BEHAVIOR OF MALASSEZ' EPITHELIAL RESTS DURING ORTHODONTIC TOOTH MOVEMENT

by

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It is generally assumed that epithelial cells of the periodontal membrane were first described by *Malassez* (1885). This statement is only partly correct. Prior to *Malassez'* first articles epithelial cells of the periodontal membrane had been described in other publications.

The term "epithelial rests" was probably first used by *Serres* (1817), who mentions "restes de l'organe de l'email". *Malassez* almost invariably applies the term debris or "amas". In addition, *Serres* was more or less aware of their persistence in adults, since he states that "atrophy of these cells does not always result in their complete disappearance". In subsequent studies by histologists such as *Kölliker* (1852, 1867), *Legros & Magitot* (1879) and others, it was always maintained that epithelial cells would atrophy and were absent in the adult supporting structures. Hence credit must be given to *Malassez* for having proved once and for all that epithelial rests persist even in the adult periodontal membrane.

Shortly after *Malassez'* first publication, and even up to our time, a great many articles have appeared concerning the origin, distribution, and possible function of epithelial rests, *v. Brunn* (1887), *Black* (1887, 1899). While most authors consider the epithelial rests as remnants of Hertwig's epithelial root sheath, there has been some disagreement as to their distribution and function. *Serres* (1817) considered epithelial chords in the marginal region as glandular organs, structures which were later on termed "glands of Serres" by *Salter* (1874). According to *Noyes* (1930), some of these "glands" were probably formed by downgrowth of epithelial strands in a marginal tissue undergoing pathologic changes. As pointed out by *Lartschneider* (1929), one must distinguish between the epithelial remnants located in the supra-alveolar tissue and those seen adjacent to the root surface. According to our present-day view, it is primarily these latter cells that should be considered as epithelial rests of Malassez.

Since the epithelial cells along the root surface are remnants of the deepest portion of Hertwig's epithelial root sheath, many authors find it quite natural that some cell clusters may be left behind during growth and eruption of teeth. *Orban* (1926), *Higaki* (1932), and *Meyer* (1932) have described epithelial cells which were located in marrow spaces or in the nerve canals of the bone at a considerable distance from the root concerned.

On the other hand, as shown in several textbooks and articles, tangential sections close to the root surface reveal that a net-like arrangement exists, *Mummery* (1921), *Noyes* (1930), *Brusst* (1932), *Fischer* (1932), *Meyer* (1932), *Orban* (1944), *Löe & Waerhaug* (1961). This network has been considered the final arrangement of the epithelial rests around the root following proliferation of connective tissue, formation of cementum and functional organization of the supporting fibers.

Fischer (1932) was of the opinion that it would be difficult to demonstrate such an epithelial network around all human teeth, and that this network probably did not exist in all cases. He found that a net-like arrangement could be produced much more readily by tangential sectioning of teeth taken from animals such as cats and sheep. He also found that epithelial rests were more numerous in the marginal and in the apical region. This last observation would explain how epithelial cells can occasionally be enclosed in the root canal during formation of the apical portion of the root (*Orban* 1926).

Most authors agree that the incidence of epithelial rests decreases with increasing age. This also applies to animal structures (*Wentz, Weinmann & Schour* 1950). In their material, comprising the molar region of 105 rats, these authors observed three morphological types: 1) a small resting type, 2) a proliferating type, and 3) a differentiating type. As to the prevalence in the rat, it was found that 53 of 105 specimens showed the presence of epithelial rests.

Several authors have stated that, apart from the epithelial cells observed in the marrow spaces, the epithelial remnants, under normal conditions, would be located somewhat differently in relation to the root surface. *Malassez* pointed out that epithelial cells could be observed fairly close to the alveolar bone surface in adults. Similar observations have been made by *Orban* (1926) and *Meyer* (1932). As shown by *Gottlieb* (1921) degenerated epithelial cells may, under certain conditions, be incorporated in cementum layers, notably in cases where the cementum appears in the form of exostoses. *v. Brunn* (1887), *Gottlieb* (1921) and others described epithelial cells as related to formation of enamel pearls, most frequently observed in the marginal region of the root and in bifurcations. Many authors have discussed the tendency to proliferation and growth of epithelial rests as a result of pathologic changes in the periapical region (*Nygaard Östby* 1939, 1944).

The possibility of an endocrine or glandular function of the epithelial remnants has been discussed by *Black* (1887), *Robinsohn* (1926), and *Higaki* (1932). Very little is said in the current textbooks concerning the function of epithelial structures of the periodontal membrane. Most of the present-day authors consider epithelial rests as remnants of structures without any particular function. *Waerhaug* (1958), and *Löe & Waerhaug* (1961) were of the opinion that Malassez' epithelial rests may act as some sort of protective system, to some extent preventing the root surface from being involved during resorptive changes. Their observations, made in experimental studies on replantation of teeth, seemed to indicate that "the epithelial rests of Malassez may be a factor in the limitation of root resorption in teeth replanted with vital periodontal membrane".

Up to the present, no investigations on experimental tooth movement have included a detailed study on the reaction of the epithelial rests of Malassez. Their location and incidence have been mentioned more or less occasionally (*Reitan* 1951, 1953, 1957, 1959). The purpose of the present study is primarily to describe the incidence and distribution of the epithelial remnants in a control material comprising human and animal supporting structures, secondly, how the epithelial cells of the periodontal membrane react during various types of experimental tooth movement.

MATERIAL AND METHODS

The present material consists chiefly of human teeth with supporting tissues. This material, cut longitudinally, was subsequently compared with animal structures, partly longitudinal, partly transversal sections. The sections were stained with hematoxylin-eosin. Observations on the incidence and location of epithelial rests were made on a control material consisting of sections of the author's experimental series (*Reitan* 1951, 1953, 1954). Most of the material was taken from young age groups. Three series of adult teeth with supporting tissues were included for comparison, together with a few series of human and animal structures not as yet published.

Supporting structures of the human premolars, described in this study, do not include the whole apical region. Only occasionally had periapical structures close to the foramen been removed with the tooth; in most cases two thirds of the apical region could be examined.

In the control series epithelial remnants of the supporting structures of first upper premolars were examined. This material consisted of teeth that had to be removed in orthodontic cases, viz. 25 patients aged 11 to 12 years. The findings were listed in a table which serves as a basis for comparison and evaluation of the number, form and location of epithelial rests in the present material as a whole. Since the material was fairly uniform, only findings made in the supporting tissues of the ten first patients will be given as an example, Table 1.

The second part of this study deals with the possible displacement or the atrophic changes of epithelial cells in the periodontal membrane as observed in a tipping, bodily and rotating movement of teeth. In addition, the effect caused by relapse or reversed tooth movement has been considered.

Table 1

Epithelial remnants of upper first premolars, 11 to 12 year old persons. 0+ = few; + = a moderate number; ++ = a large number; +++ = a very large number. 1 = round or oval form; 2 = cluster-like; 3 = strands; cl. = close; f. cl. = fairly close to the root surface. Compare Figs. 7, 8, and 9.

Patient No.	Marginal Region			Middle Region			Apical Region		
1	+ +	1	cl.	+ +	2 & 3	cl.	+ +	3	cl.
2	+	1	cl.	+	1	cl.	0 +	1 & 3	cl.
3	+	1 & 3	f. cl.	+ +	3	cl.	+ +	3	cl.
4	+	1 & 3	f. cl.	+ +	3	cl.	+ +	3	cl.
5	+	1 & 2	f. cl.	+	2	cl.	+	2 & 3	cl.
6	+ +	1 & 2	cl.	+ + +	2 & 3	cl.	+ +	2 & 3	cl.
7	+	1	cl.	+	1 & 2	cl.	0 +	1	cl.
8	+	1	f. cl.	+	1 & 2	cl.	+	2	cl.
9	+	1	f. cl.	+ +	1 & 2	f. cl.	+	1	f. cl.
10	+	1	f. cl.	+ +	2 & 3	f. cl.	+	1	f. cl.

FINDINGS

The human control material revealed that one may distinguish between certain arrangements of cells. In the present classification three forms have been chosen as typical, notwithstanding the fact that there are many variations or combinations of groups of cells.

The three forms are: (1) A pseudo-tubular, round or oval form, Fig. 7; (2) a cluster-like form, Fig. 8; and (3) strands of epithelial cells, Fig. 9. The pseudo-tubular or round form prevailed in the supra-alveolar tissue, Fig. 10. In the periodontal membrane all three forms were seen in nearly all cases, Fig. 11. Occasionally, long strands of epithelial cells could be observed.

Control material

As seen from Table 1, there are to some extent individual variations. There is a large number of epithelial rests in No. 1 and only a moderate number in No. 2, while there is a very large number in No. 6. Of all the 25 teeth only four had a periodontal membrane with a very large number of epithelial rests, and then chiefly in the middle region where long strands were located more or less parallel to the root surface. In general, there was also a greater number of cellular elements in the periodontal tissues of these four teeth, than in most of the other cases.

The form of the epithelial rests, as observed in the sections, was frequently varying. The so-called pseudo-tubular or round form prevailed in the marginal region. There was not much variation with regard to the distribution of the epithelial cells. They were seen fairly close or close to the root surface. Nowhere could epithelial rests be observed in the middle of the periodontal membrane or close to the bone surface.

No special attempt was made to detect a network formation. Nevertheless, such a network, or parts of it, could be observed in the periodontal membrane adjacent to 13 roots of the control material. Pseudo-tubular or round epithelial rests of the supra-alveolar tissue were found in 16 cases, Fig. 10.

There were in general fewer epithelial remnants in areas adjacent to the bifurcation of the roots than in other areas of the periodontal membrane. Only in one instance was a strand of epithelial cells so arranged in the bifurcation area that there could have been formation of an enamel pearl, Fig. 12.

In *Malassez'* original illustrations some of the epithelial strands were not located quite parallel to the root surface, but form a more or less acute angle with the latter, Fig. 9. This arrangement —several strands with one end turned away from the root surface—was more marked in seven of the cases examined than in the others.

Adult supporting tissues. Examination of the control material of the three adult series—patients aged 35 to 40 years—revealed that there were fewer epithelial rests in the periodontal membrane and, in general, connective tissue cells of the fibrocyte type. Compared with any control series of young tissues the observation of epithelial remnants adjacent to the root of one upper premolar is fairly representative of the whole adult series, Table 2.

