, 217-224 (Mar. 15) 1960.

[35] Cobb, J. R.—Subperiosteal vitallium implants in dogs. Oral Surg., Oral Med. and Oral Path., 13:10, 1153-1162 (Oct.) 1960.

[36] Cranin, A. N., and Cranin, S. L.—The intramucosal insert: review and progress report. J.A.D.A., 62:6, 658-665 (June) 1961.

of operation could have been responsible for the non-functional alignment in some cases and for the inadequate removal of the tooth prior to insertion of the implant. The implants were in position from 2-40 weeks and after the initial postoperative period the animals were fed on ordinary laboratory food pellets sufficiently hard to require chewing.

The method is essentially different from that originally used by Dahl[37] but resembles that of Weinberg[10] and Herschfus[7] and some of the modern techniques referred to by Linkow.[11][13] Schmidt[9] required alveolar resorption to be complete before inserting the implant subperiosteally. In this case resorption of alveolar bone would withdraw support from the implant.

The results suggest that a functional implant can be tolerated in the mandible of the rabbit for periods up to nine months. No inflammatory reactions are noted in four examples, whilst in ten some slight inflammatory reaction and in four marked inflammatory reaction had occurred in the soft tissue around a foreign body (food particle). By adequate design of the coronal shape this impaction of food may have been avoided. The bone reaction was somewhat different from that noted by Cobb,[35] since in 17 cases some bone deposition had occurred in the period beyond 29 days.

The results of these observations in rabbit mandible suggest:

(1) Functional chrome cobalt alloy implants in tooth sockets can be accepted by the tissues and remain firmly in position for periods up to nine months.

(2) The implants are accepted by the tissues without inflammatory or with only slight inflammatory reaction in the majority of cases.

(3) With appropriate design food impaction alongside the implant could have been avoided.

(4) Observations using more precise procedures in larger animals should be valuable and are now being made.

Parant[38] has expressed the view that even though implants may not be perfect they have been tolerated in the jaws of patients otherwise condemned to a life of prosthetic inefficiency. Some implants have been functional for years. However, their use is not universal. There is a severe demand for skill in diagnosis and assessment as well as manipulative skill. With the introduction of tantalum and titanium further studies are needed to assess the possible uses of the method. Behrman[39] expressed the opinion that the improved stability increased efficiency in mastication and this in turn hastened resorption of alveolar bone and thence failure of the subperiosteal implant.

Summary

1. The results of the use of chrome cobalt alloy implanted for periods up to nine months in 24 mandibular tooth sockets of rabbits have been reported.

2. The implants were firmly in position, functional and provoked a minimum inflammatory reaction in the tissues in 18 cases. Epithelial downgrowth was present but did not embrace the full length of the socket.

3. The gingival tissue was closely adapted to the implant.

4. The study in larger animals using other metals and procedures is continuing.

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United Dental Hospital,
2 Chalmers Street,
Surry Hills, N.S.W. 2010

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(37) Dahl, G. S. A.—Om möjligheten för implantationen i käken av metallskelett som bas eller retantion för fasta eller avtagbara proteser. Odont. T., 51 : 440, 1943. *Cited by* Gershkoff, A., and Goldberg, N. I.—*Ibid.*

(38) Parant, M.—Assessment of implant dentures in 1961. Internat. D. J., 11 : 4, 427-442 (Dec.) 1961.

(39) Behrman, S. J.—Dental implants: a clinical pathologic evaluation. Ann. Den. 20 : 2, 33-41 (June) 1961.

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The use of cobalt chromium alloy and titanium endosseous dental implants

R. Harris and Christa Lossin

The use of cobalt chromium alloy and titanium endosseous dental implants

R. Harris* and Christa Lossin†

"We must not ask where science and technology are taking us, but rather how we can manage science and technology so that they can help us get where we want to go"—Rene Dubos.

Introduction

A report on the use of cobalt chromium alloy tooth forms implanted in the mandibles of rabbits has been published.[1] Evidence suggested that further study of the subject was warranted and after the acquisition of appropriate shaped titanium implants** more extensive studies were carried out.

Titanium of the purity and physical properties suitable for orthopædic surgery had been available since 1953 when it was adopted as an answer to the problem of corrosion inherent in certain special stainless steels and has been in use in the United Kingdom since 1957.[2]

There is an Australian Standard, AST35-1966, covering the specifications for metals used for implants which include six types of titanium, T1-T6. T6 is the strongest material available and a British Standard, BS3531, had been in existence for some time previously.

Titanium T6 has a yield point of 34 tons/in², ultimate tensile strength 43 tons/in² and elongation of 18 per cent. It is normally used in the commercially pure form and its composition is:

Titanium 99·00 minimum.
Oxygen 0·50 maximum.
Iron 0·20 maximum.
Carbon 0·10 maximum.
Nitrogen 0·05 maximum.
Hydrogen 0·01 maximum.

Brief information on the preparation of titanium is given in the Appendix.

Formiggini[3] conceived the idea of a screw type implant and Cherchève[4] developed its shape and application. Both used cobalt chromium alloys and subsequently Linkow[5] improved the design using a self-tapping screw with a hollow shaft and vents. Linkow[6] in 1968 reported another design which did not utilize a screw. It is known as the blade vent and is inserted into a longitudinal slot in the alveolus. Some minor modifications to the screw have been suggested by Lew[7] which are designed to reduce the downgrowth of soft tissue between implant and bone. His implants are made from cobalt chromium alloy. Other types include titanium pins inserted into the bone to form a tripod (Scialom).[8]

This paper reports observations made in the use of cobalt chromium alloy and titanium implants in the jaws of dogs and in the use of titanium implants in man.

Materials and methods

1. Cobalt chromium alloy blade vents cast from Vitallium surgical were used in five implants.

2. Titanium screw vents (13), solid screws (2), blade vents (7) (Fig. 1) were used in 22 implants.

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* Director, † Chief Medical Technologist, The Institute of Dental Research, Sydney.

** Provided by courtesy of Down Bros. and Mayer & Phelps Ltd., Surrey, England.

(1) Harris, R.—Implantation of chrome cobalt alloy tooth forms in the rabbit's mandible. Austral. D. J., 14: 6, 396-406 (Dec.) 1969.

(2) Down, G. M.—Titanium as an implant material. Lecture presented before the Institute of British Surgical Technicians, London, November 23, 1965.

(3) Formiggini, M.—Protesti dentaria a mezzo di infibulazione diretta endoalveolare. Riv. Ital. Stomat., 11 (March) 1947.

(4) Cherchève, R.—Études critiques des methodes implantaires. Rev. Franc. Odontostomal., 12: 1307-1314, 1965.

(5) Linkow, L. I.—Intra-osseous implants utilized as fixed bridge abutments. J. Oral Imp. and Transplant Surg., 10: 17-23, 1964.

(6) Linkow, L. I.—The blade vent—a new dimension in oral implantology. Dent. Conc., 11: 2, 3-12, 1968.

(7) Lew, I.—The endosseous implant: evaluation and modification. Dent. Clin. N. Amer., 14: 1, 201-213 (Jan.) 1970.

(8) Scialom, J.—Implants aiguilles. J. Oral Imp. and Transplant Surg., 2: 18-25, 1965.

3. Nine adult female dogs were selected on the basis of adequate alveolar size in the premolar area and general suitability for handling.*

The surgical procedures for the implants were performed under intravenous anæsthesia [pentobarbitone sodium (Sagatal) 60 mg/ml-0·6 ml/kg body weight] and the wound closed with Ethicon sutures.

In order to shorten the recovery period from anæsthesia an intraperitoneal injection of Megimide [B : B-methyl-ethyl-glutarimide 50 mg/ml—2·5-3·0 ml] was given at the completion of surgery.

The dogs were given intraperitoneal penicillin G (1×10^6 I.U. in 5 ml H_2O) postoperatively, kept on a soft diet for a minimum period of one week and then allowed to eat a hard proprietary dog food. After a further three weeks the dogs were returned to the animal farm where they were examined at fortnightly intervals until collection of the specimens.

Procedure for insertion of the implants

In each case the teeth were extracted, gingival tissue reflected and the bone margin smoothed.

1. *Screw*

i. The socket selected was drilled to the size and depth required for the implant which was immediately inserted and the wound closed.

ii. After an interval varying from 18-26 weeks in which complete healing had occurred the soft tissues were reflected and a hole drilled in the bone to the size and depth required for the implant which was then screwed into place and the wound closed.

2. *Blade*

i. A slot of the required length, width, and depth was cut through the interseptal bone of the sockets, the implant immediately inserted.

ii. After an interval of 21-23 weeks in which complete healing had occurred the adjoining tooth was extracted, the soft tissues were reflected and a slot was cut to include part of the healed area and one tooth socket in which the implant was inserted.

iii. In one case the implant was inserted in an edentulous area.

Where a blade vent type of implant was inserted pins of the same metal were used to retain the implant in the alveolar bone to prevent the dogs from disturbing it.

In each instance radiographic examination of the jaws was performed before surgery and on completion of the experiment.

All implants were in positions where opposing teeth could be used during chewing. The implants were allowed to remain in the tissues for periods ranging from 3-67 weeks. Three implants (titanium screw vent and blade vent, and a cobalt chromium alloy blade vent) were removed because of mobility at the end of 9 weeks, 3 weeks, and 3 weeks respectively.

The dogs were killed with an intravenous injection of pentobarbitone sodium and a block of alveolar bone containing the implant was fixed immediately in 10 per cent buffered formol-saline. Decalcification was carried out in 5 per cent nitric acid or 4N formic acid and the specimens were embedded in paraffin cut at 6μ and stained with hæmatoxylin and eosin, periodic acid Schiff, Halmi, and hæmatoxylin-erythrosin-saffron.

Examples of the titanium implants in position at the time of their recovery and rœntgenograms are shown in Fig. 2, 3 and 4.

Observations

Clinical

The gingival tissues around all the implants with the exception of dog No. 4 (upper cobalt chromium alloy blade vent), dog No. 3 (upper titanium blade vent), and dog No. 3 (upper titanium screw vent) were similar in colour, texture and contour to that seen around the teeth.

These three implants were loose with slight gingivitis present and therefore were removed before the time originally set down. It is noted that they were placed in the maxilla and the reason for failure may have been inadequate bony support.

Another screw vent in the maxilla of dog No. 1 was slightly loose at recovery but the surrounding gingival tissues appeared similar

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* Appropriate prophylactic measures against distemper and intestinal parasites were provided by Mr. C. Bellenger of the Faculty of Veterinary Science, Department of Veterinary Surgery, University of Sydney, before the dogs were accepted for the treatment, and they were allowed to become accustomed to the environment of the animal laboratory before operative proceedings commenced.

The care and attention given to the animals by Mr. Peter Williams ensured the maximum of comfort for them during all the operative and postoperative stages.

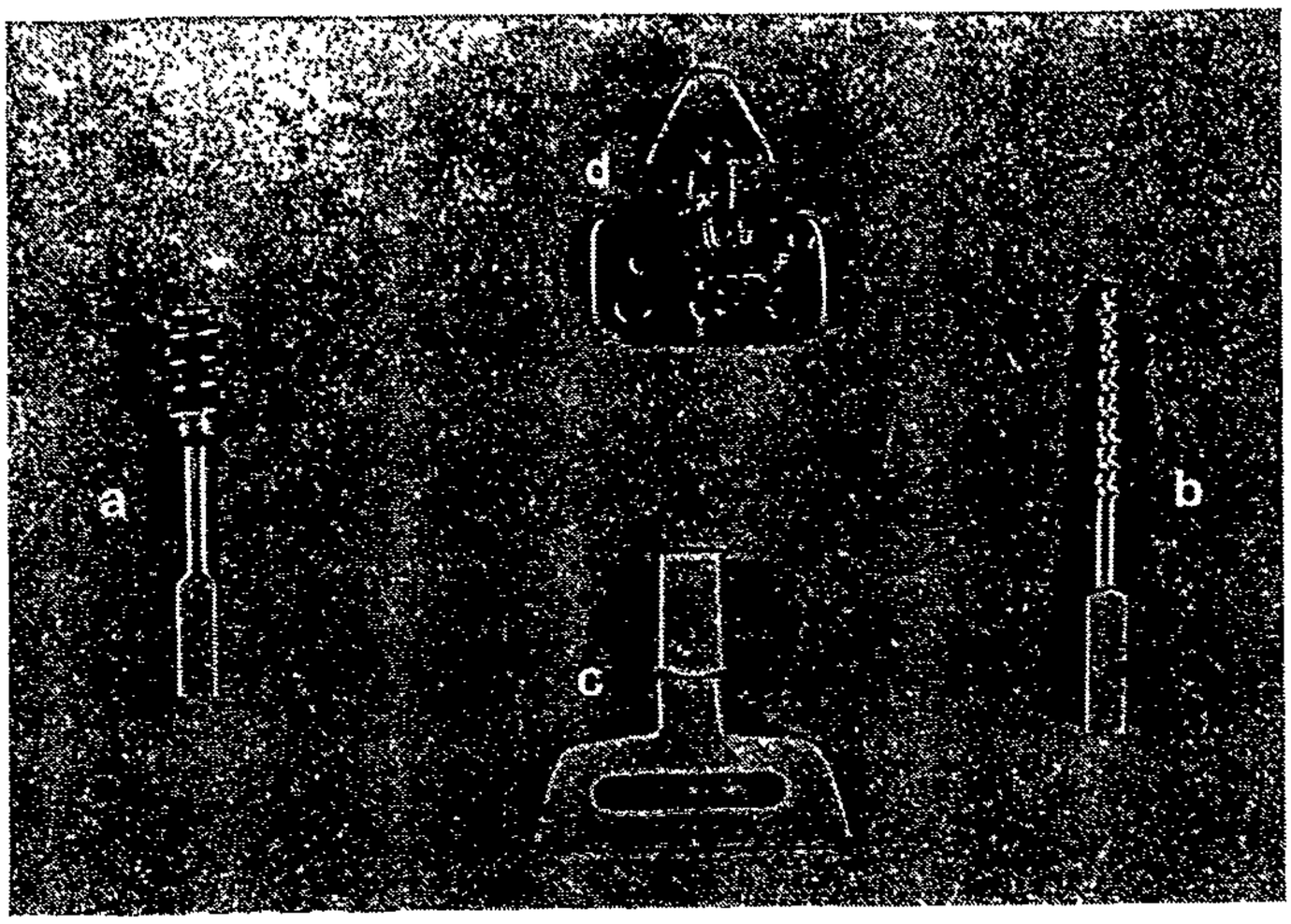

Fig. 1.—Titanium screw and blade vent implants. (a) screw vent; (b) tapering solid screw; (c) blade vent; (d) blade vent modified for use in dog.

