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Periodontal Reaction to Functional Occlusal Stress

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THE reaction of the periodontium to occlusal trauma has been studied in various laboratory animals[1, 6, 18, 21, 23]; furthermore, a few experimental investigations have been reported in humans[8, 12, 18]. The main source of histologic information regarding the adaptation of the periodontium to a variation in occlusal stress has been human autopsy material[2, 3, 4, 7, 10, 11, 12, 13, 14, 15, 17]; however, the clinical history of occlusal stress of most of the autopsy material has been very inadequate. Therefore there is still much that can be learned about the effects of occlusal stress upon the human periodontal tissues by studying material in which the clinical history of occlusal stress is known and the functional occlusal forces have been at least partially controlled.

The purpose of this paper is to present some observations of periodontal adaptation to a known functional increase and decrease in occlusal stress. The study is limited to the labio-cervical area and coronal one half of the root of fifteen anterior teeth in 14 humans.

MATERIAL

The material utilized in this study was obtained also for a study of the healing of the periodontium following gingival flap operations. A description of the procedures that were used to obtain the material has been submitted for publication[9]. Block sections, including gingival and other periodontal structures, and about one half of the root of the experimental tooth, were removed surgically from individuals who were scheduled to have complete dentures in at least one of the dental arches. About 4 to 12 millimeters of the labial alveolar process along the root was included in each specimen (Fig. 1). Detailed clinical examinations of the teeth and periodontal conditions were repeated at the various stages of the experiment. Pictures and roentgenograms were taken of all the patients.

CLINICAL FINDINGS

The clinical information has been compiled in Table I. Initially some of the patients had several posterior teeth missing, and an attempt was made at that

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TABLE I

Case No.	*Age of Patient*	*Experimental Tooth*	*Occl. Stress Prior to Experiment*	*Gingival Condition*	*Days of Incr. Occl. Stress*	*Days Without Antagonists*	*Days After Flap Oper.*
1	18	mand. r. cuspid	normal	mild gingivitis		14	14
2	16	max. r. central	heavy	mild gingivitis		14	28
3	34	max. l. cuspid	very heavy (bruxism)	severe gingivitis		15	28
4	27	max. r. cuspid	heavy	mild gingivitis	85		85
5	58	max. l. cuspid	very heavy	gingival atrophy	88		88
6	48	max. r. cuspid	normal	normal gingiva		98	94
7	27	max. r. cuspid	heavy	periodontitis	106		105
8	68	max. r. cuspid	very heavy (mobility 1)	mild gingivitis		106	112
9	68	max. l. lateral	very heavy (mobility 1)	mild gingivitis		106	112
10	55	max. r. lateral	normal	slight ging. atrophy		75	122
11	34	max. r. cuspid	heavy	gingivitis		146	138
12	37	max. r. lateral	normal	mild gingivitis	145		145
13	57	max. r. cuspid	heavy	mild gingivitis	148		145
14	64	max. r. lateral	no antagonist	mild gingivitis		169	162
15	50	max. r. lateral	very heavy	normal gingiva	198		196

time to evaluate and classify the functional occlusal stress on the experimental teeth. Occlusal relations, posterior occlusal support, mobility during functional movements, attrition, and radiographic findings served as a basis for classification of the occlusal stress as: 1) normal, 2) heavy, 3) very heavy.

Following the initial examination all the posterior maxillary teeth were extracted in 6 of the 14 patients in preparation for immediate dentures. It was assumed that this complete loss of posterior support would increase the functional load on the remaining anterior teeth. In 9 of the experimental teeth all of the teeth of the opposing jaw were extracted in preparation for dentures, thereby leaving the experimental tooth without an antagonist. The patients did not wear any opposing dentures during the period of observation, and the only functional stimuli the experimental tooth could receive would come from biting against the opposing alveolar ridge and from lip and tongue function.