In the adult tissues the epithelial rests were few, well spaced and mainly of the round type or strands. Proliferation and

Table 2

Epithelial remnants adjacent to root of upper first premolar, 37 year old person. 0 + = few; 1 = round or oval form; 3 = strands; cl. = close to the root surface.

Patient	Marginal Region		Middle Region			Apical Region		
Adult	0 +	1	cl.	0 +	1 & 3	cl.	0 +	1 & 3	cl.

thickening of single strands could be observed, Fig. 13. In spite of this seeming lack of epithelial rests, part of a network could be observed in tangential sections, Fig. 14. Occasionally, layers of epithelial cells adhering to the root surface were found, Fig. 15. Several cementicles were observed which could have been formed around degenerated epithelial cells.

Epithelial rests in the dog. A marked difference could be noted with regard to the incidence and distribution of epithelial remnants in the dog as compared with human structures. For comparison, the number, form and location of epithelial cells in four animals, 11 months old, are listed in Table 3. The teeth, upper central incisors, were cut longitudinally. As compared with Table 1, the epithelial rests adjacent to the roots of the dog teeth were few, although some variations could be noted. Thus, there are more epithelial rests in animal No. 4 than in the others. The supra-alveolar cells, described in the human material, could be

Table 3

Epithelial remnants of upper incisors in the dog. + = a moderate number; 0 + = few; 00 + = still fewer; 1 = round or oval form; 2 = cluster-like; dist. = at some distance from the root surface; f.cl. = fairly close; cl. = close.

Dog No.	Marginal Region			Middle Region			Apical Region		
1	0 0 +	1	dist.	0 +	1	f. cl.	0 0 +	1	f. cl.
2	0 0 +	1	dist.	0 +	1	f. cl.	0 0 +	1	f. cl.
3	0 +	1 & 2	dist.	0 +	1	cl.	0 0 +	1	cl.
4	+	1 & 2	dist.	0 +	1	f. cl.	0 +	1	cl.

observed, Fig. 19, but there were other strands of epithelial cells in the supra-alveolar tissue, especially adjacent to lower front teeth. In the periodontal membrane very few strands of epithelial cells were found. Types no. 1 and 2 prevailed, Figs. 17 and 35. These cell groups were located close or fairly close to the root surface.

In cross-sections of the marginal region epithelial rests were occasionally observed in the middle of the periodontal membrane, but not close to the bone surface, Fig. 32. These round cell groups may have been cross-sections of single strands. In Fig. 18 human epithelial rests are shown for comparison. No definite network formation was found in the series listed in Table 3, but short strands were observed in tangential sections.

Epithelial rests in the monkey. Teeth with supporting structures of four animals were examined. The epithelial rests were, as a rule, of the round form and, generally, larger than in the dog. There were few or a moderate number of epithelial rests as compared with human tissues. Epithelial rests in the supra-alveolar tissues were absent in many sections. The epithelial cells in the periodontal membrane were situated close or fairly close to the root surface, but variations could be observed. Around the apical end of the root, well spaced cell groups, chiefly round, were observed. In bifurcations of the molar roots spaces in which enamel pearls may have been formed were occasionally seen subjacent to a layer of epithelial cells.

Experimental material

Evaluation of any changes in the incidence and location of epithelial rests around teeth moved orthodontically was based on a comparison with the findings made in the control material. The changes observed on the pressure and tension sides of the root are discussed separately.

Epithelial rests on the pressure side

As shown in earlier investigations, tissue changes on the pressure side are, in the initial stage of tooth movement, influenced by the narrowness of the periodontal membrane. Hyalinization in circumscribed areas is inevitable in many cases, as observed by

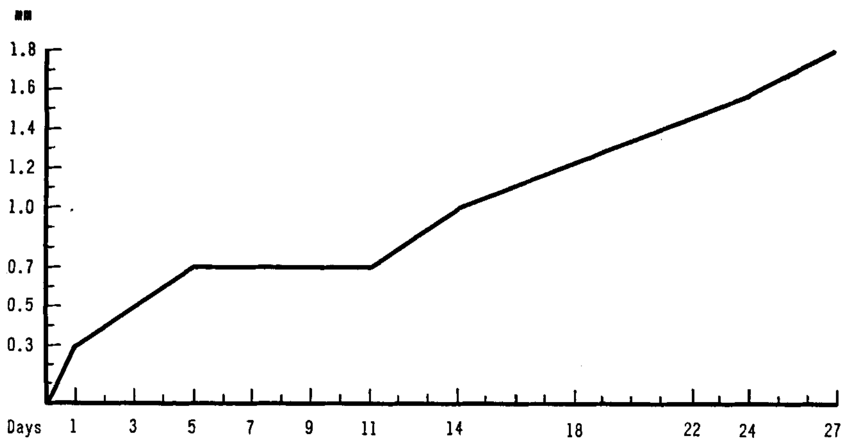

Fig. 1. Movement of human tooth with removable plate. A cell-free area existed on the pressure side from the fifth to the eleventh day. Compare Fig. 21.

measuring tooth movement at regular intervals. Cell-free areas, created by removable plates exerting a light force, will soon be eliminated by an indirect undermining resorption, Fig. 1 and Fig. 21. When the force acts continuously, hyalinization may last longer—two to three weeks on the average—even if the force is small. This applies to a tipping and a rotating movement.

It has been shown that a parallel or bodily movement may, under ideal conditions, result in the absence of hyalinized areas, (*Reitan* 1947). In practice, however, due to the narrowness of the periodontal membrane, various mechanical conditions and notably the magnitude of force, a cell-free area is frequently created in the initial stage. This is quite common when teeth are retracted by means of sectional arches, Fig. 2. What in mechanics is termed a couple is set up, by which the root is slightly tipped, a movement frequently leading to formation of pressure areas. In a bodily tooth movement hyalinization occurs approximately between the marginal and middle regions, because the periodontal membrane is narrowest in that area. At the same time direct bone resorption takes place in areas corresponding to the remaining middle and apical regions.

When the cell-free area has been undermined, space has also been created by direct bone resorption in the middle and apical regions, whereby the whole tooth moves bodily. As a result of increased resistance from stretched fibers on the tension side, further movement causes chiefly a direct bone resorption. Thus, in the initial stage, including bodily tooth movement, there are

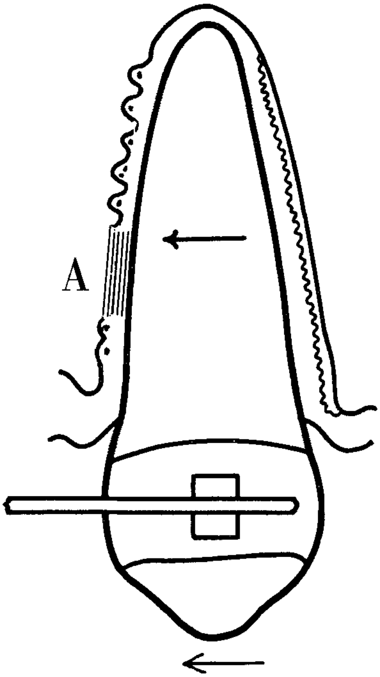

Fig. 2, illustrating location of the hyalinized area on the pressure side of an initial bodily tooth movement, A.

nearly always two types of reaction on the pressure side, hyalinization and direct bone resorption.

Comparison with control areas may reveal what happens to the epithelial rests in areas undergoing direct bone resorption or hyalinization. In addition, since the number of epithelial structures is fairly equal on the pressure and tension sides, it is possible to observe whether a decrease in the number of epithelial rests has occurred on the pressure side by comparing the two sides.

Direct bone resorption has no visible effect on the epithelial rests. In a human material it could be observed how the periodontal tissues were slightly compressed. The epithelial rests had been moved fairly close to the cementoblast chain of the root surface, Fig. 20. Apart from this slight displacement, caused by a general compression of the periodontal tissues, observation of a large number of sections revealed that no perceptible changes occur. Even if the experimental tooth had been moved several millimeters, there was always a row of epithelial cells along the root surface on the pressure side, provided there had been a direct bone resorption.

In cases in which the experimental tooth had been retained, the epithelial rests had resumed a position similar to that observed in corresponding areas of the control tooth.

Hyalinization of periodontal fibers almost invariably causes atrophy of epithelial rests by which the cells degenerate and finally disappear. The existence of a hyalinized area as well as its duration, could be controlled by measuring the movement of the experimental tooth, Fig. 1. If the tooth with supporting tissues was removed after the hyalinized tissue had disappeared, subsequent examination of the sections revealed that there was a lack of epithelial rests in a circumscribed area, frequently located in the marginal region or between the marginal and middle regions, Fig. 21. Comparison with control areas showed that there had been a fairly great number of epithelial rests prior to the hyalinization.

It was found that, during hyalinization, osteoblasts and other connective tissue cells would disappear quite soon. Degenerated epithelial cells, on the contrary, would persist for some time in the hyalinized area, Figs. 22 and 24. When the undermining resorption was completed, the epithelial rests did not reappear. This was observed in experiments on relapse and reversed tooth movement. It was shown that compression of the periodontal fibers for a period of eight days would eliminate cellular elements in a circumscribed area, Fig. 25. When the tooth was moved away from the pressure side, new connective tissue cells would soon reappear. This reorganization of the hyalinized area by formation of new cellular elements was usually completed within a period of two to three weeks. The epithelial rests disappeared and remained absent in the formerly hyalinized area, Fig. 26.

Root resorption. In the present human material comprising 40 patients (experiments conducted with forces ranging from 30 to 70 g; duration up to eight weeks) root resorption did occur only occasionally. The experimental teeth were either tipped or moved bodily. In other types of tooth movement, such as rotation of teeth in the dog, root resorption occurred quite frequently and, as in the human material, always in conjunction with hyalinization

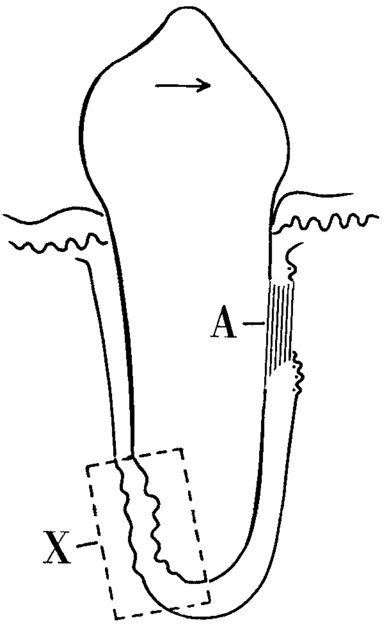

Fig. 3. Persisting hyalinized area at A; area X shown in Fig. 28. Continuous tipping movement of first lower premolar in the dog; duration of hyalinization nearly forty days.

of periodontal fibers. The periodontal membrane adjacent to the resorbed area, showed the absence of epithelial rests, Fig. 27.