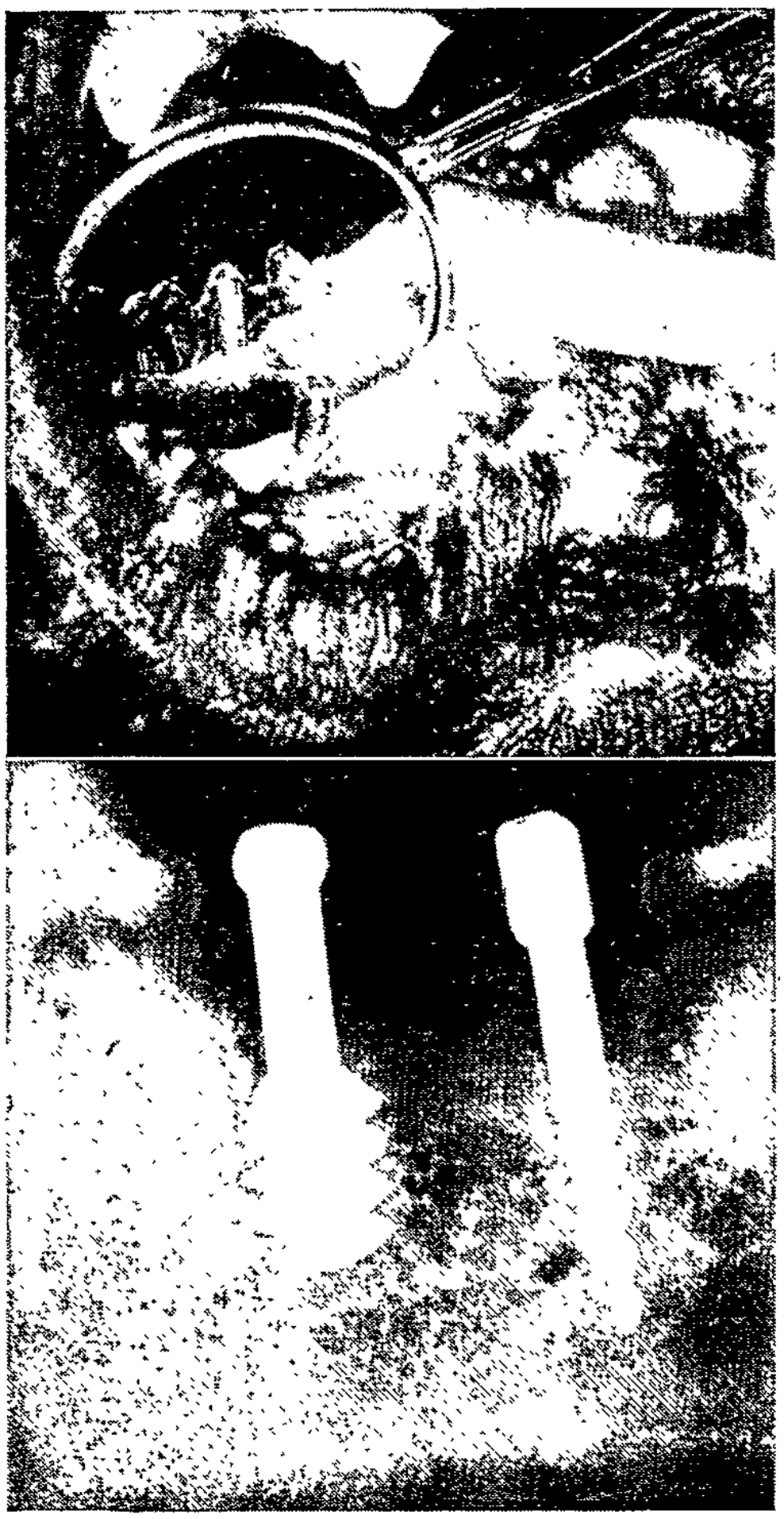

Fig. 2.—Tapering solid screw implant in right mandible of dog and roentgenogram of tapering solid screw and vent screw (36 weeks).

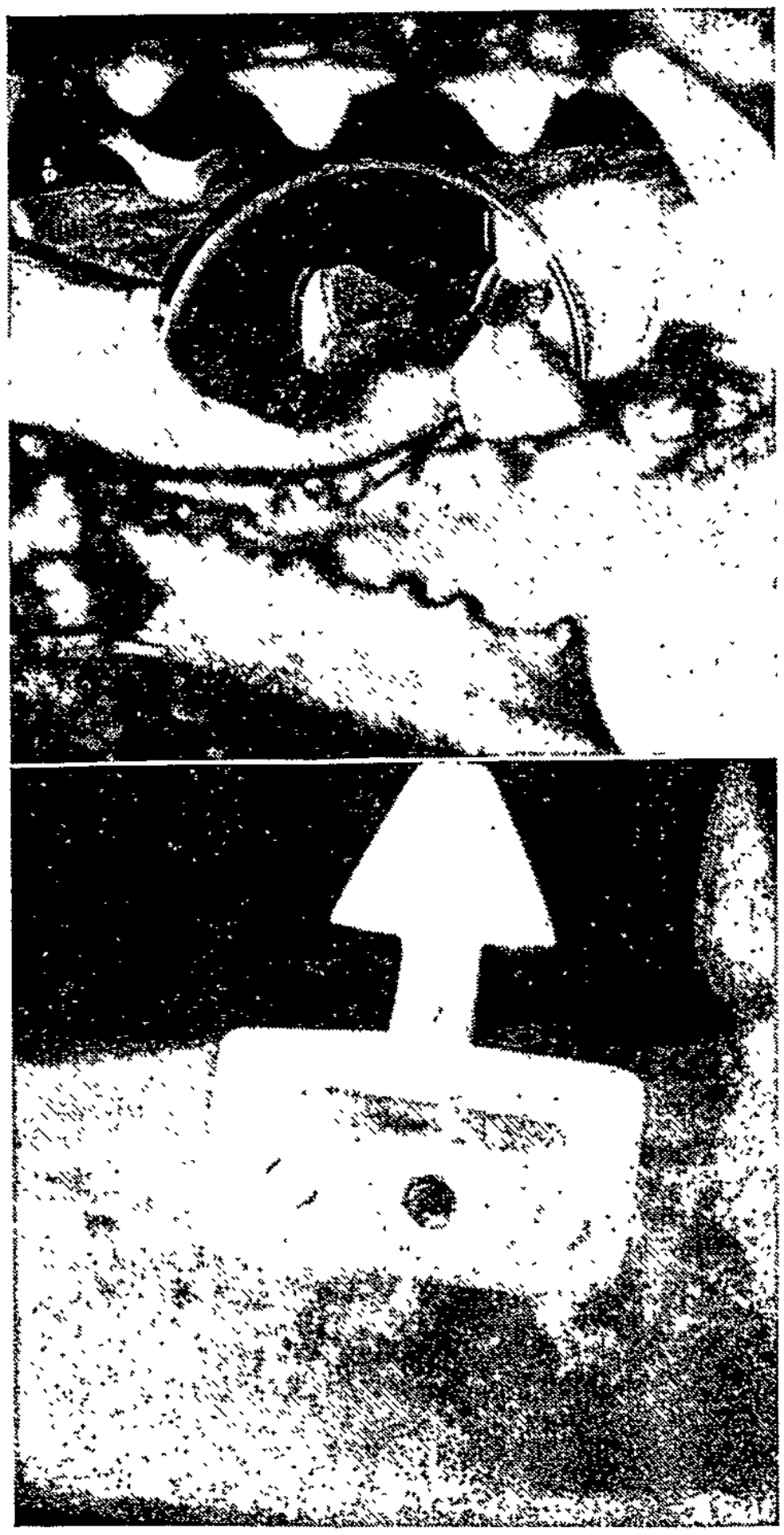

Fig. 3.—Blade vent in left mandible of dog and roentgenogram (33 weeks).

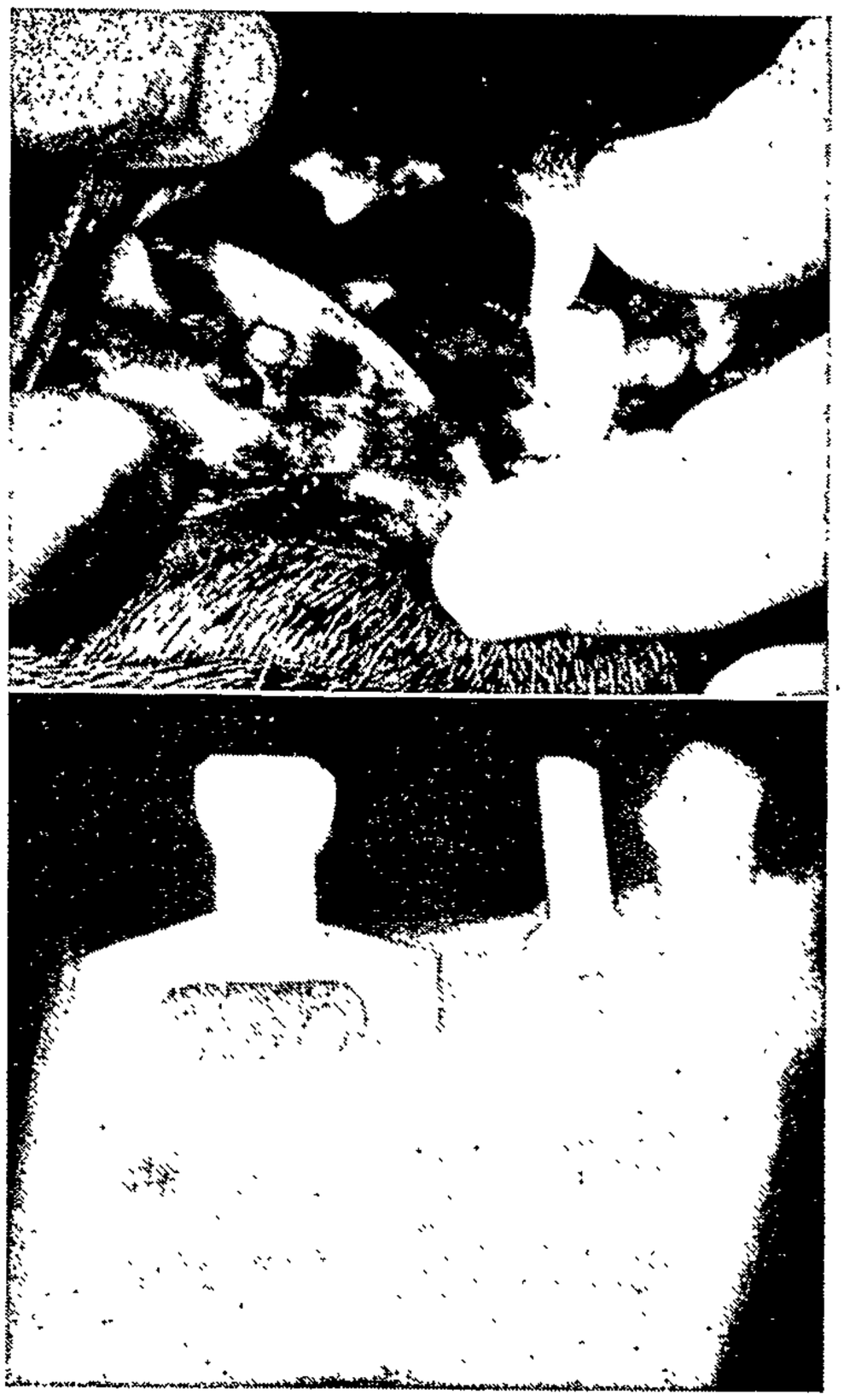

Fig. 4.—Blade and screw vents in right mandible of dog and roentgenogram (62 weeks).

to those of the adjoining teeth. In one of the cobalt chromium alloy blade vents the distal portion of the implant was protruding about 1½ mm through the gingiva for the last 20 weeks.

Deposits of calculus were seen on all the implants in place for longer than twelve weeks; and calculus was also present on the gingival third of some teeth.

The general physical condition of the dogs at the end of the experiment was excellent. They had no difficulty in chewing the hard food, all had increased in weight and their coats were glossy.

Histological

In the histological examination the following were noted:

1. epithelial sulcus;
2. presence of inflammation;
3. evidence of active bone resorption and bone deposition;
4. formation of fibrous tissue around implant.

Table 1 lists the observations made on five cobalt chromium alloy blade vent implants inserted immediately after tooth extraction. The epithelium had grown down along the shank of the implant and a moderate to severe inflammatory reaction existed in the fibrous tissue surrounding the implant in three cases. The severity of the inflammatory reaction had destroyed the epithelium surrounding the shank in dog No. 8. In one which had been in place for 18 weeks the inflammatory reaction was comparable with that seen in the tissues of the gingival sulcus of an adjoining tooth.

In proximity to the implants some bone resorption and bone deposition was still occurring up to 18 weeks and also in the two specimens at 66 and 67 weeks.

In all specimens there was a covering of dense fibrous tissue between the blade vent and the bone. Some of the fibres were arranged parallel to the contours of the implant. Purple stained fibres were seen in three specimens. In one specimen [dog No. 8] an abscess was noted in the deeper areas.

TABLE 1

Histological observations on cobalt chromium alloy blade vent implants in dogs' jaws

Dog No.	Region	Time (weeks)	Epithelium and sulcus	Inflammation	Bone resorption	Bone deposition	Fibrous tissue	Purple fibres
4	UR	3	Removed because of mobility					
6	LR	9	Along shank	Moderate to severe	Alveolar border and deeper	Non-active	Dense fibrous tissue	Present
5	LR	18	Along shank	Moderate, comparable with natural tooth	Along implant	Slight	Dense fibrous tissue over bone	Absent
8	LL	66	Destroyed	Extensive into fibrous tissue	Non-active	Along surface of bone slight	Dense fibrous tissue with small abscess	Present
7	LL	67*	Along shank	Moderate to severe to transverse bridge	Non-active	Some	Dense fibrous tissue longitudinally	Present

* Distal half of blade exposed to oral cavity for 20 weeks.

TABLE 2

Histological observations on titanium blade vent implants in dogs' jaws

Dog No.	Region	Time (weeks)	Epithelium and sulcus	Inflammation	Bone resorption	Bone deposition	Fibrous tissue	Purple fibres
3	UL	3	Removed because of mobility					
3	LR	29*	Along shank	Moderate to fibrous band	Alveolar margin and apically	Transverse bridge	Covering blade and transverse bridge, also longitudinally	Present
2	LL (M)	32 (21)	Along shank	Moderate to below bone margin on lingual	Non-active	In deeper zones	Transverse and longitudinally	Present
2	LL (D)	32	Along shank	Moderate	Non-active	Transverse bridge and in deeper portion	Thick fibrous transverse band	Present
1	LL (D)	33	Along shank	Moderate to extent of epithelium	Non-active	Transverse bridge	Transverse bridge and longitudinally	Present
1	LL (M)	33 (21)	Along shank	Slight	Some on lingual	Non-active	In apical region	Absent
4	LL (M)	48 (23)	Along shank	Moderate	Non-active	Over mesial and transverse bridge	Thick fibrous tissue	Present
4	LL (D)	48	Along shank	Moderate	Non-active	Deposition in various areas	Over "bone" and longitudinally	Present
8	LR	61	Along shank	Severe	Alongside implant in superficial areas	In deeper implant area	Thick fibrous tissue	Present
7	LR	62	Along shank	Slight	Non-active	In deeper areas transverse bridge	Thick fibrous tissue, very dense	Present

Numbers in brackets interval between extraction and implantation.
M=mesial, D=distal.
*=edentulous space.