The number of days between the flap operation and the removal of the specimens are recorded in Table I because bone

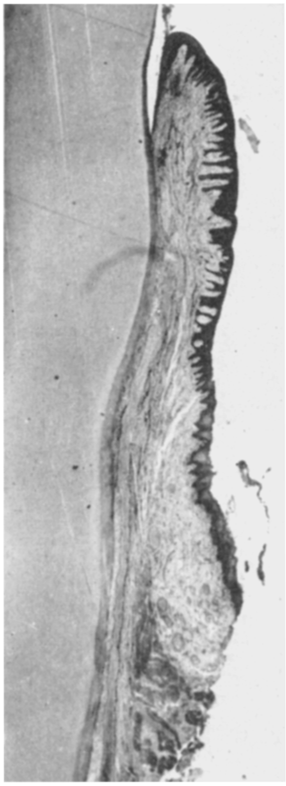


Fig. 1. Photomicrograph of a section from a typical specimen. Case 10. Maxillary right lateral incisor. Magnification X8.

changes on the labial aspect of the alveolar process and the alveolar crest should be related to the trauma of the muco-periosteal flap procedure.

HISTOLOGICAL FINDINGS

Case Number 1

Rapid formation of new bone is evident at the alveolar crest and along the periodontal membrane side of the alveolar bone. Large cuboidal osteoblasts practically cover the entire inner surface of the alveolar bone. Only a few rather heavy coarse Sharpey's fibers enter the bone with 1-5 osteoblasts between the individual fiber bundles. The alveolar process is fairly thick, and the labial surface is smooth without any indication of bone apposition or resorption. On the surface of the root a narrow zone of precementum can be observed. The cementoblasts are small and the cementoblastic activity seems to be very slow. The alveolar crest fibers and the principal periodontal fibers exhibit a well defined functional arrangement, but under high magnification early atrophy and degeneration of the principal periodontal fibers is apparent in small focal areas in the middle of the periodontal membrane. The collagen fibers appear partially disintegrated and replaced by reticulum-like fibers in an edematous intercellular substance.

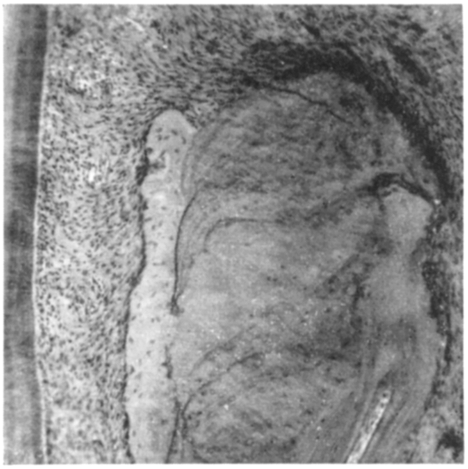


Fig. 2A. Note the distinct layer of new bone on the periodontal membrane side of the alveolar bone. Case 2. Magnification X75.

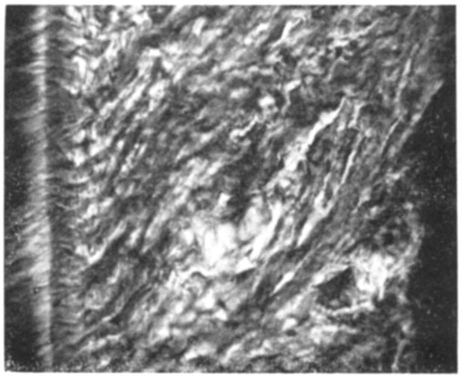


Fig. 2B. Azan stains for collagen. Numerous Sharpey's fibers entering the cementum on the left side of the picture. Heavy bundles of fibers entering the alveolar bone on the opposite side. Case 2. Magnification X800.

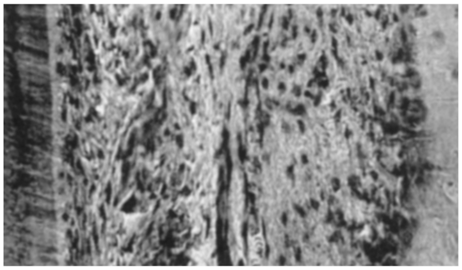


Fig. 2C. Photomicrograph of H & E stained section from same specimen as Figs. 2A and B. Well defined layer of precementum. Beginning degeneration and loss of functional pattern of collagen fibers. Magnification X800.