Bodily movement of teeth, conducted for several months with forces around 60 to 70 g, was associated with root surfaces exhibiting surprisingly few and quite superficial root resorptions. There was always a lack of epithelial rests close to the resorbed area.

Root resorptions in the marginal region were observed following tipping of front teeth in the dog with forces ranging up to

300 g. There was a considerable hyalinization in the marginal as well as in the apical region, but no resorptions were observed along the apical root surface. The two areas varied with regard to the width of the periodontal membrane, which was wider in the apical area, and also with regard to the cementum, which was much thicker in the apical portion of the root. Comparison with control areas revealed that the number of epithelial rests in the marginal and apical regions had been fairly equal. Absence of epithelial rests was observed in the periodontal tissue adjacent to the marginal root resorption as well as adjacent to the formerly hyalinized area of the apical region.

A first lower premolar in the dog was tipped mesially for a period of 40 days with a force of 40 g, Fig. 3. Because of the density of the bone, the marginal hyalinized area persisted during that period, while root resorptions were observed in the apical area where the periodontal membrane was fairly narrow. Epithelial rests were absent in the resorbed areas, Fig. 28.

Epithelial rests on the tension side

The changes observed on the tension side of the experimental teeth showed that the periodontal fibers would be more or less stretched, according to the way the tooth movement had been performed. This stretching was especially marked in experiments on rotation of teeth as well as after a rapid tipping movement, Fig. 30. Stretching of fiber bundles also occurred following a bodily tooth movement of some duration.

In experiments conducted with removable plates (duration from three days to three weeks) no perceptible displacement of epithelial cells was found. Their form and arrangement did not vary from that observed in the corresponding control areas, Fig. 18. Nor were the periodontal fibers on the tension side much stretched as compared with fibers having been subjected to a continuous tooth movement.

In a tipping movement performed with continuous forces, some compression of epithelial rests between stretched fiber bundles was observed. This compression was fairly proportional to the distance the tooth was moved. At the same time some of the epithelial rests on the tension side had been moved slightly away from the root surface.

A similar compression of epithelial rests was found following rotation of teeth, Fig. 29, notably where the experimental tooth was rotated up to 80 or 90°, Fig. 30. Since experiments on rotation were conducted in the dog, a varying location of epithelial cells was found in the marginal region, where these cell groups were often located at some distance from the root surface. It is

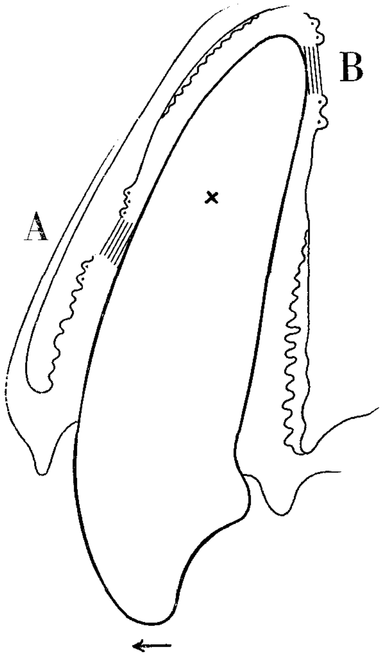

Fig. 4, illustrating location of hyalinized areas, A and B, as a result of relapse of the tooth moved. This tooth had previously been moved with a continuous force in a lingual direction and was then released.

questionable, however, whether the epithelial cells in Fig. 32 were really moved away from the root surface as a result of the pull exerted by stretched fiber bundles. This may have been their original location prior to the experiment, or they may have been only slightly moved. On the other hand, where they appeared compressed between stretched fiber bundles, this was definitely an effect elicited by the tooth movement. Orientation of epithelial strands parallel to stretched fiber bundles was occasionally observed on the tension side of adult teeth, Fig. 31.

Relapse, i.e. movement of the experimental tooth towards the tension side, occurs in nearly all types of tooth movement, especially when the tooth is suddenly released, less so after a retention period. It has been shown that the degree of relapse is marked when the experimental tooth is released after being moved through a great distance during a short period of time. This reactive movement, caused by contraction of stretched fiber

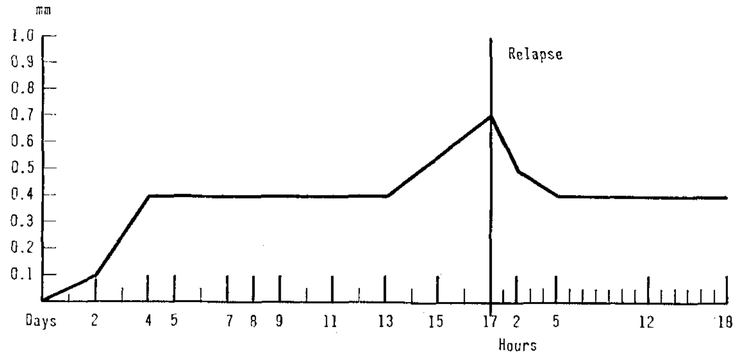

Fig. 5. Continuous movement with light continuous force and subsequent relapse of an upper first human premolar. Duration of movement seventeen days; relapse measured during eighteen hours.

bundles, is frequently strong enough to produce cell-free areas on the tension side. The result of this compression may lead to atrophy and degeneration of epithelial rests in circumscribed areas of the marginal and apical regions, Fig. 4.

Apart from these changes observed in the hyalinized areas, a sudden release of the tooth moved may result in a displacement of epithelial rests on the tension side. This was noted in experiments in which the appliances were removed after a rapid tipping movement of upper second incisors in the dog.

The degree of relapse of one human premolar is illustrated in Fig. 5. Measurements of the distance through which the tooth had relapsed, showed that a considerable movement towards the tension side occurred shortly after the tooth was released. Examination of the sections disclosed that the epithelial rests had moved close to the root surface. In some animal experiments, they were even partly embedded in the cementoid layer, Fig. 33. This movement of epithelial cells towards the root surface was only noted in cases where the experimental tooth had relapsed, not in cases where the tooth had been retained for a certain period of time. Evidence of epithelial rests being permanently enclosed in a cementoid layer was observed, but only in two animal series of the whole material.

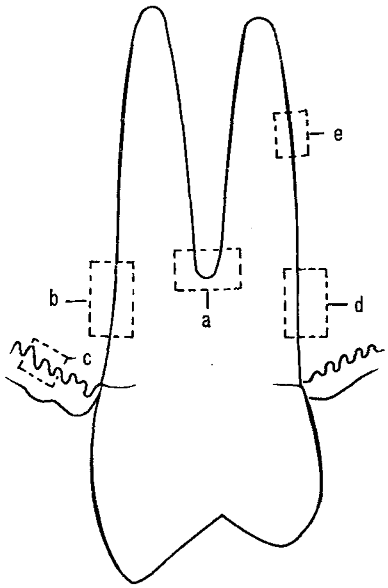

Fig. 6. Illustrating location of areas *a*, *b*, *c*, *d* and *e* which are shown in the following photographs.

DISCUSSION

The control material of this study shows that Malassez' epithelial rests are more numerous in 11 to 12 year old children than in adults. Compared with young human structures, epithelial rests in dogs and monkeys are in general less numerous and mostly seen as round or oval cell groups. The long strands observed in the human material may indicate that a network exists. The classification of epithelial rests—round, cluster-like and strands—applied in this study, can only be regarded as a method for description of what is typical in the particular sections examined. Some of the round or oval cell groups were obviously cross-sections of strands, notably those seen in the middle and apical regions.

That the epithelial rests in the dog were comparatively few and only occasionally seen in the form of strands in the middle and apical regions, does not exclude the existence of a network in that animal. It illustrates, however, that there are certain anatomical differences between animal and human structures. The great number of epithelial rests observed in the young human periodontal membrane and their regular arrangement tend to facilitate observations of possible changes in the number and location of epithelial rests in an experimental material.

Measuring the location of epithelial rests on the tension side in the animal experiments would have led to erroneous conclusions, if the findings had not been compared with those of control areas. Compression of epithelial cell groups between fiber bundles was noted in experiments on rotation of teeth, Fig. 30. However, the cell groups in the marginal region observed at some distance from the root surface, were probably only slightly displaced, Fig. 32. In the human experimental material very little displacement of corresponding epithelial cells was found.

The reason for this slight displacement of epithelial cells on the tension side can be explained by examining what happens to the periodontal fibers during tooth movement. If the periodontal fibers are subjected to stretching, an elongation will occur by some sort of a sliding movement or a rearrangement of single fibers within the bundle (*Sicher* 1923, 1942). There is nothing to prove that this elongation takes place close to the root surface. It is more likely that it occurs in the proliferation zone situated at some distance from the bone surface, Fig. 11. In this zone a great many fibrils are seen surrounded by fibroblasts, some of which undergo mitotic cell division. In support of this conclusion one may also observe that epithelial cells remain close to the root surface even if the experimental tooth is moved through a distance of several millimeters. The fiber bundles elongate and the cellular elements along the root surface move with the tooth.

The tissue reaction observed on the pressure side of animal teeth, was in many respects similar to that observed in human structures, but there were also certain differences. It was shown in the present investigation that epithelial cells on the pressure side remained close to the bone surface as long as there was a direct bone resorption, Fig. 20. During hyalinization several epithelial cells were permanently lost. In the human periodontal membrane remaining epithelial rests were observed close to the formerly hyalinized tissue, Fig. 22.

In the animal structures comparatively few epithelial remnants had been lost during hyalinization. They were frequently well spaced prior to the experiment, as observed in control areas. Hence, as shown in Figs. 34 and 35 (direct bone resorption after a short period of hyalinization) no more than two or three epithelial cell groups had been eliminated during hyalinization. Similar observations were made in the adult human material where the epithelial cells in the marginal region were comparatively few. After hyalinization there was a direct bone resorption.