TABLE 3

Histological observations on titanium screw vent and solid screw implants in dogs' jaws

Dog No.	Region	Time (weeks)	Epithelium and sulcus	Inflammation	Bone resorption	Bone deposition	Fibrous tissue	Mandibular canal	Antrum	Purple fibres
11	LL	12	Level of bone	Slight	Active	Along thread	Around shank	Penetrated with fibrous tissue cover	—	Present
3	UR	9	Removed because of excessive mobility							
3	UL	23	Level of bone	Slight and similar to adjoining tooth sulcus	Non-active	Along thread	Around shank and first thread	—	Penetrated bone surface with fibrous tissue cover	Present
3	LL	23 (26)	Level of bone	Slight	Non-active	Central core	Around shank and screw	Penetrated with fibrous tissue cover	—	Present
3	LR	29 (22)	Level of bone	Slight	Non-active	Central core	Around shank and first thread	—	—	Present
2	UR	32	Level of bone	Slight	Non-active	Central core	Around shank	—	In close proximity	Absent
2	LR	36 (18)	Level of bone	Moderate	Non-active	Central core	Around shank	—	—	Absent
1	UR	33*	Around shank	Moderate to deep	Alveolar margin and along implant	Central core	Around shank and screw	—	In close proximity	Present
4	LL	48	Level of bone	Moderate	Non-active	Central core	Around shank	—	—	Absent
4	UL	48	Level of bone	Moderate	Non-active	Central core	Around shank	—	Into antrum. Fibrous tissue covering	Absent
4	LR	45 (26)	Level of bone	Severe	Along implant	Along thread	Around shank and screw	Penetrated with dense fibrous tissue	—	Present
8	LR	61	Level of bone	Slight and similar to adjoining tooth sulcus	Non-active	Central core	Around shank and in deeper portions around thread	Penetrated but no fibrous tissue covering	—	Absent
7	LR	62	Level of bone	Slight, more in tooth sulcus	Non-active	Central core	Around shank and first thread	—	—	Absent
2	LR†	36 (18)	Present along shank	Slight	At alveolar border	Non-active	Surrounding shank	Penetrated with fibrous band cover	—	Absent
1	LR†	37	Present along shank but does not reach bone level	Slight and similar to adjoining tooth	Non-active	Non-active	Surrounding shank	—	—	Absent

Numbers in brackets interval between extraction and implantation.
* Slightly loose on recovery. † Solid screw.

Table 2 lists the observations made on seven titanium blade vent implants covering a period of 3-62 weeks. In three of these the tooth in the mesial area was extracted 21-23 weeks prior to the insertion of the implant.

All specimens showed epithelium covering the fibrous tissue along the shank.

In only one specimen [dog No. 8 LR 61 weeks], in which the implant was made directly into the tooth sockets, was the inflammatory reaction classed as severe. In most instances it did not pass the epithelium or the dense fibrous band overlying the blade vent and in one [dog No. 2 LL (M) 32 weeks] where the implant was made 21 weeks after removal of the tooth it reached just below the bone margin on the lingual side. In proximity to the implants bone resorption was still active in three specimens, Nos. 3, 1 and 8, which had been in place for 29, 33 and 61 weeks respectively; bone deposition was evident in all specimens except the mesial of No. 1 which was inserted 21 weeks after extraction of the tooth. The dense fibrous tissue covered the blade vent and the fibres for their greater part were arranged parallel to its contours. This arrangement changed where the fibres were embedded in the bone. Purple stained fibres (elastic fibres-Halmi stain) were seen in all specimens except the mesial of No. 1 (33 weeks) which was inserted 21 weeks after extraction.

Table 3 lists the observations made on 13 screw vent and 2 solid screw implants covering a period of 9-62 weeks. One specimen [dog No. 3 UR] which had been in place for 9 weeks was removed because of extreme mobility and tissue taken from the region showed extensive inflammatory reaction with granulation tissue and bone resorption. Four of the seven vent implants were inserted at intervals ranging from 18-26 weeks after removal of the tooth and nine were immediately inserted into the enlarged socket of the extracted tooth.

In eight specimens epithelium covered the fibrous tissue as far as the level of the crest of the alveolar bone and in one case [dog No. 1 UR] it had surrounded the shank but could not be found at the level of the bone.

In seven specimens inflammatory reaction was slight. In two of these it was comparable to that found in the gingival sulcus of an adjoining tooth and in one it was less.

There was moderate inflammatory reaction in four specimens and in one it was severe. Bone resorption was still active after 12, 33, and 45 weeks in specimens Nos. 11 (LL), 1 (UR), and 4 (LR) but bone deposition was also noted along the thread of the implant in specimens Nos. 11 (LL) and 4 (LR), and after 23 weeks in No. 3 (UL). In the remaining nine specimens there was evidence of some bone deposition in the central core corresponding with the vent of the implant. Dense fibrous tissue was present around the shank only in five specimens, around the shank and first thread in three and around the shank and screw in four specimens. Purple stained fibres (elastic fibres-Halmi stain) were seen in six specimens in the dense fibrous tissue around the thread.

Four of the implants had penetrated the wall of the mandibular canal and in three of these, Nos. 11 (LL), 3 (LL) and 4 (LR), a dense fibrous tissue layer covered the end of the implant. In specimens Nos. 3 (UL) and 4 (UL) the antrum cavity had been penetrated but a dense fibrous tissue layer covered the end of the implant.

Two solid tapering screw implants were inserted in the mandible (36 and 37 weeks). One of these [dog No. 2] was placed 18 weeks after the extraction of the tooth. Both had epithelium covering the shank, extending to the level of the bone in No. 2. Slight inflammatory reaction occurred around the shank comparable to that around the adjoining tooth. Bone resorption at the alveolar border was present in the case of the delayed implant. A thin layer of fibrous tissue surrounded the shank and the dense fibrous tissue seen in the blade vent and some of the screw vent implants was absent. A fibrous layer covered the screw where it had penetrated the mandibular canal.

Some examples of the histological material are shown in Fig. 5-15.

Figure 5 shows the cross-section of a blade vent implant in the mandible for 33 weeks with a transverse bridge of bone and thick dense fibrous tissue between the implant and bone. More detailed arrangement of the fibrous tissue in relation to implant and bone is shown in Fig. 6.

A similar type of arrangement exists in the screw vent inserted in the maxilla 33 weeks (Fig. 7). Some fibres which were purple stained are seen in the fibrous tissue from around the thread from a 45 week implant (Fig. 8). The central area shows bone and

Fig. 5

Fig. 6

Fig. 5.—Section cut from mesial to distal through a blade vent in mandible of dog (33 weeks). (e) epithelium; (f) fibrous tissue; (b) transverse bone bridge; (arrow) limit of longitudinally orientated fibres; (mc) mandibular canal. Halmi stain, original mag. × 8.

Fig. 6.—Details of transverse bridge of bone from Fig. 5. (f) longitudinally orientated fibres; (arrows) limit of the longitudinal fibres. Original mag. × 80.

fibrous tissue from the vent (Fig. 7). More extensive bone formation in the central area from another implant in a mandible for 29 weeks is seen in Fig. 9.

The gingival sulcus of the natural tooth (Fig. 10) can be compared with the "sulcus" of the implant (62 weeks) (Fig. 11), which has less inflammation, and with Fig. 12 where only very slight inflammatory reaction is present around the implant and the tooth.

Figure 13 shows the penetration of the floor of the antrum by a screw vent implant (48 weeks). Fibrous tissue has been formed over the end of the implant (Fig. 13f). The lining of the antrum (Fig. 13m) contains mucous glands and some lymph nodules; lymphocytes are scattered throughout. A higher magnification of the fibrous tissue (Fig. 14) also shows the presence of lymphocytes. However, the soft tissues in proximity to the bone appear to be normal.

At the time of recovery and following the methods suggested by Brill and Krasse[9] 0·5-2·0 ml of 20 per cent fluorescein sodium was injected intravenously. Pointed filter paper strips were placed in the gingival crevice around teeth and implants. The filter paper was then examined under fluorescent light and found to fluoresce in a similar manner from both types of crevices.

Discussion

Interest in the use of endosseous implants has developed at a rapid pace since the early work of Cherchève and others who followed the implant technique of Formiggini in 1947.[3] Linkow has been especially interested and has reviewed the progress in a seven year survey.[10] He developed the endosseous vent implant in screw and blade forms. Lew[7] uses cobalt chromium alloy (**Vitallium Surgical**) and claims that the early endosseous implants failed because of the narrow shank. His design has a shank of similar size to the body of the screw, which is separated from the square superstructure by a collar. He does not advocate the screw vent nor the blade vent.

[9] Brill, N., and Krasse, B.—The passage of tissue fluid into the clinically healthy gingival pocket. Acta Odont. Scand., 16: 3, 233-246 (June) 1958.

[10] Linkow, L. I.—Endosseous oral implantology: a seven year progress report. Dent. Clin. N. Amer., 14: 1, 185-200 (Jan.) 1970.

Fig. 7.—Section cut from buccal to lingual in maxilla of dog (33 weeks). (e) epithelium; (f) fibrous tissue; (b) core of bone; (a) antrum; (t) adjoining tooth. Halmi stain, original mag. × 8.

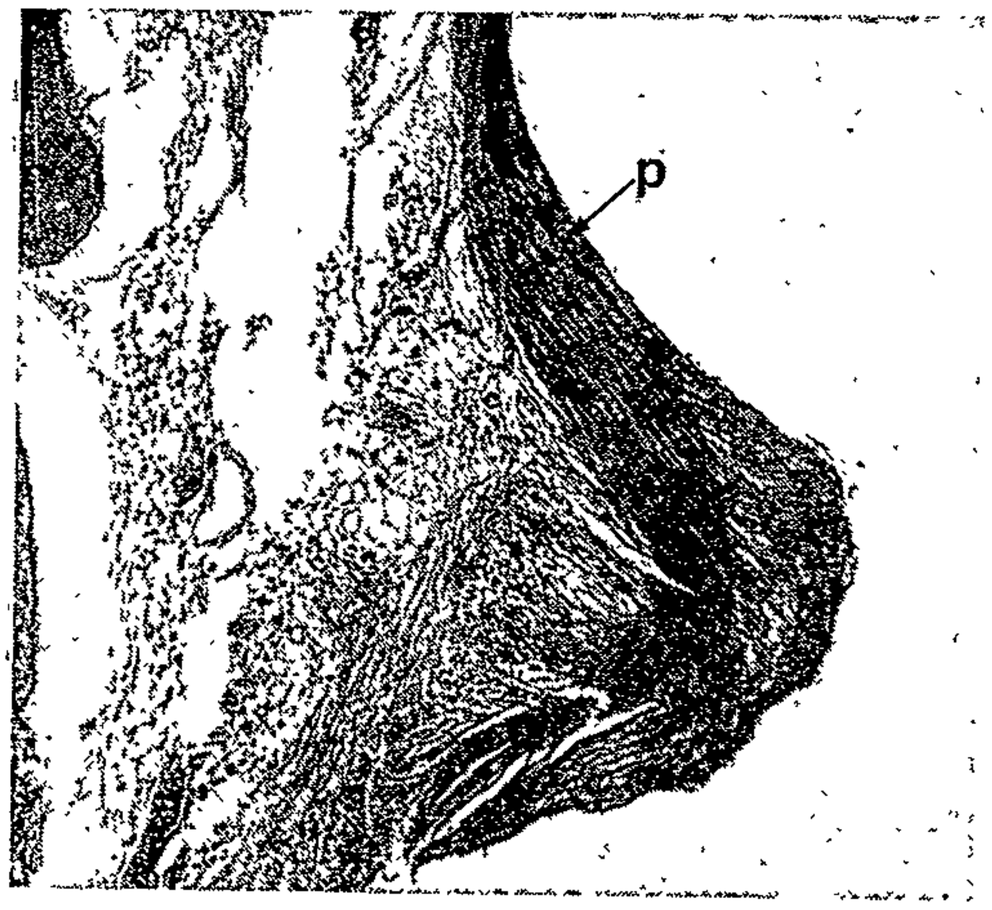

Fig. 8.—Fibrous tissue from around thread of screw vent (45 weeks). (p) purple stained fibres. Halmi stain, original mag. × 336.

Strock[11] had carried out some investigations into the use of metallic implants with **Vitallium** into fresh sockets of both dogs and humans and found them retained and apparently well tolerated for periods up to six months. Further

Fig. 9.—Section cut from mesial to distal in mandible of dog (29 weeks) showing a well formed central core of bone. H & E original mag. × 8.

work by him does not appear to have been widely reported.

Dahl[12] and Izikowitz[13] have reported the use of endosseous types of implants in unilateral saddle prostheses attached to anterior teeth. The latter reported that after a period of observation up to 14 months the prosthesis was functional, the abutment teeth firmly placed, there were no signs of bone resorption and the soft tissues showed no inflammatory change.

From the study reported here it is apparent that the titanium implant appears to be superior to the cobalt chromium alloy (Tables 1, 2 and 3). Both types of implants were in place for approximately similar periods in functioning positions in the jaws and of the five cobalt chromium alloy implants one was removed after only three weeks in place because of its obvious instability and another had the distal portion of the blade exposed to the oral

(11) Strock, A. E.—Experimental work on a method for the replacement of missing teeth by direct implantation of a metal support into the alveolus. Amer. J. Orth. Oral Surg., 25: 5, 467-472 (May) 1939.

(12) Dahl, G. S. A.—Mechanical principles of superplants. Acta Odont. Scand., 21: 6, 515-531 (Dec.) 1963.

(13) Isikowitz, L.—Superplants. Acta Odont. Scand., 23: 1, 1-39, 40-50, 51-70 (Jan.) 1965.

Fig. 10

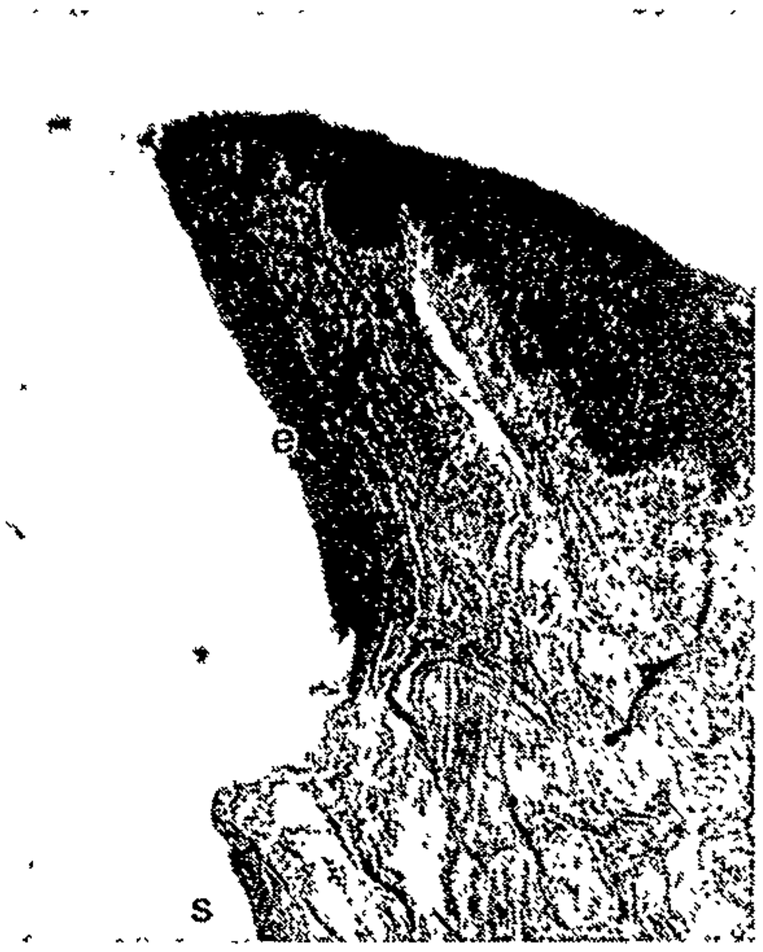

Fig. 11

Fig. 10.—Gingival sulcus cut from buccal to lingual of lower right premolar of dog. (e) epithelium; (d) dentine. H E S original mag. × 80.

Fig. 11.—Gingival "sulcus" cut from buccal to lingual of screw vent implant (62 weeks) in lower right of same dog as in Fig. 10. (e) epithelium; (s) shank of implant. H E S original mag. × 80.

cavity for 20 of the 67 weeks prior to recovery. It was firm but fairly extensive inflammatory reaction was present in the tissues down to the transverse bridge of bone. It appeared that the inflammatory reaction develops early and persists.

Where titanium was used it was possible to demonstrate thick fibrous tissue between implant and bone in which the fibres conformed to the implant contours in all the blade vent implants (Fig. 5 and 6). However, it was not comparable with the structure of the periodontal membrane as has been reported by some authors[14][15][16] where plastic tooth implants have been used. This type of fibrous tissue reaction was also present in some of the screw vent implants (Fig. 7). The fibrous tissue here was also densely packed and conformed to the contours of the implant, where it joined the bone the appearance followed that usually seen in the normal periodontal tissues (Fig. 6). In some areas of the thick fibrous bands purple stained fibres (Halmi), probably elastic, were present (Fig. 8) and were of similar size to those found in the rabbit's tissues.[1] In the case of the two solid tapering screws only a thin fibrous layer was present (Fig. 12).

In some cases bone resorption and bone deposition were active in close proximity to the implant and this may indicate bone remodelling was present especially as this was noted in 12 of the 7 screw vent and the 7 blade vent implants (Fig. 6, 7 and 9). There appeared to be no difference between the degree of bone resorption whether the implant was made directly following extraction or delayed for periods up to 26 weeks.

There was a limited downgrowth of epithelium. Bodine and Mohammed[17] did not find a downgrowth of epithelium along the abutment to encapsulate the frame in a subperiosteal implant. The epithelium had penetrated only 2-3 mm in 12 years. They noted the same type of connective tissue reaction as found in the blade and screw vents in this study. Manderson[18] using titanium vent implants in mandibles of miniature pigs noted the same reaction as that found by Mack[19] (who used

[14] Shklar, J., Hodosh, M., and Povar, M.—Tissue reactions to the plastic tooth implants. Oral Surg., Oral Med., Oral Path., 22: 3, 349-357 (Sept.) 1966.

[15] Hodosh, M., Povar, M., and Shklar, J.—Plastic tooth implants with root channels and osseous bridges. Oral Surg., Oral Med., Oral Path., 26: 6, 831-836 (Dec.) 1967.

[16] Hodosh, M., Povar, M., and Shklar, J.—Periodontal fibre attachments to the plastic tooth implant. J. Periodont., 39: 4, 187-189 (July) 1968.

[17] Bodine, R. L., and Mohammed, C. I.—Histologic studies of a human mandible supporting an implant denture. J. Prosth. Dent., 21: 2, 203-215 (Feb.) 1969.

[18] Manderson, R. D.—Experimental intraosseous implantation in the jaws of pigs. Paper presented at the Annual Conference of the British Society for the Study of Prosthetic Dentistry, April, 1970. Quoted by L'Estrange, P. R.—Austral. D. J., 15, 5, 371-376 (Oct.) 1970.

[19] Mack, A. O.—Reactions of the oral tissues to subperiosteal appliances. Int. Dent. J., 18: 4, 779-789 (Dec.) 1968.

subperiosteal implants in monkeys), namely epithelial downgrowth.

It is to be noted that bone readily grew into the vent spaces of the blade and the screws (Fig. 7 and 9) which had been anticipated from our previous study[1] on the rabbit's mandible. It therefore seems an unnecessary complication to use a trephine to drill the hole as suggested by Viscido[20] or the additional complication suggested by Linkow[21] in which a core of bone is taken from the edentulous symphysis region and placed inside the screw

Fig. 12.—Similar situation as in Fig. 10 and 11 but with very slight inflammation. Solid screw implant in place (37 weeks). (e) epithelium; (f) fibrous tissue; (b) bone. H & E original mag. × 8.

vent before insertion. It has been emphasized by Chase and Herndon[22] that following massive transfer of bone the periosteum in great measure survives and retains its osteogenic capacity while most of the bone and marrow die. Repair and reorganization occurs through the agency of vascular, fine-fibred connective tissue from the periosteum of both host and graft. All reorganization of bone is by resorption and apposition as demonstrated by Axhausen in 1907. Some believed metaplasia of surrounding soft tissue is the major factor, others, that the metaplasia is from the soft tissue associated with the bone.

[20] Viscido, A. J.—Endosseous implants as fixed abutments. J. Amer. Dent. Ass., 79: 6, 1421-1426 (Dec.) 1969.

[21] Linkow, L. I.—Endosseous blade vent implants: a two year report. J. Prosth. Dent., 23: 4, 441-448 (Apr.) 1970.

[22] Chase, S. W., and Herndon, C. H.—The fate of autogenous and homogenous bone crafts. J. Bone and Joint. Surg., 37A: 4, 809-841 (July) 1955.

Care was taken to reduce damage to adjoining structures such as teeth or the contents of the mandibular canal or the mucosa of the antrum. In seven situations where this did occur these structures suffered no ill effect and a fibrous band appeared to encapsulate the end of the implant (Fig. 13 and 14). In one case a screw had penetrated cementum and dentine of the root of the lower canine. Some minor resorption of dentine occurred followed by its replacement with bone.

Clinical examination of the implants disclosed no greater degree of gingivitis around the implants than around the adjoining or opposing teeth despite the presence of calculus on some of the implants. Figures 10, 11 and 12 disclose a comparative series which shows rather more inflammation around the tooth (Fig. 10). The fluorescein test demonstrated a similar reaction around the implant and tooth which suggests the same close apposition of the soft tissue to the implant.

It should be noted that the design of this study required recovery of the material for histological examination at intervals and except for the three failures this was done irrespective of the clinical status of the specimen.

The results of the observations made on the use of the 22 titanium implants over a period of 12-62 weeks indicated:

1. the metal was acceptable to the tissues,
2. where failure occurred it was apparent quite early after implantation,
3. gingivitis appeared to be no more frequent or intense around the implant than around the teeth,
4. the implant was firmly held in place although one screw vent was slightly loose,
5. the implants could function under masticatory stress.

It was therefore decided to use titanium implants in patients requiring restorations in short edentulous spaces.

Case report*

A man aged 37 years, in good health, with suitable edentulous areas agreed to have implant prostheses in maxilla and mandible.

Careful clinical and radiographic examinations suggested that there was the possibility of using endosseous implants for the restora-

* The restorative procedures were carried out by Associate Professor A. W. Bull, Faculty of Dentistry, University of Sydney, to whom our grateful acknowledgement is made.

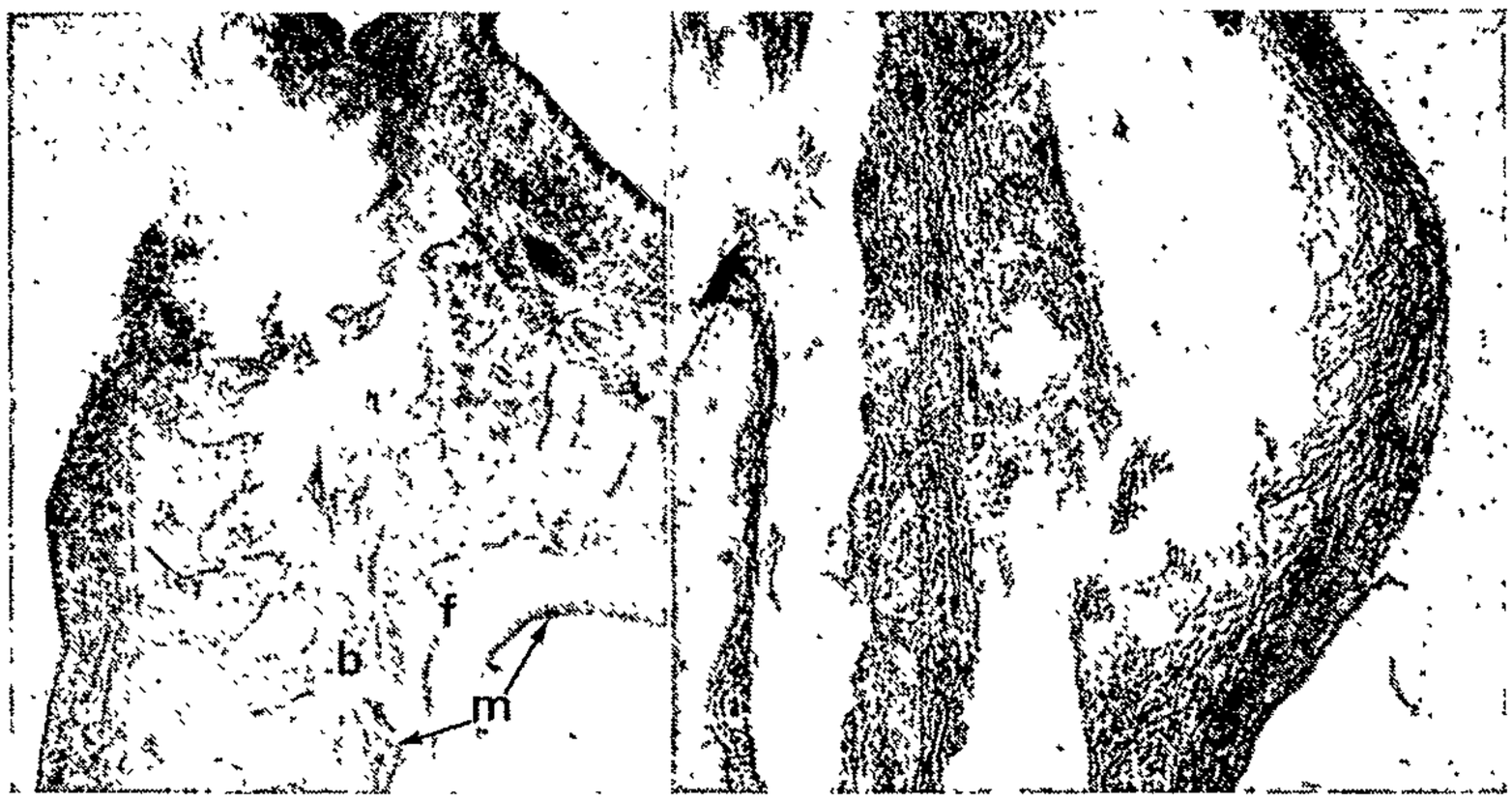

Fig. 13 Fig. 14

Fig. 13.—Screw vent implant in maxilla of dog (48 weeks) cut from mesial to distal showing penetration of the antrum floor. [The specimen has been damaged in preparation.] (b) bone; (f) fibrous tissue; (m) membrane of antrum. H & E original mag. × 8.

Fig. 14.—Fibrous tissue from Fig. 13. Original mag. × 80.

tions. Models of the maxillary and mandibular arches when mounted on an articulator enabled this assessment to be confirmed and additional radiographic examinations to include a true lateral film of the maxilla and a panoramic film of the mandible from which accurate measurements of the alveolar bone were obtained.

Screw vent implants selected to suit the dimensions estimated from models and roentgenograms were inserted under lignocaine anæsthesia and the soft tissues replaced and sutured.

Figures 15, 16a, 17 and 18 show the completed restorations and roentgenograms one year after implantation.

The original restoration for the upper lateral was a porcelain jacket crown. After nine months, some slight mobility being still present, it was decided to remove the porcelain jacket crown and replace it with a plastic resin crown supported by occlusal rests in the adjoining teeth in which silicate restorations already existed. The removal of the porcelain jacket crown was an extremely difficult and prolonged procedure at the end of which the implant was loose. Although subject to heavy stress during mastication the new restoration is completely stable. Roentgenograms taken some months later reveal good bone support around the screw.

In the mandible immediately after the implantation a temporary plastic splint was inserted and cemented with zinc oxide and eugenol. Four weeks after implantation the restoration was inserted. This final restoration was a cantilever fixed bridge attached to the lower right first and second premolars by united three-quarter veneer crowns cast in hard gold, the pontics being of porcelain fused to gold (Fig. 17, 18).

The patient was instructed in suitable oral hygiene procedures and clinical and radiographic examinations at intervals have followed.

It can be noted in the final roentgenograms (Fig. 16a) that a thin lineal radiolucent zone surrounds the screw vent and this can be compared with the roentgenogram and the histological picture from the dog's tissue (Fig. 16b and 7).

From observations with fluorescein the idea arose that tetracycline could be used similarly. During the writing of this paper it was noted that other investigators[23] had used oral tetracycline and where a firm attached gingiva was present the fluid flow from the gingival crevice appeared to decrease compared with a gingival crevice where inflammation existed.

The test is carried out with the patient taking a 250 mg capsule of tetracycline two hours after eating. Three hours after the dose of tetracycline thin filter paper strips are placed in the gingival sulcus around a tooth

[23] Ponitz, D. P., Gershkoff, A., and Wells, H.—Passage of orally administered tetracycline into the gingival crevice around natural teeth and around protruding subperiosteal implant abutments in man. Dent. Clin. N. Amer., 14: 1, 125-136 (Jan.) 1970.

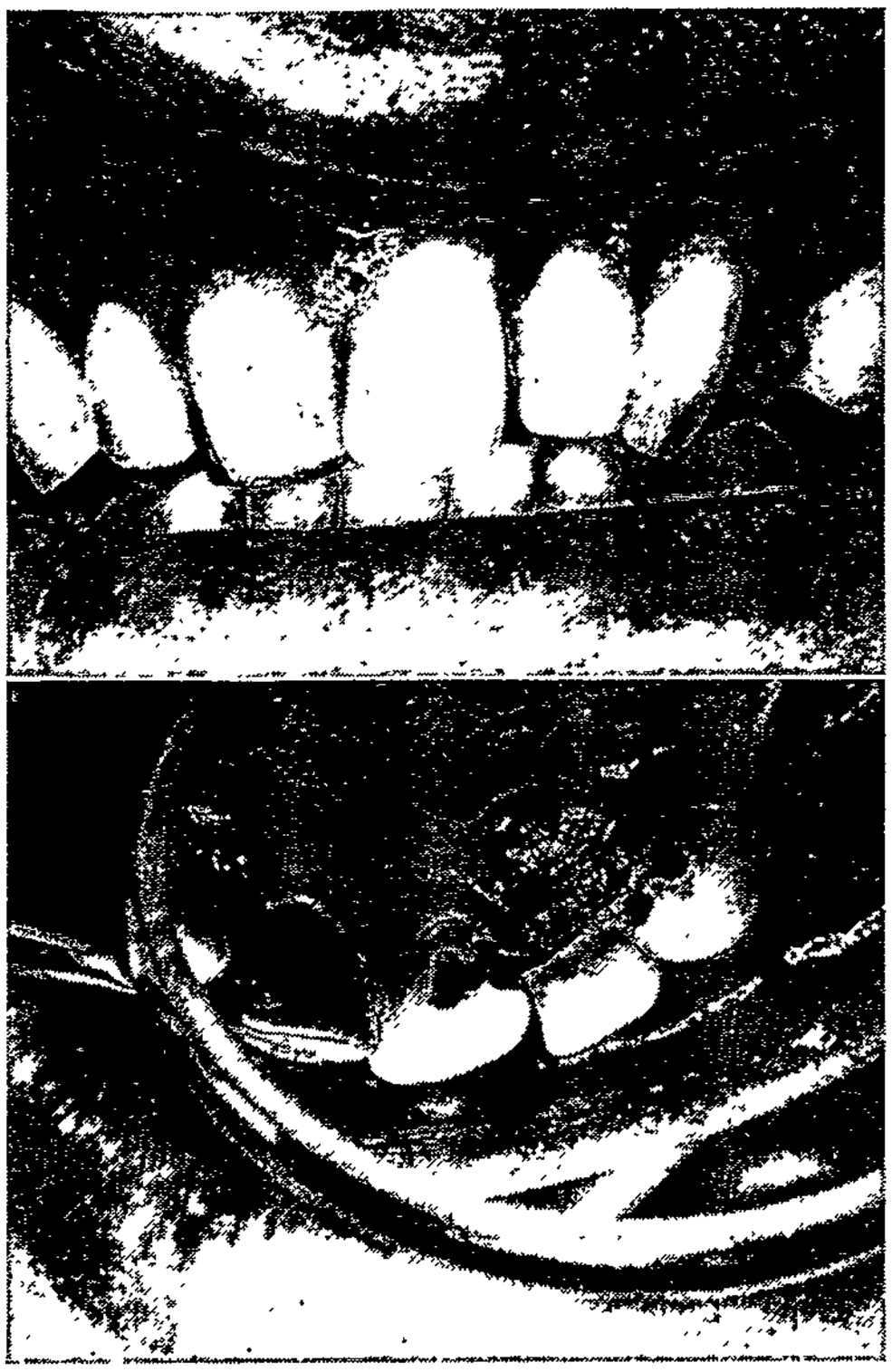

Fig. 15.—Upper left lateral restoration (1 year).

and in the "sulcus" around an implant. The strips are then examined in a darkened room with ultraviolet light.