In the experiment, illustrated by Figs. 3 and 28, several hyalinized areas, followed by root resorptions, were formed successively because a new compressed area was formed as soon as the first one was eliminated. Comparison with control areas showed that epithelial cells were absent adjacent to the resorbed areas. If the periodontal membrane had been wider, there might have been a direct bone resorption without any root resorption even if there had been a short period of hyalinization. This explains why there are few root resorptions in a bodily tooth movement, in which the displacement of the root is largely controlled by stretched fiber bundles on the tension side. There may be formation of hyalinized areas during the initial period of tooth movement, but new connective tissue cells will soon invade the formerly cell-free area. The tissue changes frequently continue as a direct bone resorption without any root resorption.

These observations show that such a favorable reaction can hardly be compared with, for instance, the much more drastic tissue changes following replantation of teeth (*Löe & Waerhaug* 1961). The periodontal membrane, which may be considered a highly specialized organ, remains normal all around the circumscribed hyalinized area. The hyalinized tissue does not become necrotic. Connective tissue cells proliferate and capillaries regenerate from the surrounding tissue, but the epithelial rests remain absent. Absence of epithelial cells is, therefore, characteristic of a reorganized, formerly hyalinized, fibrous tissue on the pressure side and also of a resorptive process in the cementum and the dentin of the tooth.

In practice, other factors—such as the duration of the movement—must be taken into consideration. It has been found that there may be formation of some hyalinized areas, but in general only a few shallow root resorptions, provided the tooth concerned is not moved for a period longer than a few months. When the tooth is moved more or less continuously for a much longer period, a progressive type of resorption may start, frequently shortening the apical portion of the root. There is a sort of "tissue fatigue" not as yet fully explained. Practice has also shown that this type of apical resorption may be avoided by appropriate rest periods during the treatment. To what extent epithelial remnants are preserved during such a prolonged tooth movement, is a problem for further investigation.

CONCLUSIONS

The principal observations made in this study may be summarized as follows:

(1) Epithelial rests are more numerous in the periodontal membrane of 11 to 12 year old children than in that of 35 to 40 year old adults. An epithelial network exists around all roots of which tangential sections could be obtained.

(2) In the dog the epithelial rests are less numerous than in 11 to 12 year old children and are generally not observed in the form of strands, but as round or oval cell groups. Some of the epithelial rests in the marginal region are normally located at some distance from the root surface. In the monkey round or oval epithelial rests, slightly larger than those in the dog, prevail.

(3) On the tension side tooth movement may result in some compression of epithelial cells between stretched fiber bundles, but the cells are moved only slightly away from the root surface. During direct bone resorption epithelial rests on the pressure side move slightly towards the root surface.

(4) Hyalinization of periodontal fibers causes atrophy of cellular elements in a circumscribed area whereby connective tissue cells disappear rapidly, epithelial cells after a few days. Proliferation of fibroblasts and regeneration of capillaries start as soon as the subjacent bone area is removed by undermining resorption. The epithelial cells of the formerly hyalinized tissue do not reappear.

(5) Hyalinization, during which epithelial rests and other cellular elements disappear, will always lead to an undermining bone resorption. In a certain number of cases root resorptions occur, but quite frequently the root surface remains intact while the tissue reaction continues as a direct bone resorption.

(6) Epithelial rests were not observed in the periodontal membrane adjacent to resorbed lacunae of the root surface.

SUMMARY

Incidence and location of Malassez' epithelial rests in the periodontal membrane of control teeth, upper first premolars taken from 25 11 to 12 year old children, were examined. The findings were listed in a table and compared with observations of epithelial rests in adults, and in dogs and monkeys. It was found that epithelial rests in the periodontal membrane of 11 to 12 year old children were more numerous than those in 35 to 40 year old adults. An epithelial network existed around all roots from which tangential sections could be obtained. The epithelial rests in the dog were less numerous than those in 11 to 12 year old children and generally not observed in the form of strands, but as round or oval cell groups. Some of the epithelial rests in the marginal region were normally located at some distance from the root surface. In the monkey round or oval epithelial rests, slightly larger than those in the dog, prevailed.

Epithelial rests in the periodontal membrane of 40 human teeth, either tipped or moved bodily, were examined. In addition, epithelial rests adjacent to teeth rotated, tipped or moved bodily in the dog, were examined and compared with those of the human material. It appeared that tooth movement resulted in a temporary compression of epithelial cells between stretched fiber

bundles on the tension side, but they were moved only slightly away from the root surface. During direct bone resorption the epithelial rests on the pressure side were moved slightly towards the root surface.

Hyalinization of periodontal fibers causes atrophy of cellular elements in circumscribed areas by which connective tissue cells disappear rapidly, epithelial cells after a few days. Proliferation of fibroblasts and regeneration of capillaries from the surrounding tissues start as soon as the subjacent bone area is removed by undermining resorption. The epithelial cells of the formerly hyalinized tissue do not reappear. During hyalinization root resorptions occur in a certain number of cases, but, frequently, the root surface remains intact while the tissue reaction continues as a direct bone resorption. Absence of Malassez' epithelial rests is, therefore, characteristic of the reorganized, formerly hyalinized, periodontal tissue on the pressure side, and also of the periodontal tissue adjacent to resorbed lacunae of the root surface.

RÉSUMÉ

COMPORTEMENT DES DÉBRIS ÉPITHÉLIAUX DE MALASSEZ PENDANT LES DÉPLACEMENTS DENTAIRES ORTHODONTIQUES

L'auteur a étudié la présence et la localisation des débris épithéliaux de Malassez dans le desmodonte de dents de contrôle, des premières prémolaires supérieures provenant de 25 enfants âgés de 11 à 12 ans. Les résultats ont été portés sur un tableau et comparés avec des observations sur les débris épithéliaux chez des adultes et chez des chiens et des singes. Les débris épithéliaux trouvés dans le desmodonte chez les enfants de 11 à 12 ans étaient plus nombreux que chez les adultes de 35 à 40 ans. Un réseau épithélial existait autour de toutes les racines dont on avait pu faire des coupes tangentielles. Les débris épithéliaux chez les chiens étaient moins nombreux que chez les enfants de 11 à 12 ans et ne se présentaient en général pas sous forme de cordons mais comme des groupes cellulaires ronds ou ovales. Quelques uns des débris épithéliaux de la région marginale étaient normalement placés à quelque distance de la surface radiculaire. Chez le singe, il y avait prédominance de débris épithéliaux ronds ou ovales, légèrement plus grands que chez le chien.

L'auteur a examiné les débris épithéliaux dans le desmodonte de 40 dents humaines qui avaient été déplacées soit par version, soit par gression totale. De plus, les débris épithéliaux adjacents à des dents ayant subi une rotation, une version ou une gression chez le chien ont été examinés et comparés à ceux du matériel humain. Il est apparu que le mouvement dentaire avait pour conséquence une compression temporaire des cellules épithéliales entre les faisceaux de fibres étirées, du côté de la traction, mais elles n'étaient que faiblement éloignées de la surface radiculaire. Pendant la résorption osseuse directe, les débris épithéliaux du côté de la pression étaient légèrement rapprochés de la surface radiculaire.

Une transformation hyaline des fibres desmodontales provoque l'atrophie des éléments cellulaires dans des zones circonscrites, faisant disparaître les cellules du tissu conjonctif rapidement, et les cellules épithéliales au bout de quelques jours. La prolifération des fibroblastes et la régénération des capillaires à partir des tissus environnants commencent dès que disparaît la zone osseuse sous-jacente, minée par la résorption. Les cellules épithéliales des tissus ayant subi une transformation hyaline ne réapparaissent pas.

Pendant cette transformation il se produit dans un certain nombre de cas une résorption radiculaire, mais souvent, la surface radiculaire demeure intacte tandis que la réaction des tissus se continue par une résorption osseuse directe. L'absence de débris épithéliaux de Malassez est donc caractéristique du tissu desmodontal du côté de la pression, réorganisé après transformation hyaline, et de même caractéristique du tissu desmodontal adjacent aux lacunes de résorption de la surface radiculaire.

ZUSAMMENFASSUNG

VERHALTEN DER MALASSEZ'SCHEN EPITHELRESTE WÄHREND DER KIEFERORTHOPÄDISCHEN ZAHNBEWEGUNG

Bei 25 elf- bis zwölfjährigen Kindern wurde die Häufigkeit und die Lokalisation der Malassez'schen Epithelreste in der Wurzelhaut der oberen ersten Praemolaren untersucht.

Es wurden Vergleiche über das Vorkommen der Epithelreste bei diesen Kindern und Erwachsenen, Hunden und Affen angestellt. Dabei konnte beobachtet werden, dass bei elf- und zwölfjährigen Kindern häufiger Epithelreste in der Wurzelhaut vorkommen als bei Erwachsenen im Lebensalter zwischen 35 und 40 Jahren.

Anhand von tangentialen Schnitten wurde festgestellt, dass ein epitheliales Netzwerk die Wurzeln rings umgibt. Bei Hunden traten die Epithelreste nicht so häufig auf wie bei den Kindern, und zwar nicht so sehr in Form von Strängen, sondern mehr als runde oder ovale Zellgruppen.

Alle Epithelreste in den marginalen Abschnitten waren in einem gewissen Abstand von der Wurzeloberfläche angeordnet. Bei den Affen herrschten runde oder ovale Epithelreste vor, die etwas grösser waren als die der Hunde.

Die Epithelreste in der Wurzelhaut von vierzig menschlichen Zähnen, die entweder gekippt oder körperlich bewegt waren, wurden untersucht. Bei Hunden konnte festgestellt werden, dass die Epithelreste, die dem Zahn anliegen, bei einer Bewegung des Zahnes zugrunde gehen. Diese Beobachtung wurde mit den Erscheinungen an menschlichem Untersuchungsmaterial verglichen. Es hat den Anschein, dass bei der Bewegung der Zähne eine zeitweilige Kompression der Epithelzellen zwischen den Faserbündeln auf der Spannungsseite auftritt, sie bewegten sich aber nur wenig von der Wurzeloberfläche weg. Bei Knochenresorption dagegen bewegen sich die Epithelreste auf die Druckseite zur Wurzeloberfläche hin.