The test showed in this patient that fluorescence could not be detected from the gingival sulcus around the teeth or implants.

Discussion

The implants placed in this patient are of the screw vent type selected for length to suit the edentulous spaces. In the lateral restoration the original construction did not have occlusal rests from the gold core on to the adjoining tooth. Though a technically difficult procedure subsequent events demonstrated the value of this. Schmidt[24] used a fixed abutment on a tooth in addition to the implant (he used a saddle type periosteal implant) and Plischka[25] suggests that the shank should be close to the size of the drilled hole to reduce the amount of soft tissue between implant and bone to ensure that it adheres firmly. He noted that resorption around the post does not produce a bony pocket. All who have any extensive experience in the use of implants for abutments stress the necessity of placing the permanent restoration either immediately or within a very short time after the insertion of the implant.[25][26][27] Cranin[27] prefers teeth as fixed abutments together with the implant and also specially made cobalt chromium alloy castings because of the individual variability achieved in design. He does not use gold copings over the implant because of the possibility of galvanic action. Linkow[10] reports no difficulty from this source and Down's[2] observations clearly support this. Brown[28] referring more specially to stainless steels noted instances where sudden acute inflammation without bacterial infection has developed in tissue surrounding metal implants after years of apparent quiescence and on occasion unexplained pain at the site of metal implants. He also noted that corrosion is enhanced by the deposition of molecules of a different steel alloy from the instrument used in handling the prosthesis or from pipe and sterilizer scale deposited on the prosthesis during autoclaving. Down[2] has suggested methods of overcoming such difficulties in which the points or edges of the steel instruments are covered with tungsten carbide but careful handling of the implants at all stages is essential.

Kaminski and Oglesby[29] have suggested that the reactions to implants may depend somewhat on the shape of the implant. There was a difference in the reaction around the two solid screws in the dogs compared with the screw and blade vents but this difference could not be valid in such small numbers. Brown[28] observed that plastics in sheet or film form embedded in tissues caused malignancy in significant numbers compared with the same plastic embedded as a textile, sponge or powder. Becker, Bassett and Bachman[30] refer

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[24] Schmidt. H. J.—Langzeiterfahrung mit dem Sattelimplantat. Deutsch Zahnaerztl. Z., 23: 9, 944-956 (Sept.) 1968.

[25] Plischka, G.—Das intraossale implantat. Die Quintess., 20: 7, 25-29 (July) 1969.

[26] Flander, S.—Periodontic, orthodontic and endodontic considerations in conjunction with implant dentistry. Dent. Clin. N. Amer., 14: 1, 137-143 (Jan.) 1970.

[27] Cranin, A. N.—Some comments on the endosseous implants. including operative and postoperative care and observations. Dent. Clin. N. Amer., 14: 1, 173-184 (Jan.) 1970.

[28] Brown, D. E.—Tissue reaction to plastic and metal implants. Arch. Otolaryng., 88: 81-85 (Sept.) 1968.

[29] Kaminski, E. J., and Oglesby, R. J.—Certain aspects of implant shape and experimental testing of biological materials. New York. Plenum Press, 1969.

[30] Becker, R. O., Bassett, C. A., and Bachman, C. H.—Bioelectric factors controlling bone structure. *In* Bone dynamics, ed. H. M. Frost. London. J. & A. Churchill Ltd., 1963 (pp. 209-232).

Fig. 16.—Roentgenograms (a) upper left lateral restoration in Fig. 15, screw vent, after one year; (b) screw vent in right maxilla of dog (33 weeks). Note the radiolucent line surrounding the threads in both cases and compare with Fig. 7.

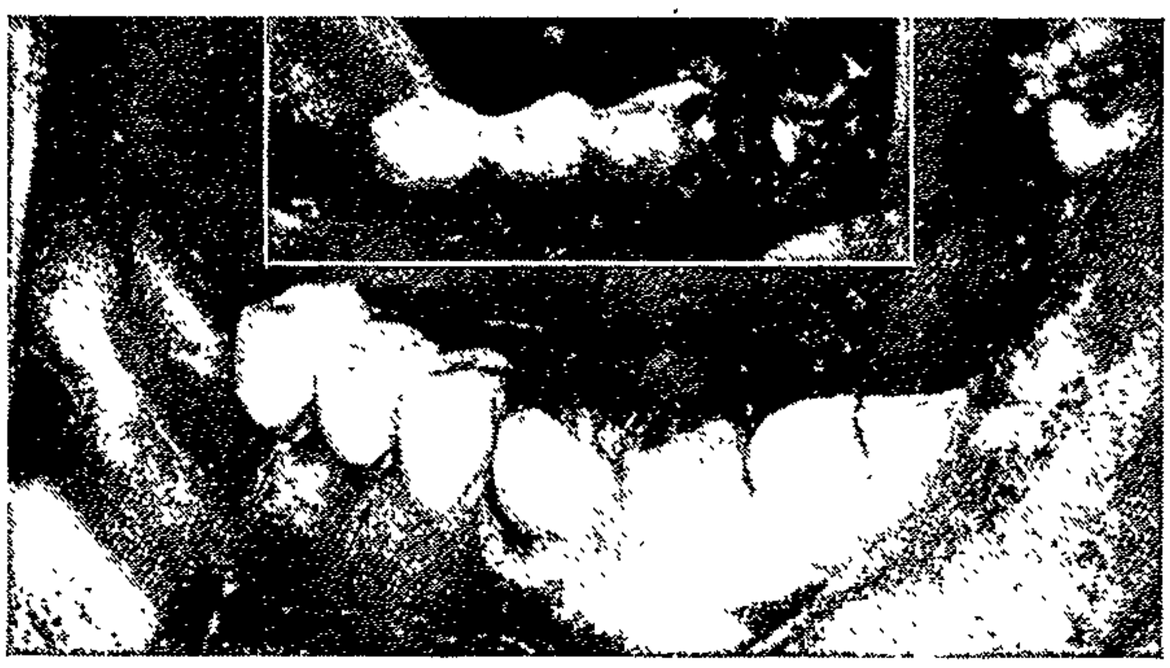

Fig. 17.—Lower right fixed bridge restoration in same patient as in Fig 15 (10 months); (arrows) shank of implant. Inset lingual view.

to bioelectric factors controlling the bone structure. Gold[31] refers to the production of electrical effects in bone under stress. Bone deposition has been produced in the femur of the dog after 14 days' mild electric stimulation from an implanted small battery pack.[32] It could be that the differences in reaction apparently due to shape arise from such mild electrical charges.

Sicard[33] in 1958 queried whether the technique of alloplastic implantation had overcome the experimental stage and could be recommended for clinical use. Since then many publications reporting large numbers of implants have appeared. Held and Spirgi[34] believed that the problem still remained controversial. They examined a number of substances but did not include titanium. Obwegeser,[35] in a carefully prepared report on the use of a cobalt chromium alloy as a subperiosteal implant, noted one-third of his cases as successful but emphasized the importance of exercising the utmost skill in the construction of the prosthetic restoration.

The difference between implantations for dental purposes as described in this paper and

[31] Gold, P.—The electrical phenomenon in bone: a review of a possible direction for the treatment of osseous defects. J. Periodont., 38: 2, 119-123 (March-Apr.) 1967.

[32] Bassett, C. A. L., Pawluk, R. J., and Becker, R. O.—Effects of electric currents on bone *in vivo*. Nature, 204: 652-654 (Nov.) 1964.

[33] Sicard, A.—Réactions tissulaires à l'égard des corps étrangers. Méd. et Hygiène, 399: 295-300, 1958.

[34] Held, A. J., and Spirgi, M.—Osteoperiosteal response to various implants in rabbits. Helv. Odont. Acta, 12: 1, 1-14 (Apr.) 1968.

[35] Obwegeser, H. L.—Experience with subperiosteal implants. Oral Surg., Oral Med., Oral Path., 12: 7, 777-786 (July) 1959.

those used elsewhere in the body is that the implant projects into the mouth. It is this communication which raises the controversy about the use of implants in dental practice because the system permits a possible avenue of infection, and hence the procedure has been condemned by some authorities. In applying therapeutic procedures the limitations of biological variability must be recognized and some tissues may not tolerate any implants.

If resorption exceeds deposition so that bone is replaced by fibrous tissue the implant will fail and infection hastens resorption.

Fig. 18.—Roentgenogram of right molar region in Fig. 17 Note close apposition of bone to shank.

The report presented here gives the findings of a study in dogs and the application of the procedure based on these observations in a patient in whom three implants were in place for 17 months. It is therefore a preliminary report. However, the results are encouraging. These findings demonstrate certain limitations in the method and the necessity for sound assessment of the patient's problem and for meticulous planning and execution of the technical and surgical procedures.

Summary

A study of the application of five cobalt chromium alloy, and 22 titanium implants inserted in the jaws of dogs for periods up to 67 weeks has been presented.

The titanium implants of both vent and solid type in screw and blade form were used and appeared equally successful.

A report of the history of a patient with three screw vent implants on which prostheses have been placed is given.

Acknowledgments

The co-operation of Professor L. H. Larsen and Mr. C. Bellenger, Department of Veterinary Surgery, of Associate Professor R. G. Wales, Department of Veterinary Physiology, University of Sydney, and of Mr. J. Tye of the Castle Hill Research Station Animal House made possible the work on the animals. Our thanks are due to Miss B. Bischoff for her photographic work.

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Appendix

W. Gregor, a clergyman and amateur mineralogist, published an account in 1791 of the findings of a black magnetic sand in the parish of Menaccan in Cornwall and stated that it contained the oxide of an unknown element which he proposed should be called menaccanite. About the same time a German chemist, M. N. Klaproth, was engaged in a systematic examination of rocks and minerals amongst which were samples of rutile. He carried out extensive examinations of the physical properties of this mineral and came to the conclusion that rutile was the oxide of a new metal which he called titanium. Later Klaproth examined samples of ilmenite (from the Ilmen Mountains in the Urals) and found it also contained titanium and that this element was identical with menaccanite.

Both ilmenite and rutile are widely distributed—the former principally in Canada, the U.S.A., and the U.S.S.R. and the latter in Australia and the U.S.A.

The process of production is difficult but results in titanium granules which are compacted in a 2,500 ton press to form briquettes. The briquettes are melted in an arc furnace *in vacuo* to form an ingot and the process is repeated until an ultrasonically tested ingot is free from flaws.

The cylindrical ingots are forged to billets or slabs, machined or shot blasted to remove surface defects which might otherwise be rolled into the mass during subsequent stages. Rod forms are then machine finished whilst the rolled sheet has a smooth surface and needs no further attention. Titanium is unique among structural metals since the varying degrees of ductility and strength are obtained by the selection of sponges with slightly differing oxygen contents (0·08-0·40 per cent). The differences in electro-potential between the six types are not measurable and each can be used in conjunction with one another without creating electrolytic cells. There is also no galvanic action of sufficient magnitude to cause tissue reaction between dissimilar metals such as cobalt chromium alloy and titanium. Corrosion rates are infinitesimal and as such are incapable of producing breakdown products of any significance. For example, the magnitude of the current produced in an electro-couple of cast cobalt chromium alloy and T.130 (T1) in which T.130 is anodic to the alloy was in the range 0·1-0·12μ A/3 cm^2.*

Some alloys of titanium have been adopted in Russia where a titanium-aluminium-tin combination is used and in America where vanadium has replaced the tin. But they do not appear to have useful advantages over commercially pure titanium of T.160 (T6).

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* 1μA = 1/10^6 amp.

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The reaction of the oral tissues to implants

R. Harris
With the technical assistance of Christa Lossin

The reaction of the oral tissues to implants

R. Harris* with the technical assistance of Christa Lossin†

Introduction

Reports have been published on the reactions of tissues to implants made of titanium and cobalt chromium alloys in the jaws of rabbits and dogs and on the use of titanium in the mouths of patients.[1] [2]

A variety of materials has been used either as abutment to fixed prostheses or for mandibular and maxillary reconstructions and although there have been many failures some success has been achieved.

More recently plastics, ceramic materials, and cartilage have been used and the results suggest that some degree of success may be expected.

Certain limitations arise in the use of implants. They must have adequate strength to function, must be accepted without immunological reactions by the tissues, and they must be made of materials that can be adapted for use in the mouth.

A preliminary statement on the use of polytetrafluoroethylene **(Fluon)**, silicone rubber, and bovine cartilage has been published.[3] This paper is an extension of that earlier study and covers the tissue reactions associated with endosseous implants and alveolar bone reconstruction. It will not report on the clinical application of the methods.

* Director, Institute of Dental Research, Sydney.
† Chief Medical Technologist, Institute of Dental Research, Sydney.

[1] Harris, R.—Implantation of chrome cobalt alloy tooth forms in the rabbit's mandible. Austral. D. J., 14 : 6, 396–406 (Dec.) 1969.
[2] Harris, R., and Lossin, Christa—The use of cobalt chromium alloy and titanium endosseous dental implants. Austral. D. J., 16 : 2, 94–108 (Apl.) 1971.
[3] Harris, R.—Implants. Scientific and Educ. Bulletin I.C.D., 5 : 1, 37–42, 1972.

Material and methods

1. In a series of 10 female dogs the jaws were prepared by the removal of teeth and minor alveolectomy. Following an appropriate period of healing (about three months) 34 implants were inserted for the purpose of rebuilding the alveolar bone as follows :

(i) Silicone rubber : eight (35–455 days).
(ii) Polytetrafluoroethylene* **(Fluon)** block : eight (133–336 days).
(iii) Polytetrafluoroethylene **(Fluon)** felt : seven (112–232 days).
(iv) Bovine cartilage† : eleven (112–436 days).

2. One example of 23 endosseous implants for comparative purposes.

The implants were inserted as follows :

(*a*) Subperiosteal, in which the material was inserted beneath a tunnel in the periosteum ;
(*b*) the material was slotted into the alveolar bone and covered only by mucoperiosteum ;
(*c*) the material was inserted as an inlay placed beneath the surface of the alveolar ridge. The surgical procedure was designed so that the mucoperiosteal flap was raised from the buccal only sufficiently to allow a thin slice of alveolar bone to be removed with a small tapering fissure bur. The elevation of the flap across the crest of the ridge to the lingual was then continued and a mucoperiosteal flap with attached bone was reflected.