Eine Atrophie der Zellelemente im Bindegewebe wird durch Hyalinisierung der periodontalen Fasern ausgelöst, wobei die Bindegewebszellen sehr schnell atrophieren, die Epithelzellen erst nach einigen Tagen. Fibroblasten und Kapillaren treten vom umgebenden Gewebe aus ein, sobald der Knochen resorbiert ist. Im hyalinisierten Gewebe treten Epithelzellen nicht wieder auf. Während der Hyalinisierung, bei der es zu unterminierenden Knochenresorptionen kommt, werden auch Wurzelresorptionen beobachtet.

In vielen Fällen blieb die Wurzeloberfläche intakt, trotz der sonst vorhandenen Bereitschaft zur Knochenresorption.

Das Fehlen der Malassez'schen Epithelreste ist folglich charakteristisch für das neugebildete, vorher hyalinisierte periodontale Gewebe auf der Druckseite und für das periodontale Gewebe in der Nachbarschaft von Resorptionslakunen an der Wurzeloberfläche.

RESUMEN

COMPORTAMIENTO DE LOS RESTOS EPITELIALES DE MALASSEZ DURANTE EL MOVIMIENTO ORTODÓNCICO DE LOS DIENTES

Se observó la incidencia y localización de los restos epiteliales de Malassez en la membrana periodontal de primeros premolares en dientes de control extraídos a 25 niños entre 11—12 años de edad.

Los hallazgos fueron registrados en una tabla y comparados con observaciones realizadas de restos epiteliales de Malassez hallados en adultos, perros y monos.

Se encontró que en los niños entre 11—12 años, era mayor el número de restos epiteliales que en adultos entre 35—40 años.

Pudo constatarse la existencia de una red epitelial alrededor de todas las raices, en las que se consiguieron cortes tangenciales.

Los restos epiteliales encontrados en los perros fueron menos numerosos que en los niños y en general no se observaron en forma de cordones, sino como grupos celulares redondeados ú ovalados.

Se localizaron algunos restos epiteliales en la zona marginal a cierta distancia de la superficie radicular. En el mismo predominaron restos epiteliales redondeados ú ovalados, ligeramente más grandes que los hallados en el perro.

Se examinaron los restos epiteliales en la membrana periodontal de 40 dientes humanos a los que se les realizó un movimiento total ó solo de inclinación. Se comparó este material humano con los restos epiteliales adyacentes a dientes movidos totalmente ó inclinados en perros.

Como consecuencia del movimiento dentario, resultó una compresión temporaria de las células epiteliales que se hallan entre las bandas de fibras extendidas del lado de tensión, pero solo fueron movidas ligeramente fuera de la superficie radicular.

Durante la reabsorción ósea directa los restos epiteliales en el

lado de la presión fueron movidos ligeramente hacia la superficie radicular.

La hialinización de las fibras periodontales causa atrofia de los elementos celulares en areas circunscriptas en las cuales los elementos celulares del conectivo desaparecen rápidamente, mientras que las células epiteliales lo hacen después de algunos días.

La proliferación fibroblástica y regeneración capilar de los tejidos vecinos, comienza tan pronto la zona de hueso subyacente es removido por reabsorción ósea socavante. Las células epiteliales del tejido antes hialinizado no regeneran.

Durante la hialinización tiene lugar una reabsorción ósea socavante, y en cierto número de casos, reabsorciones radiculares, pero frecuentemente las superficies radiculares permanecen intactas mientras la reacción tisular continúa como reabsorción ósea directa. La ausencia de los restos epiteliales de Malassez, es por lo tanto característica de reorganización del anteriormente tejido periodontal hialinizado del lado de la presión y también del tejido periodontal adyacente a la reabsorción lacunar en la superficie radicular.

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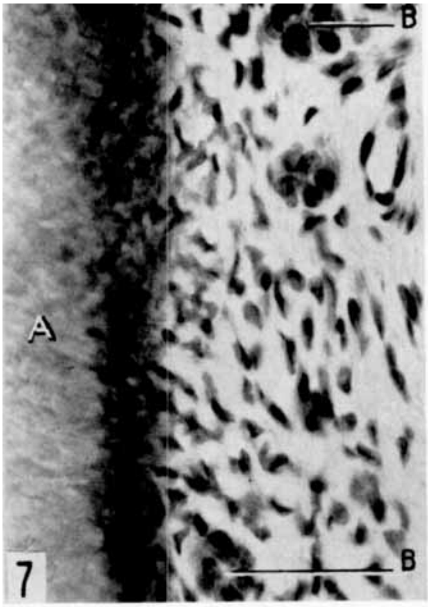
PLATES

Plate 1.

Fig. 7. Round epithelial remnants, marginal region, twelve year old person. A, root surface. B, epithelial rests, the upper fairly close, the lower close to the root surface.

Fig. 8. Cluster-like form of epithelial remnants, B, close to the root surface.

Fig. 9. Adult person. A, strand of epithelial cells. B, aplastic bone surface.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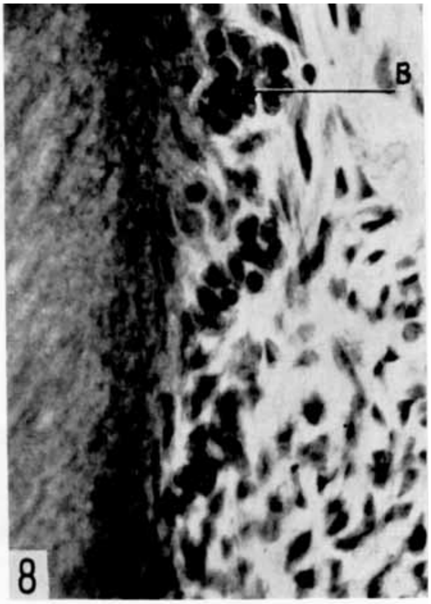
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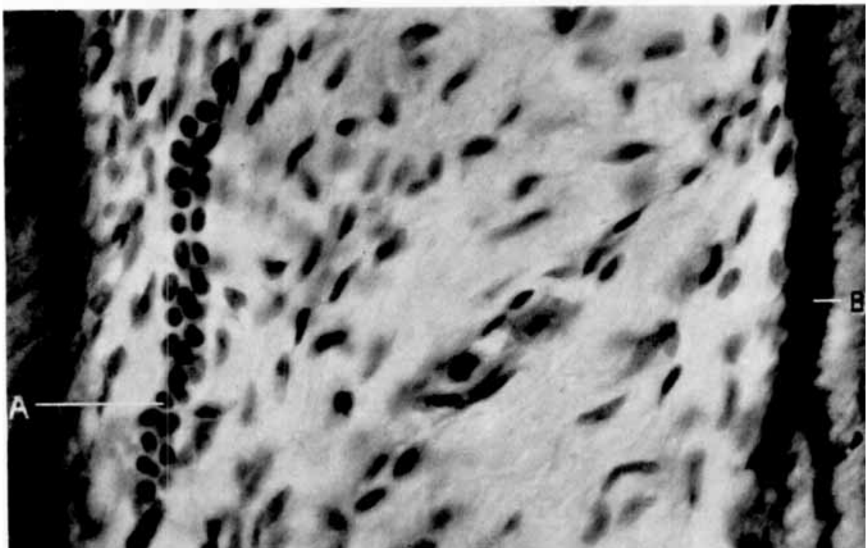
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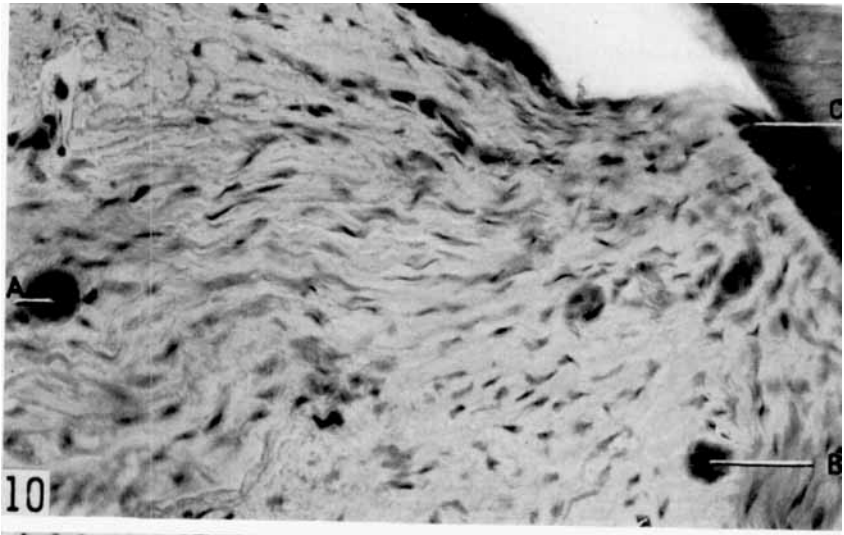
Plate 2.

Fig. 10. Human material. A and B, round epithelial rests in supra-alveolar tissue. C, cementum close to the cemento-enamel junction.

Fig. 11. Twelve year old person, tension side, continuous tooth movement for ten days. A, epithelial strand in the middle region of root. B, osteoid. Arrow indicates proliferation zone with osteoblasts and fibroblasts.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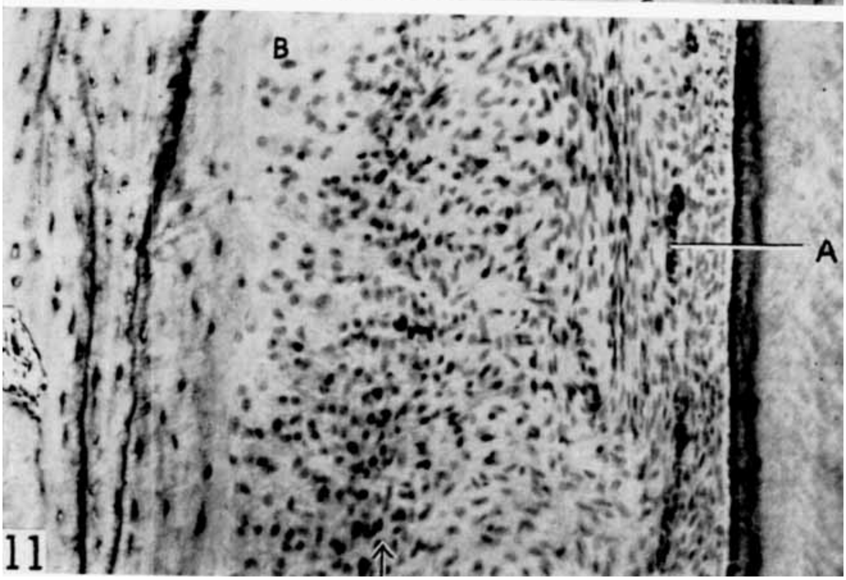
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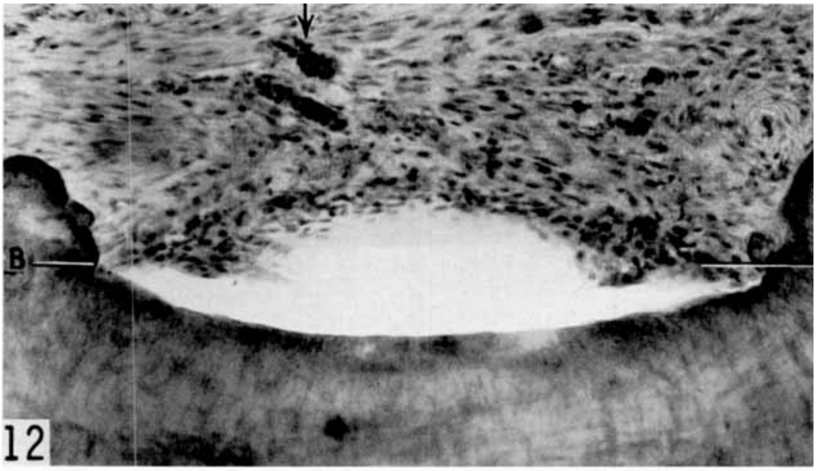
Plate 3.

Fig. 12. Eleven year old person. Bifurcation area shown at ***a*** in Fig. 6. Enamel pearl in white area below epithelial layer A. Cemento-enamel junction at B. Two epithelial remnants indicated by arrow.

Fig. 13. Adult tissue, middle region of root. A, thickened epithelial strand; B, cluster of epithelial cells.

Fig. 14. Approximately area ***e*** in Fig. 6. Part of epithelial network in adult person.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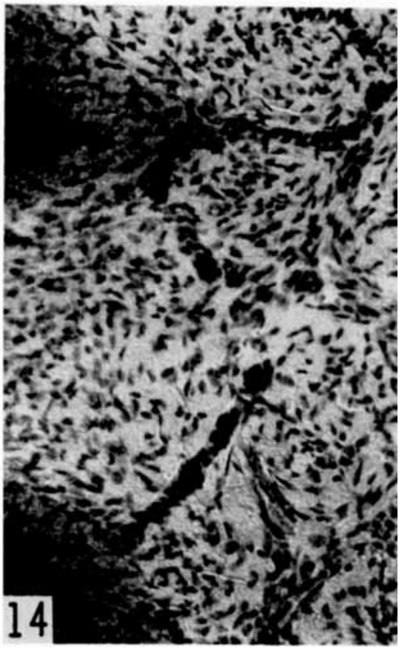
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Plate 4.

Fig. 15. Adult tissue, area ***d*** in Fig. 6. Epithelial layer adhering to the root surface.

Fig. 16. Basal layer of epithelium and part of lamina propria, approximately area ***c*** in Fig. 6, same specimen as shown in Fig. 15.


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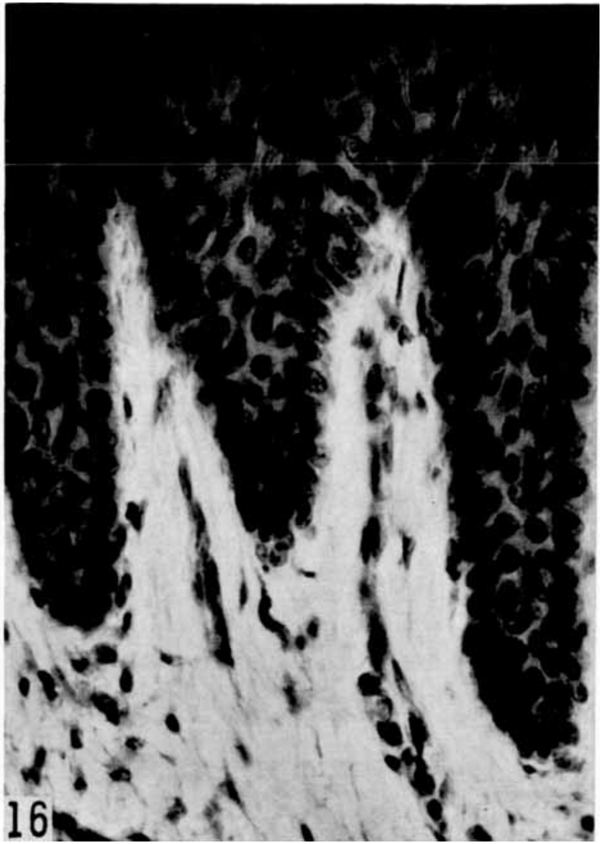
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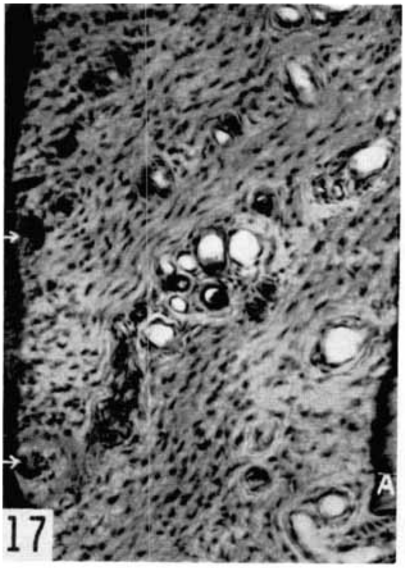
Plate 5.

Fig. 17. Arrows indicate round epithelial remnants in four year old dog. A, aplastic bone surface.

Fig. 18. Twelve year old person, approximately area ***d*** in Fig. 6. Tension side, tooth moved for two weeks with activator. A, cementum; B, epithelial remnants; C, border line between old and new bone; D, partly calcified new bone formed as a result of tooth movement.

Fig. 19. Cross-section of supra-alveolar tissue in dog, eleven months old. A, layer of epithelium. B, epithelial rests.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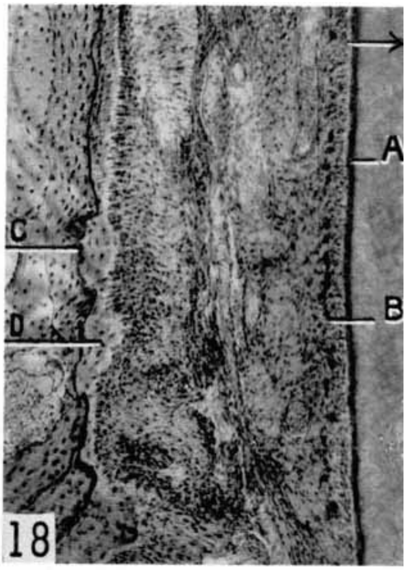
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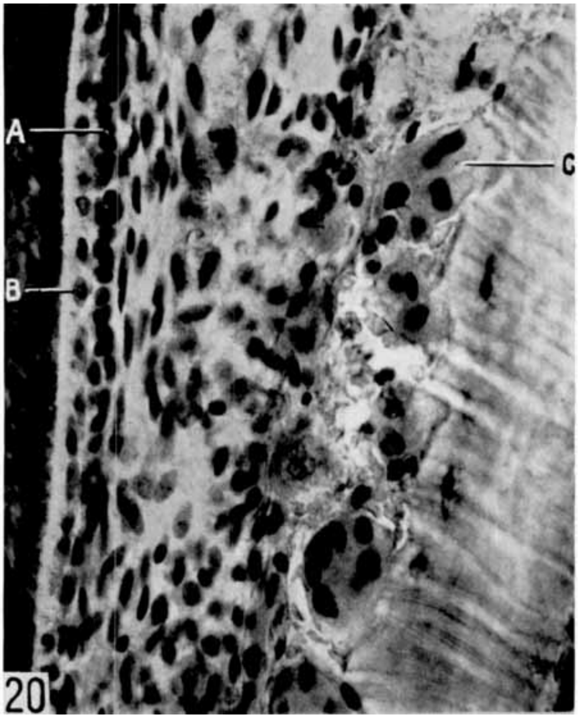
Plate 6.

Fig. 20. Adult tissue, approximately area ***e*** in Fig. 6. Direct bone resorption with slight compression of periodontal membrane. A, long strand of epithelial cells. B, cementoblast. C, osteoclast. Continuous tooth movement. Duration two weeks.