The blocks of **Fluon** or bovine cartilage were prepared in the shape of a long " T " bar and a

* Imperial Chemical Industries, Australia and New Zealand.
† Obtained by courtesy of Mr R. Brydon, State Abattoirs and Meatworks, Homebush, N.S.W.

slot cut into the body of the bone received the vertical stem of the " T " form. The mucoperiosteal flap, together with its strip of bone, was replaced and the tissues sutured.

The operative surgery was performed under intravenous anæsthesia [pentobarbitone sodium **(Sagatal)** 60 mg/ml–0·6 ml/kg body weight] and the wounds closed with **Ethicon** sutures. The

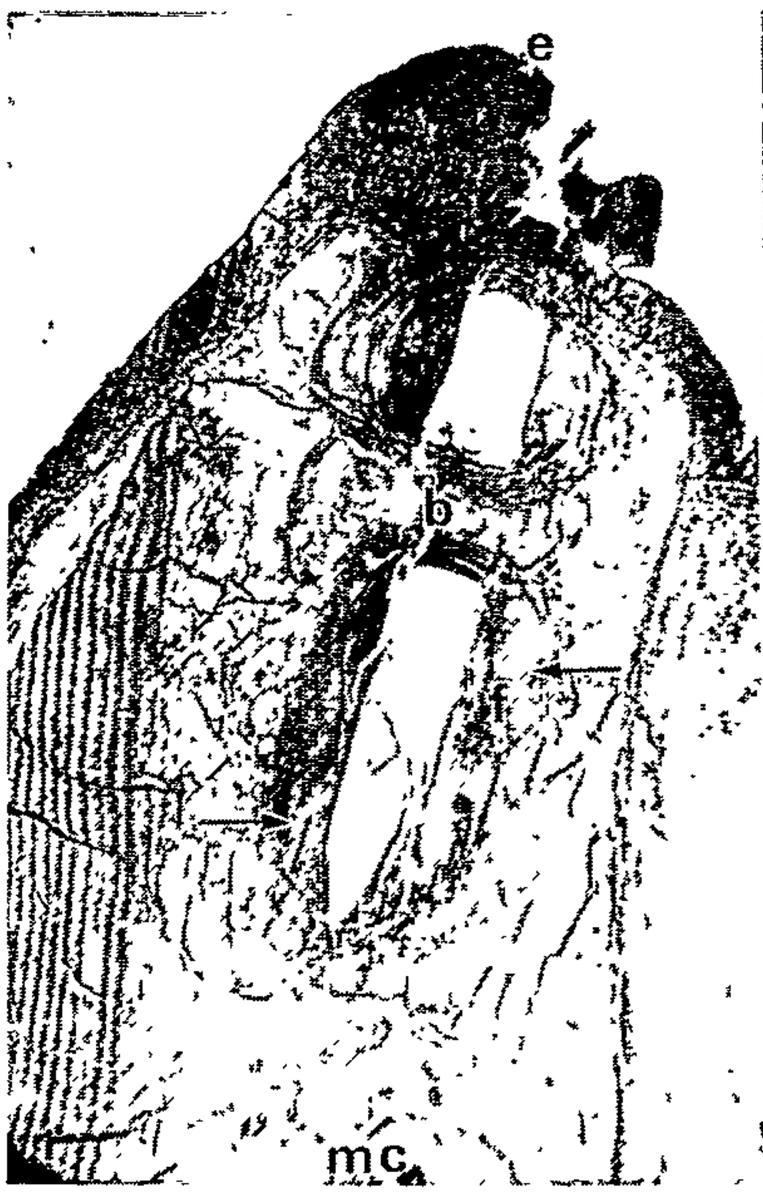

Fig. 1.—Section cut from mesial to distal through a blade vent in the mandible of dog showing the relation between bone and implant (231 days). (e) Epithelium; (f) fibrous tissue; (b) transverse bone ridge; (arrows) limit of longitudinally orientated fibres; (mc) mandibular canal. Halmi stain. Original mag. ×8.
Fig. 2.—Details of transverse ridge of bone from Fig. 1. (f) longitudinally orientated fibres; (arrows) limit of longitudinally orientated fibres. Original mag. ×80.

Silicone rubber and **Fluon** felt trimmed to suitable rectangular shape were placed beneath the slice of alveolar bone and no attempt was made to slot these implants into the remaining bone.

The bovine cartilage (xiphoid) from freshly killed calves (approximately six months old) was cleaned of all soft tissues and cut into appropriate shapes, perforated, and left overnight in physiological saline; freeze-drying was carried out for 52 hours.

The cartilage was placed in glass petri dishes, sealed with adhesive tape, wrapped in a cellophane bag, enclosed in thin copper containers and despatched for Gamma radiation* [2·5 megarads for three hours]. Immediately prior to use a suitable piece was selected and soaked for two hours in a normal saline solution to which had been added penicillin 300,000 IU and streptomycin 0·5 g. The procedure was adapted from that published by Stadnicki and Krajnik.[4]

* Australian Atomic Energy Commission, Lucas Heights, N.S.W.

[4] Stadnicki, J., and Krajnik, J.—Klinische Untersuchungen uber die Amvendung von lyophilisiertem heterogenem Knorpel bei der Behandlung von Kieferdefekten. Die Quint., 1: 8, 23–25 (Aug.) 1970.

animals were given intraperitoneal penicillin G [1×10^6 IU in 5 ml H_2O] and kept on a soft diet for a minimum period of one week; they were then allowed to eat a hard proprietary food and after two weeks were returned to the animal farm, where they were examined at intervals of not more than three weeks until the material was collected for histological examination.

3. For comparison a specimen from an endosseous titanium implant is shown in Fig. 1, 2. The blade vent was one of a series of 23 specimens inserted for periods of 12–62 weeks which were firmly implanted in the bone.

Observations

1. *Subperiosteal implants* (silicone 4, **Fluon** felt 2, block 2)

Implants placed in a tunnel beneath the mucoperiosteum were unsuccessful on either a short- or long-term basis. They became exposed to oral fluids and in more advanced cases the **Fluon** and silicone were exfoliated. One **Fluon** implant was exfoliated in one week and all had been lost by 13 weeks.

2. *Subperiosteal slotted into alveolar bone* (silicone 4, **Fluon** felt 4, block 2)

This was a more satisfactory procedure for the silicone and **Fluon** felt. However, there was some loss of alveolar ridge height during the slot preparation and the implants ultimately became exposed.

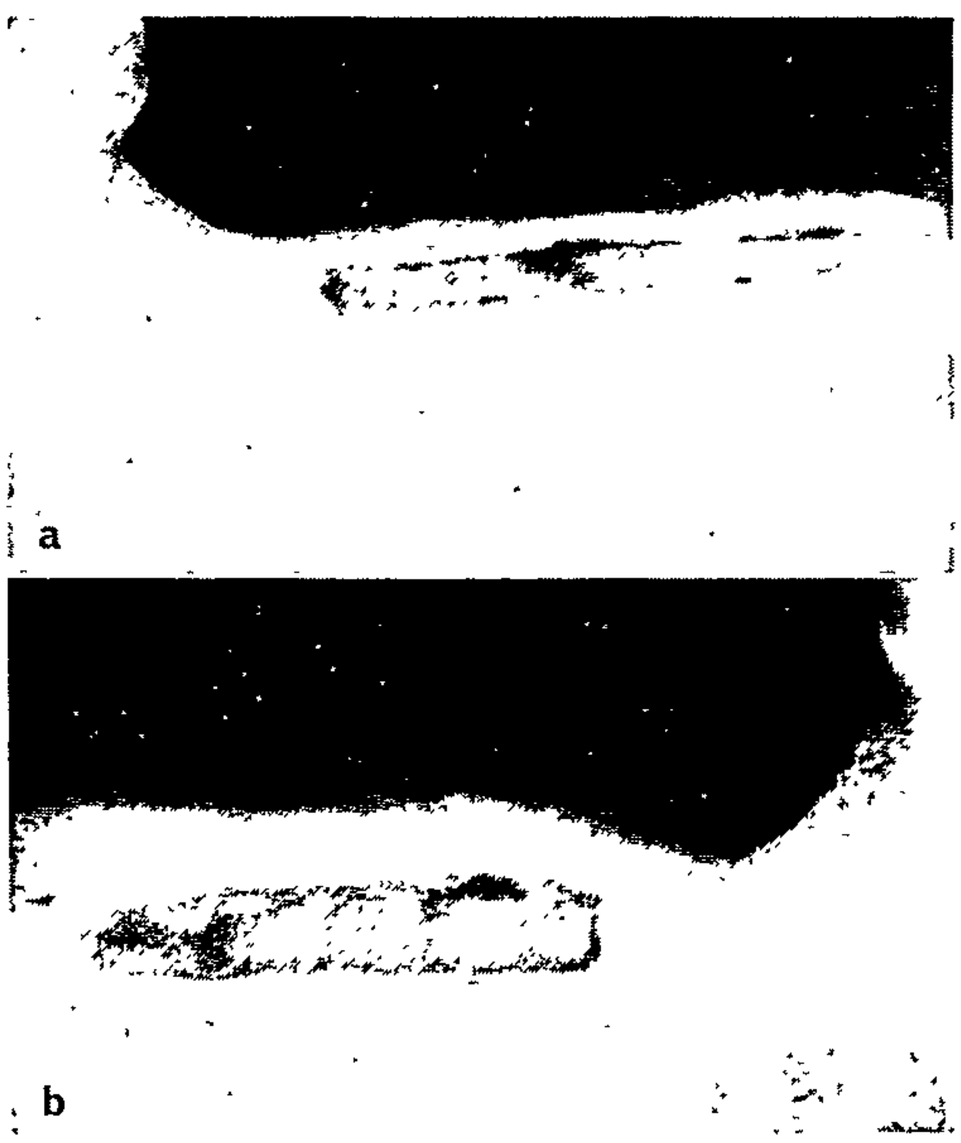

Fig. 3 (*a*), (*b*).—Radiographic appearance of mandibular reconstruction with block **Fluon** (133 days).

3. *Subperiosteal and bone inlay* (**Fluon** block 3, cartilage 11)

The inlay procedure gave a uniformly better result and it was found that a bridge of bone developed across the **Fluon** and the cartilage (Fig. 3 (*a*), (*b*), 4).

Histological examination

1. *Silicone* (slotted into bone)

Acceptance of the implant with bone deposited but separated from it by a layer of dense fibrous tissue covered by several layers of flattened epithelial cells was noted after a period of 18 weeks (Fig. 5 (*a*), (*b*)). No signs of inflammatory reaction in the surrounding tissues or infiltration of cells and invasion of bone into the silicone was observed.

2. (*a*) **Fluon** *felt* (slotted into bone)

The fibres of the felt were surrounded by masses of fibrous tissue and in some regions multinucleated cells were present. Where the felt had been inserted into the bone calcification has proceeded and the bone has surrounded the fibres (Fig. 6 (*a*), (*b*)).

(*b*) **Fluon** *block*

The "T"-shaped implant is accepted by the tissues; there is no inflammatory reaction and bone has grown into the perforations with a minimum amount of fibrous tissue separating it from the **Fluon** (Fig. 7 (*a*), (*b*)).

Fig. 4.—Radiographic appearance of mandibular reconstruction with bovine cartilage (436 days).

3. *Cartilage*

The reaction to bovine cartilage varied. In some of the shorter term specimens (200 days or less) some resorption occurred and multinucleated cells were present (Fig. 8 (*a*), (*b*)). In some regions where fibrous tissue only was in contact with the cartilage no changes appeared to be taking place (Fig. 9 (*a*)), whilst in other regions infiltration with fibrous tissue extensions running through the implant were seen (Fig. 9 (*b*), (*c*)), and in yet other regions where perforations had been drilled in the cartilage bone had been deposited (Fig. 9 (*d*)) and this can be compared with bone deposition around a titanium pin used to hold the cartilage in place (Fig. 9 (*e*)).

Where bone lay in contact with the cartilage infiltration and ossification occurred. The cartilage immediately in contact with the advancing ossification showed a PAS-positive reaction (Fig. 10 (*a*)). Examples of the ossification process can be seen in Fig. 10 (*b*), (*d*), and can be compared with Fig. 10 (*a*). Varying degrees of intensity of PAS-positive staining were observed, but it was noted that the most significant examples of ossification progressively increased in the older specimens (Fig. 10 (*a*), (*d*), (*e*)). It is to be noted that the PAS-positive stained areas of cartilage exhibited changes in the spaces formerly occuped by chondrocytes.

4. *Titanium endosseous implants*

In the 23 specimens inserted for varying periods a general pattern existed:

(*a*) Some inflammatory reaction in the epithelial zone with dense hyalinized fibrous tissue surrounding the titanium;

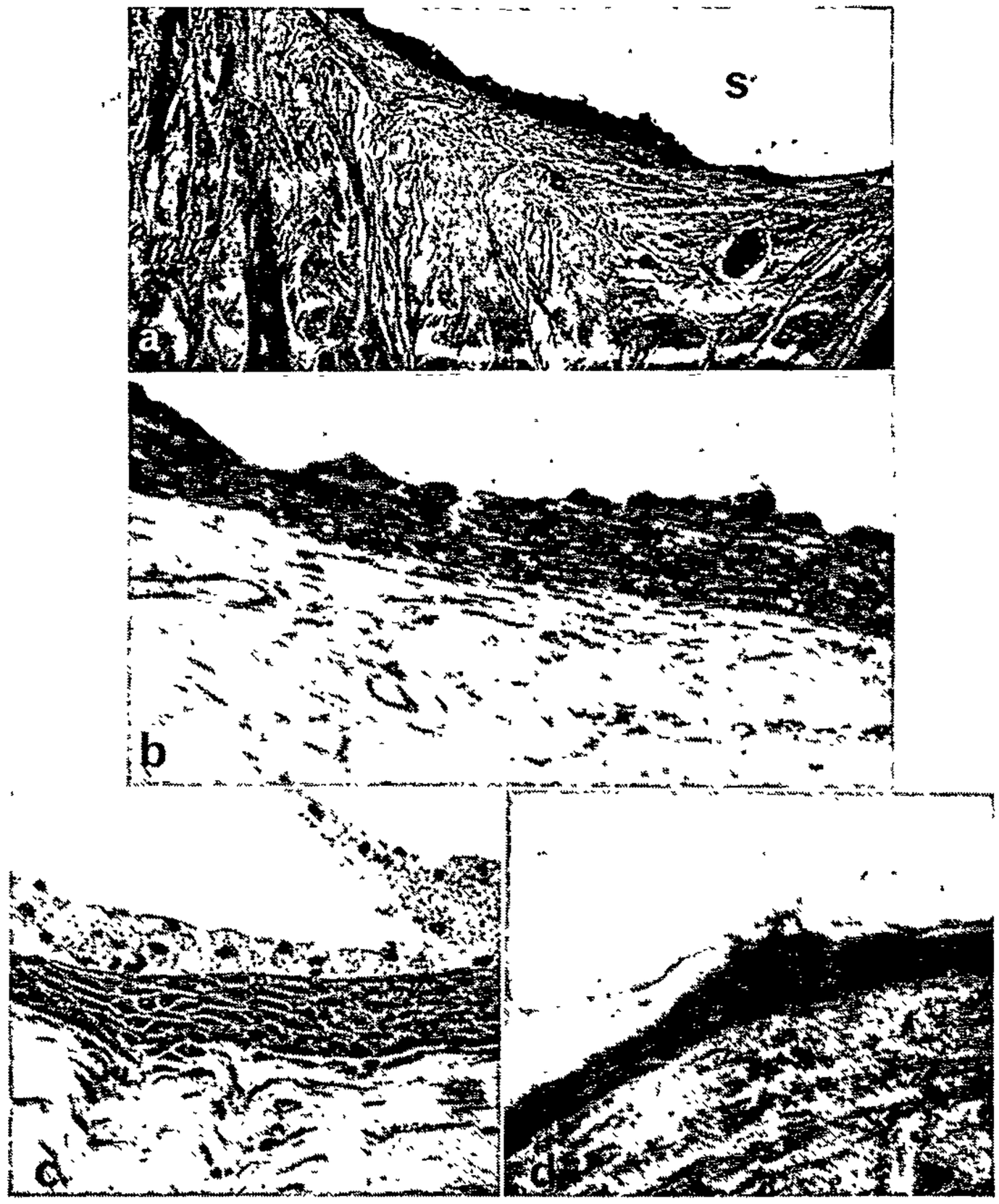

Fig. 5.
(*a*) Epithelial lining to silicone rubber foam implant with fibrous tissue support. (s) Implant. H.E. Original mag. ×80.
(*b*) Epithelial lining from (*a*). Original mag. ×360.
(*c*) Dental cyst. (d) Keratocyst. H.E. Original mag. ×360.