Fig. 21. Twelve year old person, marginal pressure area some time after hyalinization, ***b*** in Fig. 6. Movement of tooth shown in Fig. 1. Reorganized tissue, adjacent to root surface at A, reveals lack of epithelial rests. B, osteoclast.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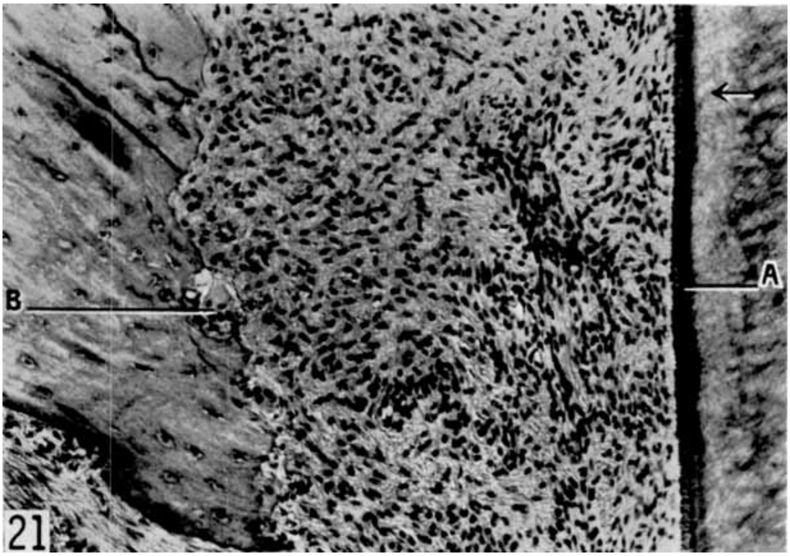
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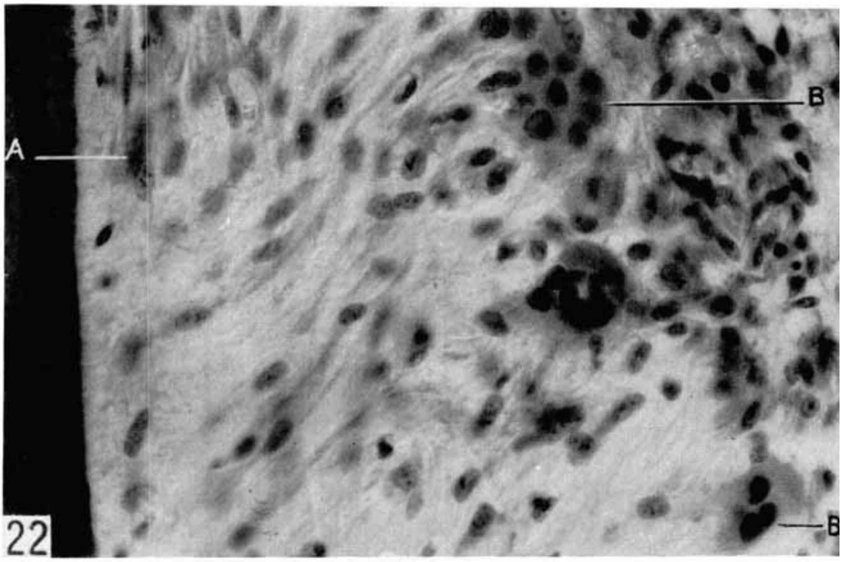
Plate 7.

Fig. 22. Human periodontal tissue following undermining resorption, area corresponding to ***d*** in Fig. 6. A, persisting degenerated epithelial rest above formerly hyalinized tissue. B, migrating osteoclasts.

Fig. 23. Lower magnification of same area. A, persisting epithelial rest. Below several young connective tissue cells. No epithelial rests. B, direct bone resorption. Note osteoclasts in middle of periodontal membrane.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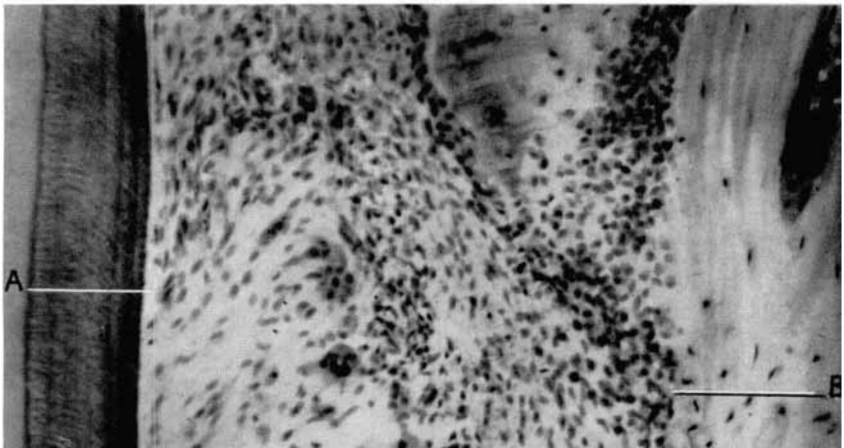
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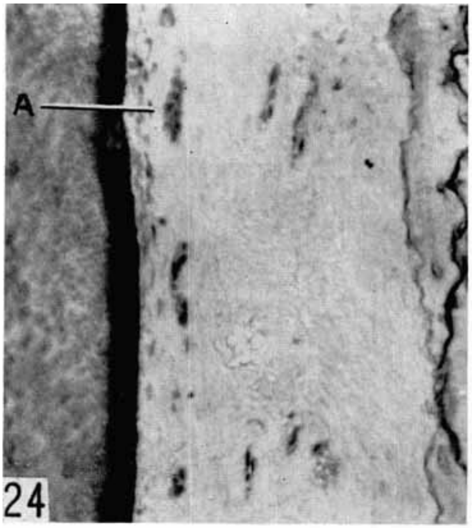
Plate 8.

Fig. 24. Human tissue, pressure area seen at ***b*** in Fig. 6. Continuous force 60 g, duration five days. Most connective tissue cells have disappeared. Persisting degenerated epithelial strand at A. Below degenerated cluster-like epithelial rests.

Fig. 25. Initial stage of reversed tooth movement following continuous pressure for eight days. Lack of epithelial cells adjacent to root surface A. B, osteoclasts. Arrow indicates cell proliferation from surrounding tissue.

Fig. 26. Later stage of cell proliferation. Center of hyalinized tissue was located at A. B, persisting undermining resorption.

Fig. 27. Incidental finding. Human tissue. Shallow resorbed area of root surface, duration of movement three weeks. A and B osteoclasts. No epithelial rests in adjacent periodontal tissue.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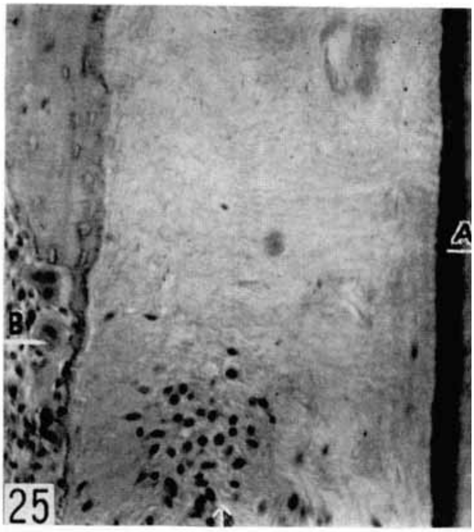
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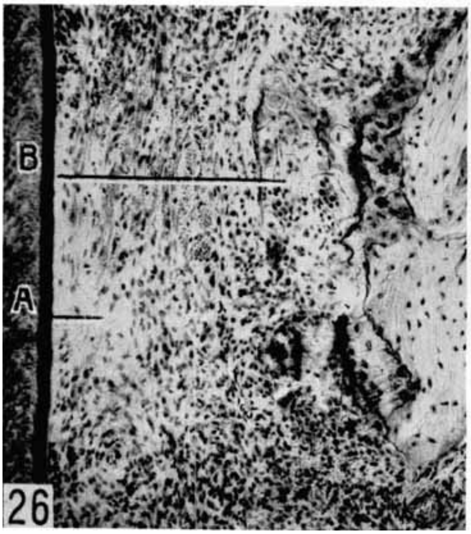
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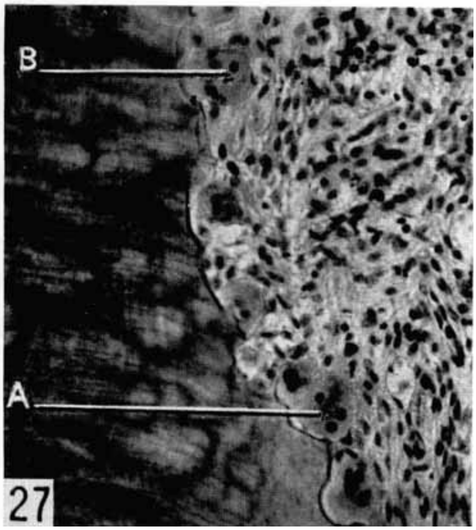
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Plate 9.

Fig. 28. Animal material, area shown at X Fig. 3. Arrows indicate round epithelial remnants. No epithelial rests adjacent to resorbed areas 1, 2, and 3. In periodontal membrane several dark capillaries.

Fig. 29. Cross-section of root in the dog. Tension side of rotated tooth. Epithelial rests, A, slightly compressed between fiber bundles. Along the root surface thick cementoid layer.

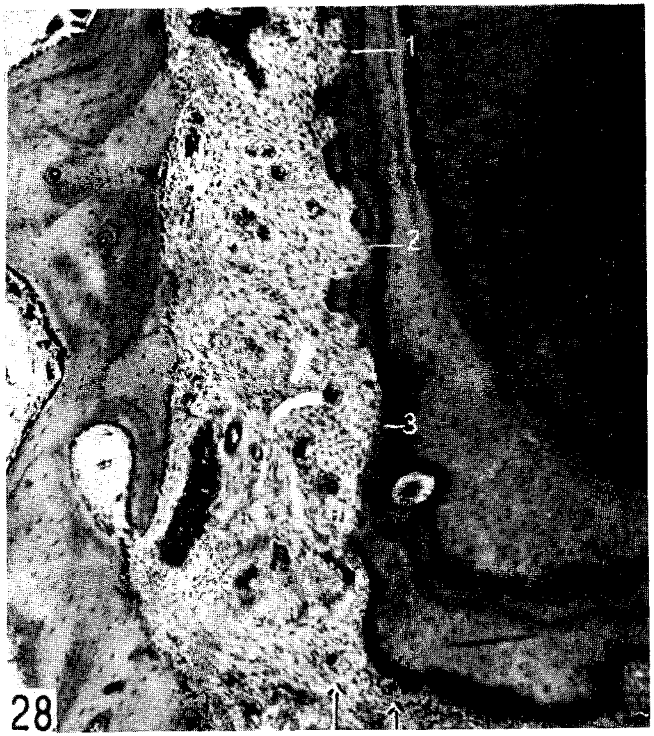

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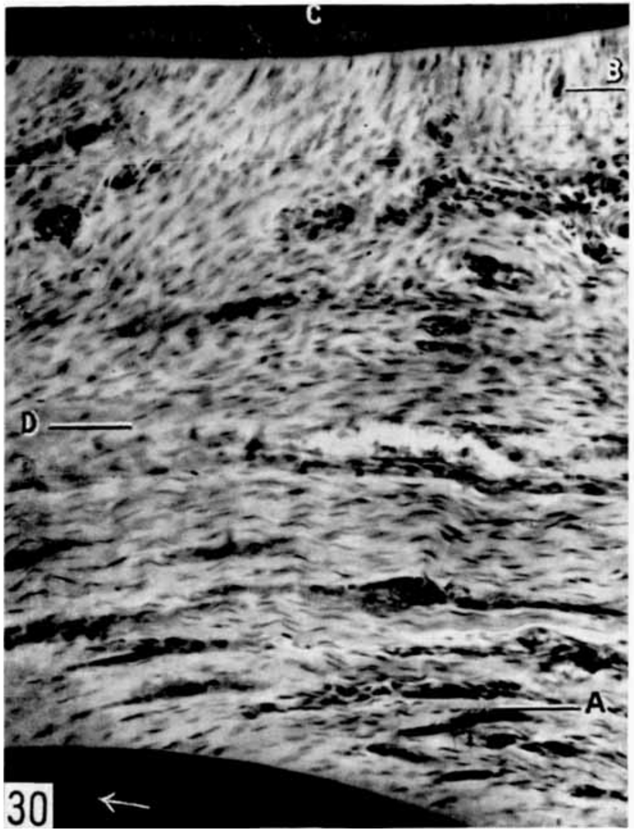
Plate 10.