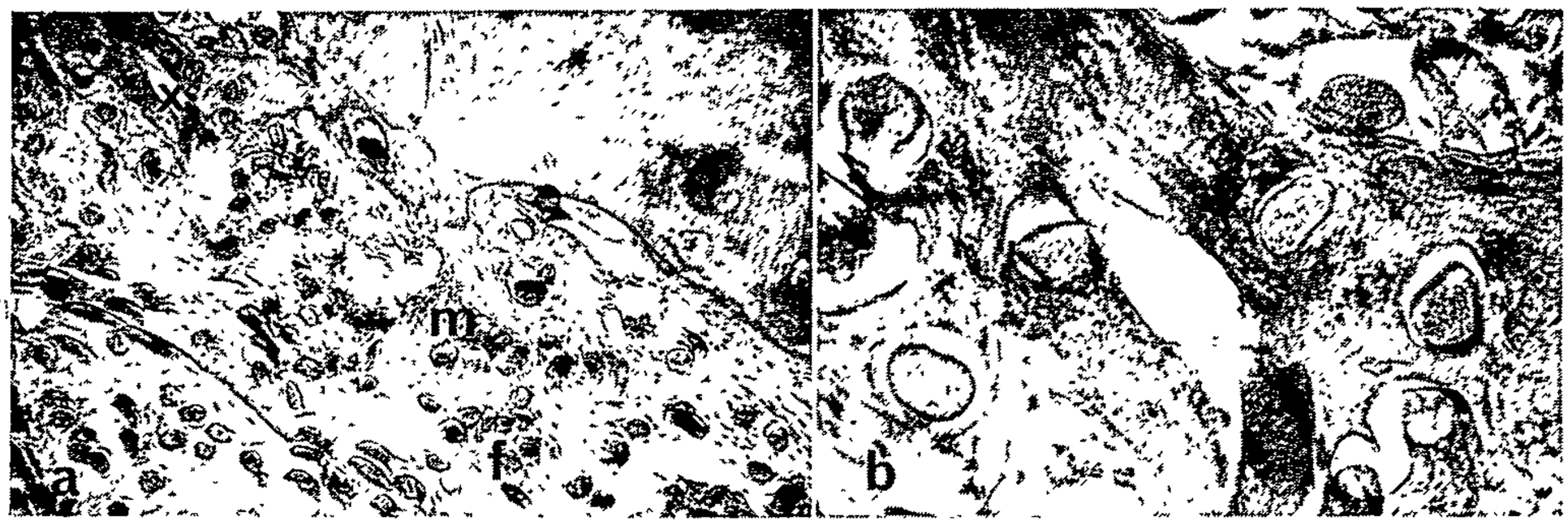

Fig. 6.
(*a*) **Fluon** felt implant (232 days). (f) Felt particles; (m) multinucleated cells. H.E. Original mag. ×80.
(*b*) Area marked X from (*a*). Original mag. ×360.

(*b*) bone regeneration was observed in the vent spaces of either screw or blade ;
(*c*) some slight epithelial invasion to a short depth in an apical direction along the implants (Fig. 11).

Fig. 7.
(*a*) **Fluon** "T" shape block implant (303 days). H.E. Original mag. ×12.
(*b*) Bone deposition within perforation of the Fluon. H.E. Original mag. ×80.

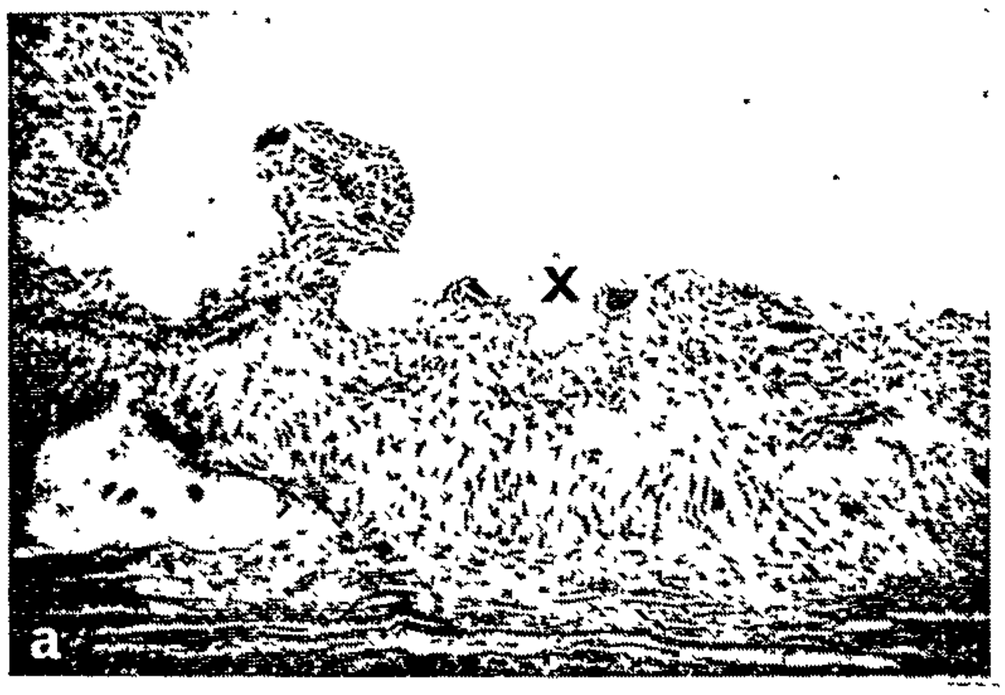

Fig. 8.
(*a*) Cartilage implant (200 days) with multinucleated cells. H.E. Original mag. ×80.
(*b*) Area marked X from (*a*). Original mag. ×360.

Discussion

Attempts to use a variety of materials for reconstruction of lost tissues have been met with varying degrees of success and largely with failure. More recently the range of materials has been extended to include plastics and ceramic materials and sometimes in combination with high tensile strength metals. Where success has been achieved it has not been so in all cases in which the method has been used. Obwegeser,[5] in reporting on cobalt chrome alloy subperiosteal implants, found success in nine out of 32 cases, and he emphasized that if the implant was successful, and he was unable to determine the reason for success, the dentures must be constructed with the utmost skill and care. Subperiosteal implants for use in unilateral situations are contraindicated when there is residual alveolar bone. This may be a reason why some authors have noted exposure of such implants as the bone resorbs beneath them.

The major problem encountered in all types of implants that have to support, by external projections, a prosthetic appliance, is epithelial encroachment along the interface between implant and connective tissue and the ingress of infection followed by inflammatory reaction. The inflammatory reaction may be no more extensive than that seen around the adjoining teeth[2] (Fig. 11). The patient must perform intensive and careful oral hygiene with frequent supervision.

The most noticeable feature of either the blade vent or screw vent is the surrounding of the implant with a zone of dense hyaline-like fibrous tissue and the ingrowth of bone into the fenestra of the metal implant (Fig. 2, 3). Careful examination of intra-oral rœntgenograms will show at the macroscopic level the extent of this fibrous tissue. The probable length of service of an implant may be estimated from such data, but it can only be an approximation since there are many variable factors operating in the process of resorption of bone or rejection of the foreign body.

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[5] Obwegeser, H. L.—Experience with subperiosteal implants. Oral Surg., Oral Med., Oral Path., 12 : 7, 777–786 (July) 1959.

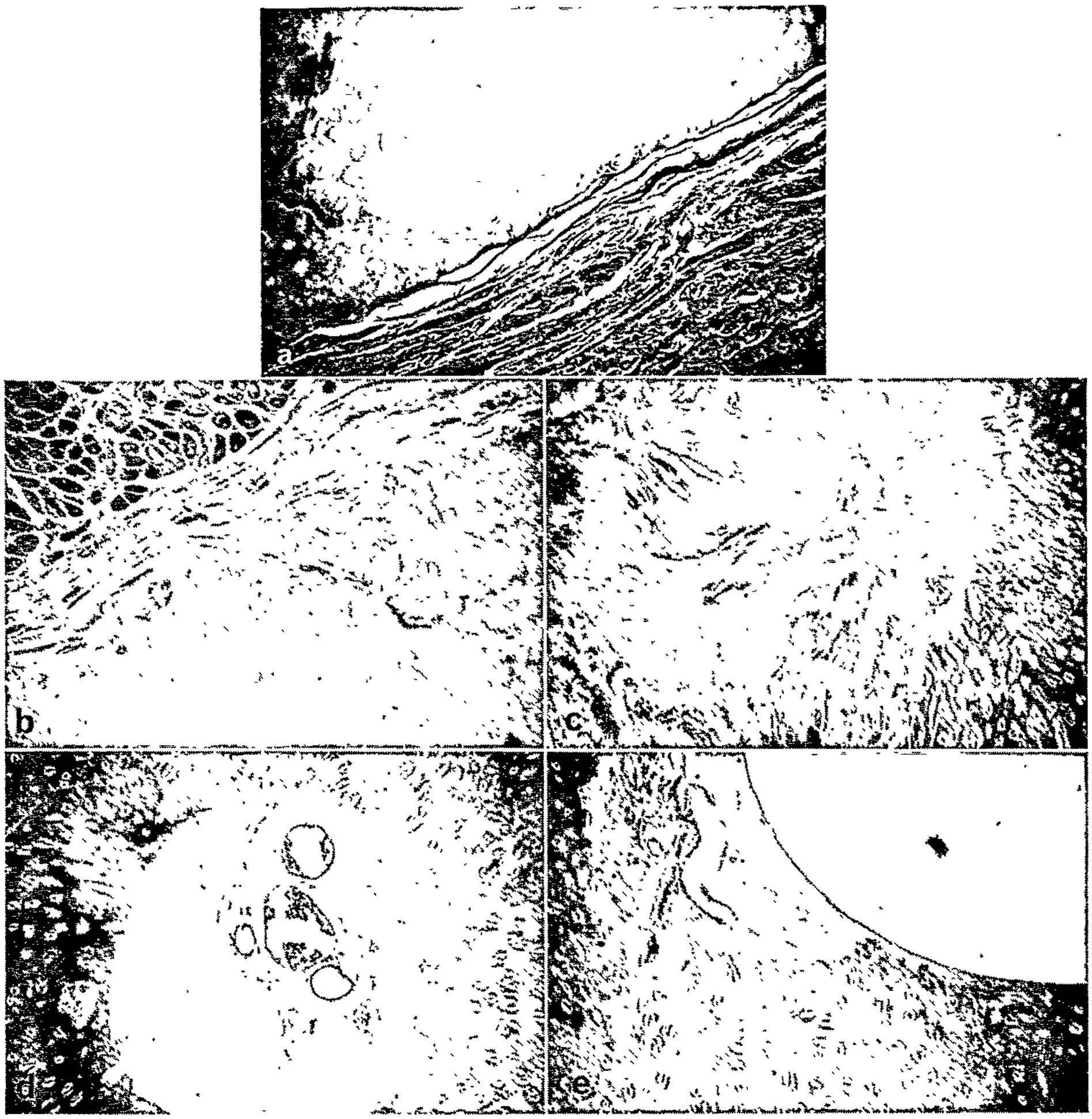

Fig. 9.
(*a*) Cartilage implant (436 days) covered with fibrous tissue. H.E. Original mag. ×80.
(*b*), (*c*) Cartilage implant (436 days) with invasion of strands of fibrous tissue. PAS. Original mag. ×80.
(*d*), (*e*) Other areas with ossification well developed in perforation and fibrous tissue between titanium pin and cartilage. Note the strongly PAS-positive area. PAS. Original mag. ×80.

Block and Baden[6] examined an endosseous screw vent implant that had been in place for three years and which apparently showed no signs of abnormality and the patient reported no symptoms. The implant was removed because the adjoining non-vital abutment was extracted. Histologic examination demonstrated a gingival crevice lined by a thin stratified squamous epithelium " somewhat resembling the epithelial attachment "; bone and hyalinized fibrous connective tissue had entered the fenestra of the implant. These findings are similar to those seen by Bodine and Mohammed[7] in a subperiosteal implant in place for 12 years and those seen in the jaws of dogs.[2]

Other substances have been suggested for implants, and these include ceramic materials, plastic polymers, and combinations of either one of these with a suitable metal. Hulbert, Klawitter, Talbert and Fitts[8] have reviewed the use of such

[6] Block, V. P., and Baden, E.—Tissue tolerance of metallic implants. Report of a case. J.A.D.A., 83 : 4, 856–859 (Oct.) 1971.

[7] Bodine, R. L., and Mohammed, C. I.—Histologic studies of a human mandible supporting an implant denture. J. Prosth. Dent., 21 : 2, 203–215 (Feb.) 1969.

[8] Hulbert, S. F., Klawitter, J. J., Talbert, C. D., and Fitts, C. T.—Materials of construction for artificial bone segments. *In*, Research in dental and medical materials. Edit. Korostoff, B. New York, Plenum Press, 1969 (p. 32).