Fig. 30. Cross-section of rotated tooth and proximal tooth in the dog. Capillaries and epithelial rests, A, flattened between fiber bundles. B, epithelial rest adjacent to proximal root, C. Intermediate layer, D.

Fig. 31. Adult human tissue, initial tooth movement, tension side, area approximately corresponding to ***d*** in Fig. 6. Several epithelial rests along the root surface. A, epithelial strand displaced and slightly compressed between fiber bundles. B, aplastic bone surface.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A
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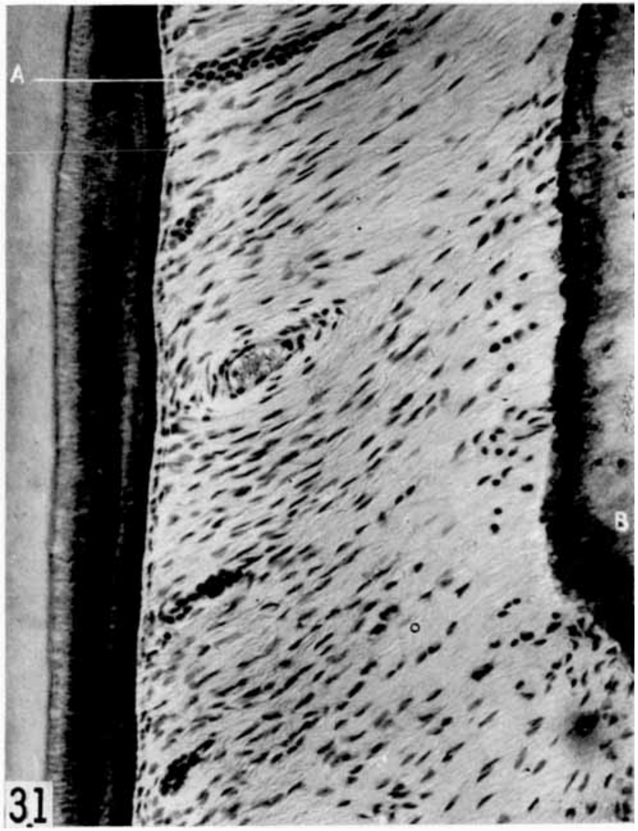
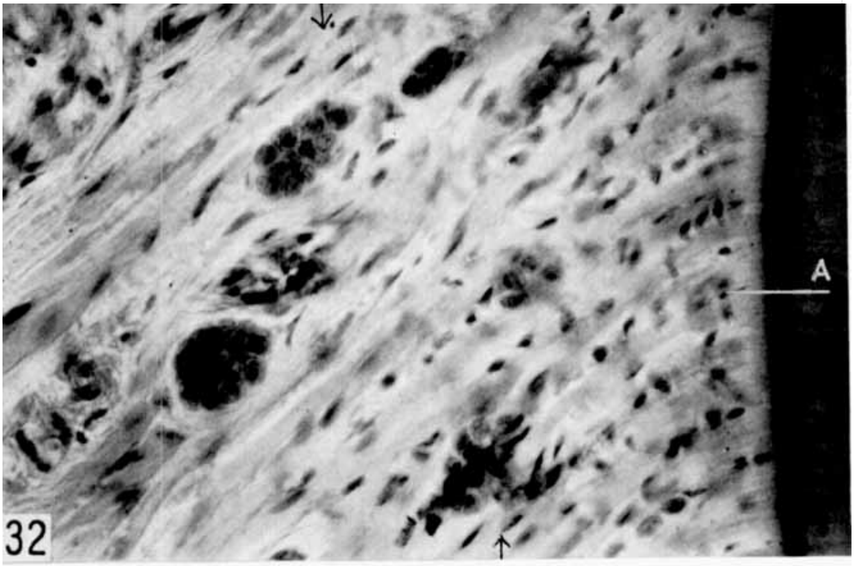

A
B
31

Plate 11.

Fig. 32. Rotated tooth, marginal region. Stretched fiber bundles, A. Below upper arrow three epithelial rests, neither displaced nor compressed. Above lower arrow three epithelial rests slightly compressed.

Fig. 33. Above, cross-section of relapsed tooth. Two epithelial rests close to the root surface. The epithelial remnant at A is partly embedded in cementoid layer.


A
32

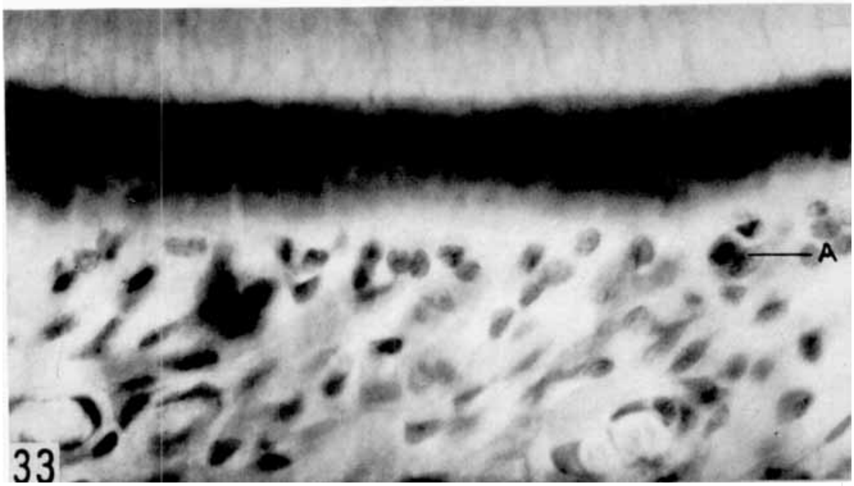
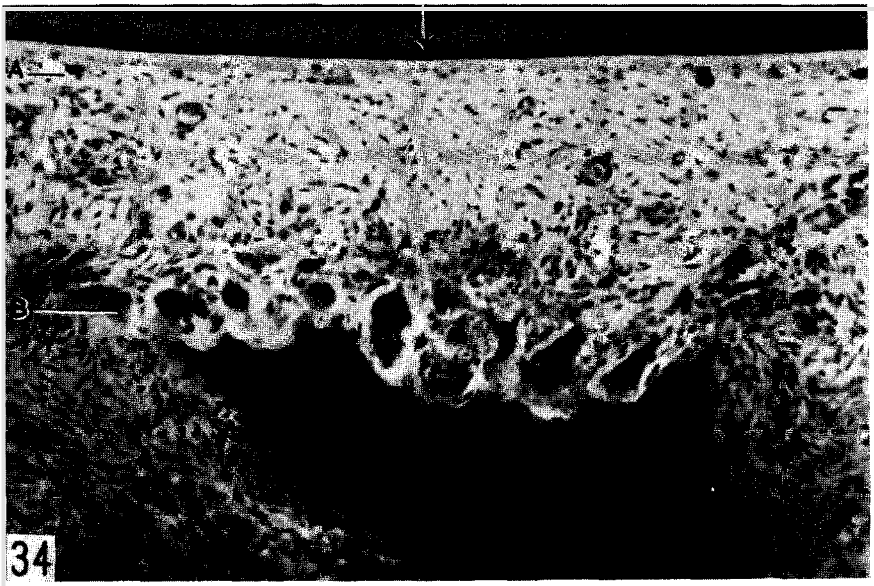

A
33

Plate 12.

Fig. 34. Direct bone resorption following hyalinization. Arrow indicates center of formerly hyalinized tissue. A, one of the three remaining epithelial rests. B, osteoclasts.

Fig. 35. Corresponding area of control tooth. Normal distribution of epithelial remnants in the dog. B, one of three well spaced epithelial rests.



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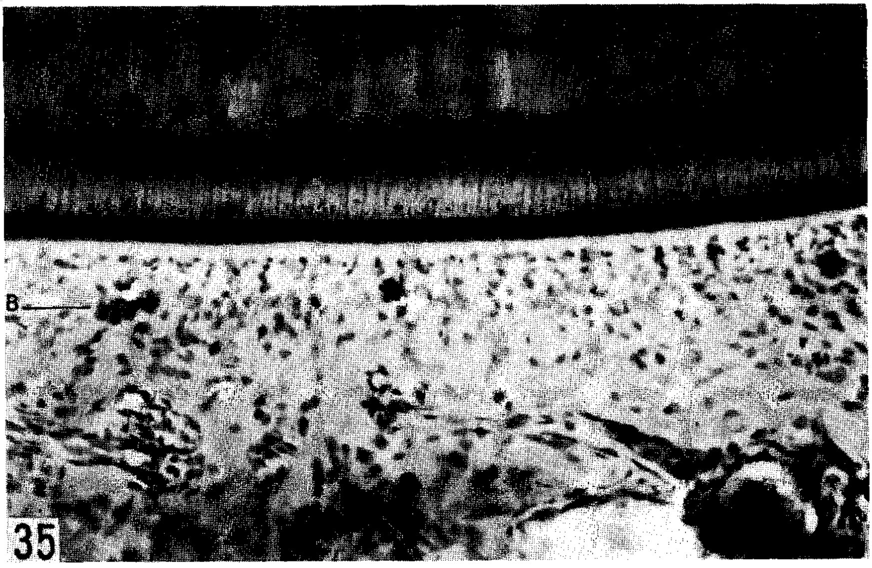

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