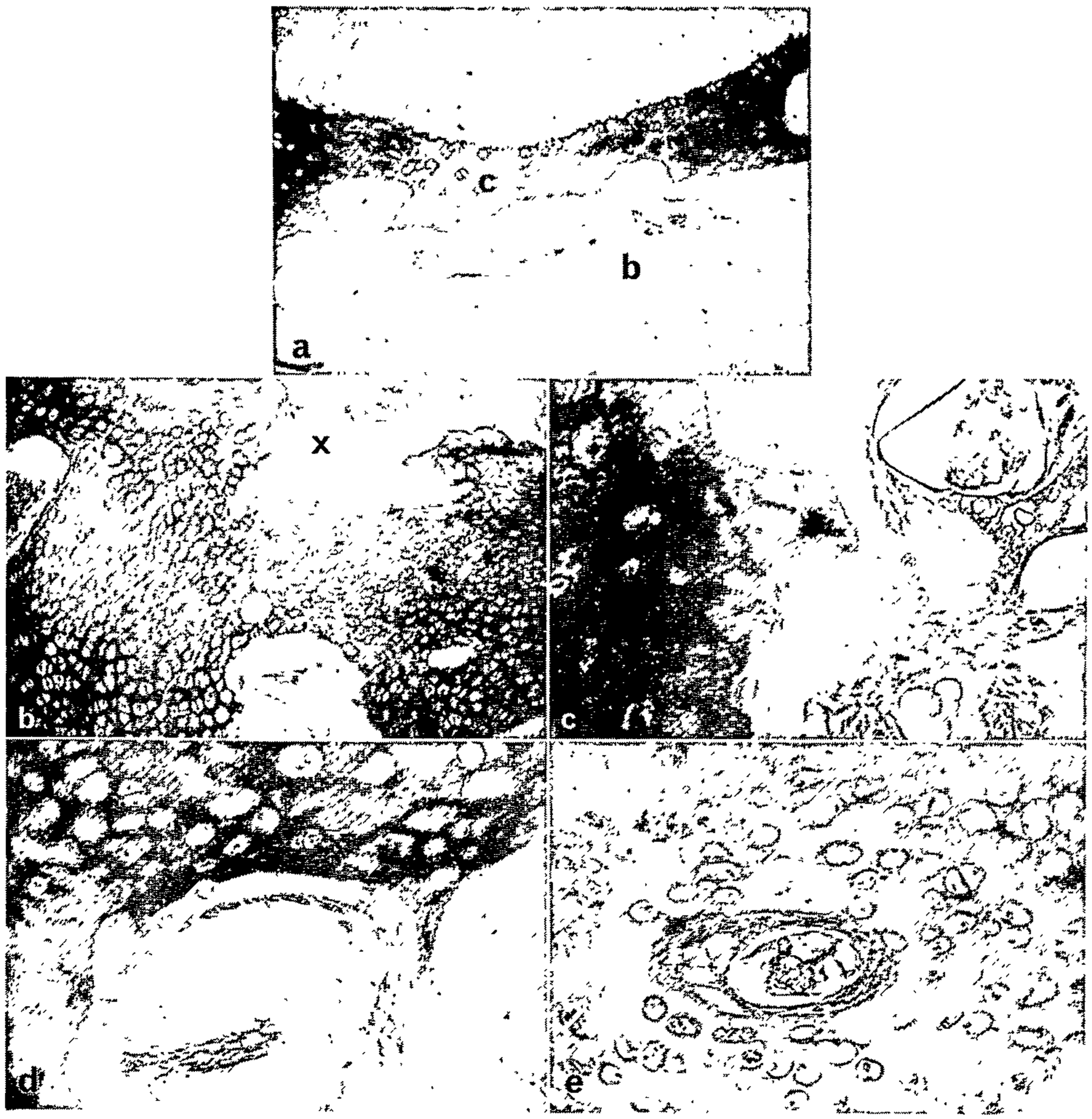

Fig. 10.

(*a*) Cartilage implant (367 days). (b) Bone; (c) PAS-positive cartilage. PAS. Original mag. ×80.
(*b*) Cartilage implant (436 days). Note varying degrees of PAS-positive staining and bone formation with narrow cavities. PAS. Original mag. ×80.
(*c*) Area marked X from (*a*). Original mag. ×360.
(*d*), (*e*) Other areas of same specimen showing ossification and variation in PAS staining. Original mag. ×360.

substances in closed situations and emphasize that the " highly corrosive and immunologically sensitive type of environment into which any internal bone prosthetic material is placed and with which it is not only expected to co-exist but to behave as a functioning integral member discounts most all materials from potential use in permanent implant applications. Corrosion or similar chemical degradation caused by the action of body fluids and tissues on the implant not only change the physical properties of the implant, but, in return, the products so formed are toxic, causing allergenic and/or carcinogenic responses." The importance of design should not be overlooked. Kaminski and Oglesby[9] noted round cell infiltration around the sharp angles and edges compared with none along smooth flat surfaces of metals implanted in connective tissues.

Brown[10] observed that plastics in sheet or film form embedded in the tissues of rats caused malignancy in significant numbers compared with the same material embedded as a textile, sponge or

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[9] Kaminski, E. J., and Oglesby, R. J.—Certain aspects of implant shape in experimental testing of biological materials. I. *In*, Research in dental and medical materials. Edit. Korostoff, E. New York, Plenum Press, 1969 (pp. 113–119).

[10] Brown, D. E.—Tissue reaction to plastic and metal implants. Arch. Otolaryng., 88: 81–85 (Sept.) 1968.

powder. Fitzpatrick[11] has stated that silicone in the form of **Silastic** foam seems more prone to inflammatory cleavage than other materials and that this may be due to the " dead space " features

Other studies have been made[13] on the use of porous methyl methacrylate and the response depends largely on the size of the porous spaces. Some investigations have been made using ceramic

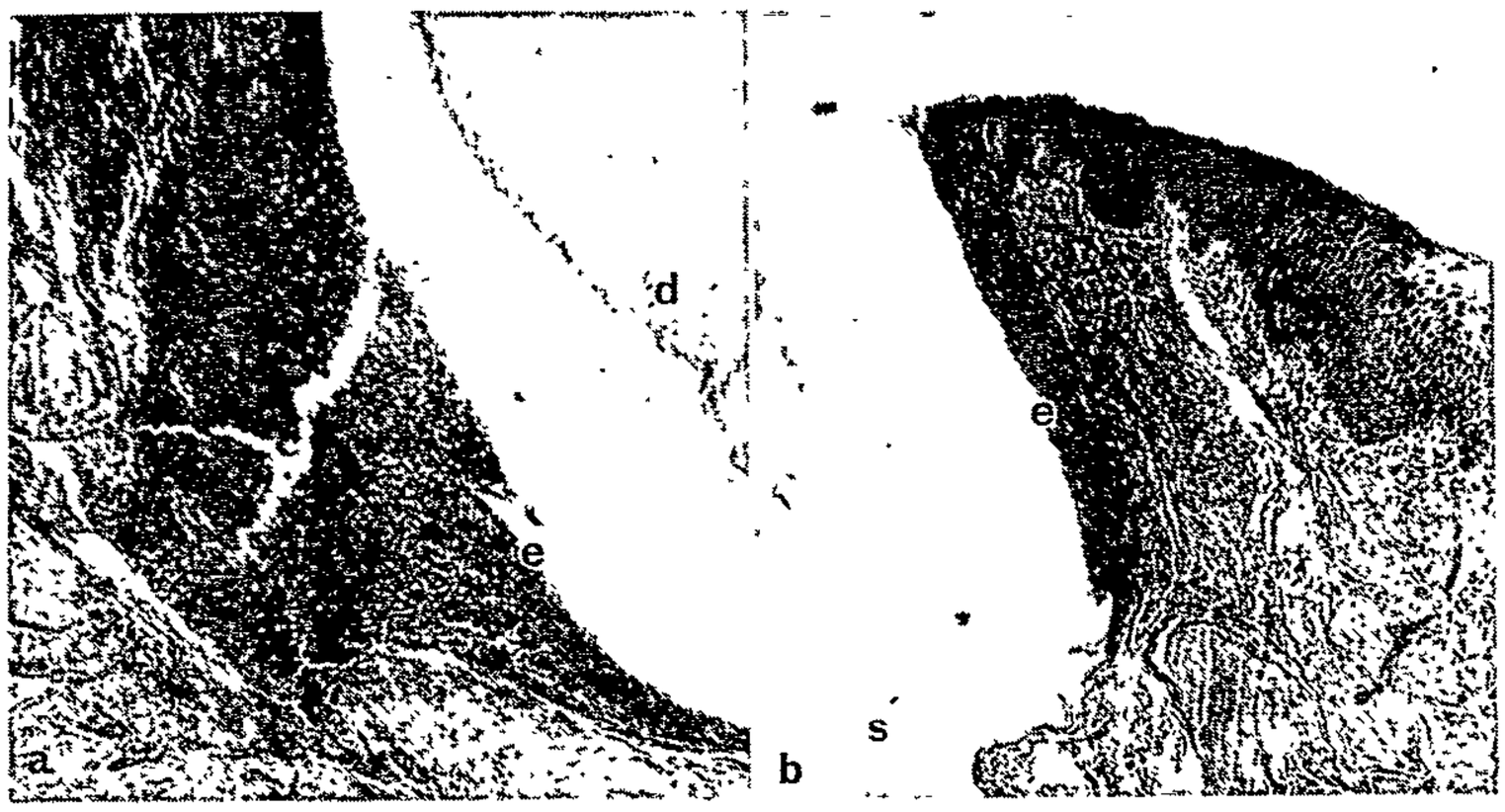

Fig. 11.

(*a*) Gingival sulcus cut from buccal to lingual of lower right premolar of dog. (e) Epithelium; (d) dentine. H.E. Original mag. ×80.
(*b*) Gingival sulcut cut from buccal to lingual of screw vent implant (62 weeks) in same dog. (e) Epithelium; (s) shank of implant. H.E. Original mag. ×80.

of its surface texture. This comment should be compared with the results noted and shown in Fig. 6 (*a*), (*b*). He preferred **Teflon*** felt for reconstruction of alveolar bone and stated that it appeared to be an ideal material to withstand bacterial invasion. It was noted in this study that although the felt fibres became incorporated in bone some multinucleated cells were present (Fig. 7 (*a*), (*b*)).

Dresser and Clark[12] studied the response to polyvinyl resin sponge implants in the jaws of dogs, but although the implant was compatible with the tissues there were failures.

In the present study it was found that three of eight silicone and two of seven **Fluon** felt implants were exfoliated; in these cases the implant was lost within a period ranging from one to 16 weeks. By contrast where the two blocks of **Fluon** were implanted subperiosteally these were exfoliated in eight weeks. However, where the **Fluon** had been implanted as an inlay superimposed by bone it was accepted by the tissues for periods up to 48 weeks without any signs of exfoliation.

materials which must have a certain degree of porosity. Studies had been reported[14] [15] in which root forms made of calcium aluminate were implanted into freshly made natural tooth sockets for periods up to 10 months. The maximum porosity was in the range of 100–150μ and osteoid material grew into the ceramic. It is claimed that it is easy to cut to shape. This is an important advantage which exists with **Fluon** since it can be cut to shape with a sharp knife and perforated readily with an appropriate size round bur.

Bovine cartilage has been used for a number of years and North[16] assessed 205 grafts in humans; the clinical evidence indicated a high degree of failure and the histological evidence indicated even higher failure. Most authorities supported this view and considered the use of cartilage whether in the form of homografts or heterografts as a

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* A form of polytetrafluoroethylene.

[11] Fitzpatrick, B.—A comparative study of some implant materials. II. Austral. D. J., 13: 6, 422–434 (Dec.) 1968.

[12] Dresser, W. J., and Clark, H. B.—Study of tissue response to polyvinyl resin sponge implants in the jaws of dogs. Jnl. Oral Surg. Anaesth. Hosp. Dent. Service, 17: 6, 5–13 (Nov.) 1959.

[13] Taylor, F. D., and Smith, F. B.—Porous methyl methacrylate as an implant material. Jnl. biomed. Mat. Res. Symposium No. 3. Edit. Hall, C. W., Hulbert, S. F., Levine, S. N., and Young, F. A. New York, Interscience Publishers, 1972 (pp. 467–479).

[14] Bhaskar, S. N., Cutright, D. C., Knapp, M. J., Beasley, T. D., Perez, B., and Driskell, T. D.—Tissue reaction to intrabony ceramic implant. Oral Surg., Oral Med., Oral Path., 31: 2, 282–289 (Feb.) 1971.

[15] Hamner III, J. E., Reed, O. M., and Grenlich, R. C.—Ceramic root implantation in baboon. Jnl. biomed. Mat. Res. Symposium No. 3. Edit. Homsy, C., and Armeniades, C. D. New York, Interscience Publishers, 1972 (pp. 1–13).

[16] North, J. E.—The use of preserved bovine cartilage in plastic surgery. Plast. and Reconstruct. Surg., 11: 4, 261–274 (Apl.) 1953.

second best type of procedure, although Gillies and Kristensen[17] claimed varying degrees of success depending upon the location of the graft. More recently interest in the use of bovine cartilage has been revived. Methods of tissue conservation have been developed based on lyophilization and sterilization with Gamma rays in which not only is the morphological structure preserved but the immunological intolerance to the graft is diminished. The original work of Ostrowski, Komender and Kwarecki has been referred to by Komender, Jendyk and Leibschang[18] and applied to dental problems by Stadnicki and Krajnik.[4] This is important since the major disadvantage in the use of heterografts, such as bovine cartilage, has been the immunological reaction. Ostrowski and his colleagues have demonstrated[19] that radiation sterilization (Gamma rays) of the tissues for clinical purposes destroys or at least strongly diminishes the antigenic properties of the irradiated tissue in addition to being a satisfactory means of sterilization.

It would seem that with control of the antigenic properties of the bovine cartilage the implant acts as a matrix for the processes of calcification and osteogenesis to operate. Thus the defect is gradually obliterated. Stadnicki and Krajnik used the method for filling defects in bone which had arisen from cystic cavities or the lack of union in fractures of the mandible. It is possible that the technique described in this paper can be utilized for clinical purposes to provide alveolar ridge reconstruction. Its one disadvantage is that the prepared cartilage is somewhat fragile and should be handled with great care.

The observations noted in this paper cover periods of 112–436 days in which replacement of the cartilage by bone appeared to require approximately six months before significant changes occurred (Fig. 10 (*a*), (*d*), (*e*)).

The problems encountered in the greatly resorbed mandibular alveolar ridge is a difficult one for the prosthodontist to solve. Whether the materials and methods that have been used most successfully in this study, namely **Fluon** and bovine cartilage, can be used clinically requires further study.

The advantage of the heterograft is that the patient does not have to submit to additional surgery in order to provide a donor site and banks of treated tissue can be established with little difficulty, and unlike **Fluon** the implant is gradually replaced with bone.

McLean and Urist[20] refer to the process of replacement of cartilage and suggest that following transplantation it produces new bone by endochondral ossification. New bone arises from ingrowing cells. They note that the favourable results reported following the use of devitalized tissue are evidence that the major factor in bone grafts is induction to which is added the desirable feature of provision of a lattice or bridge upon which new bone will form.

They point out that there is a prolonged latent period during which the donor tissue seems completely separated from the host. This was noted in the specimens of less than 200 days' duration (Fig. 9). They further state the condition may persist indefinitely or the donor tissue and the surrounding capsule may eventually be resorbed and replaced by new bone. The latent period may be determined by the immune reactions of the host. Since Gamma radiation has been demonstrated as an effective means of reducing immune responses, it would seem that the application of the work of Ostrowski, Komender and Kwarecki as suggested by Stadnicki and Krajnik should be given serious consideration.

Summary

1. The tolerance of dog's tissues to implants in alveolar bone of polytetrafluoroethylene, silicone rubber, and lyophilized irradiated bovine cartilage has been studied.

2. The cartilage and block polytetrafluoroethylene were accepted by the tissues, the former being gradually replaced by bone at intervals between 178 and 436 days, and the latter having bone grow into close proximity to it.

3. There is no evidence of inflammatory reaction to either material.

4. Silicone rubber foam produces a reaction not greatly dissimilar to the epithelial lining of the dental or keratocyst.

5. Polytetrafluoroethylene felt provoked a multinucleated cell reaction and was exfoliated in a number of cases.

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N.S.W., 2010.

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[17] Gillies, H., and Kristensen, H. K.—Ox cartilage in plastic surgery. Brit. Jnl. Plast. Surg., 4 : 63–73, 1951–52.

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