Case Number 2

Like in case number 1 there is evidence of rapid osteogenesis at the alveolar crest and along the periodontal membrane surface of the alveolar bone (Fig. 2 A). Relatively few heavy bundles of Sharpey's fibers are seen entering the alveolar bone. The labial surface of the alveolar process appears rough. The alternating areas of resorption and repair are possibly related to surgical trauma at the time of the flap operation 28 days prior to the removal of the specimen. The resorptive activity may also be related to the rebuilding that takes place in the alveolar process following loss of antagonists and the apposition of alveolar bone. A great number of small Shar

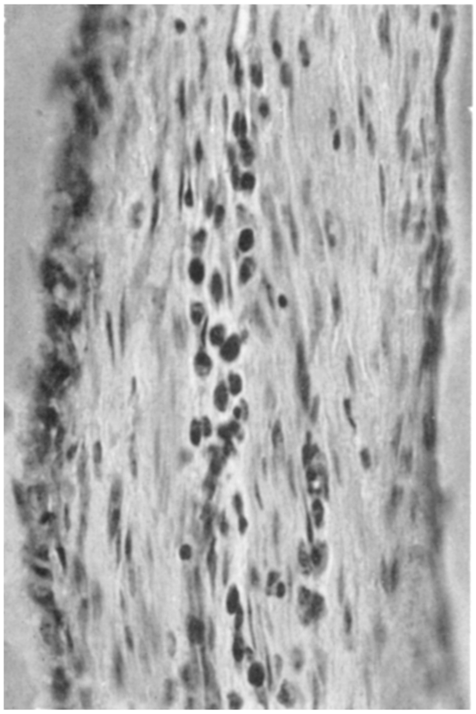


Fig. 2D. Plasma cells and lymphocytes in the middle of the periodontal membrane. Collagen fibers parallel with the surfaces of the tooth and the alveolar bone. Case 2. Magnification X650.

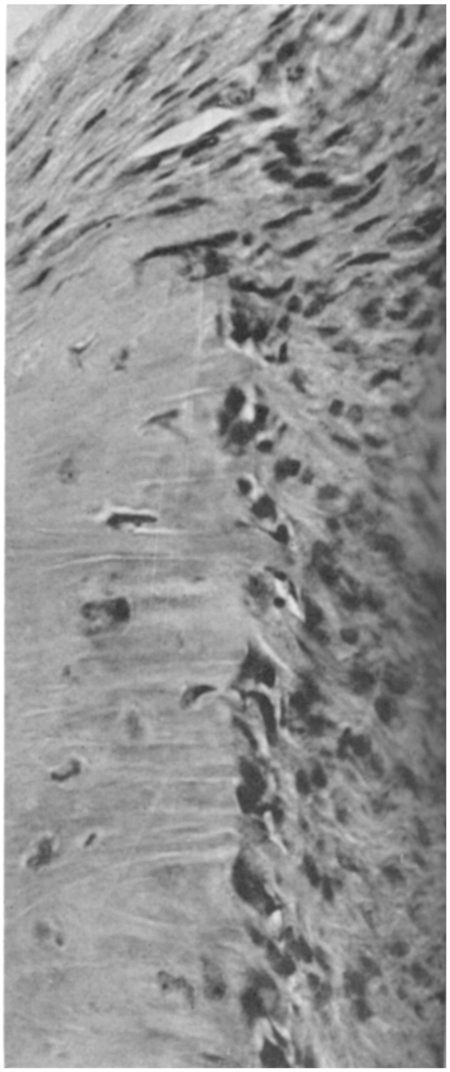


Fig. 3A. High magnification of the alveolar crest and the attachment of Sharpey's fibers. Case 3. Magnification X800.

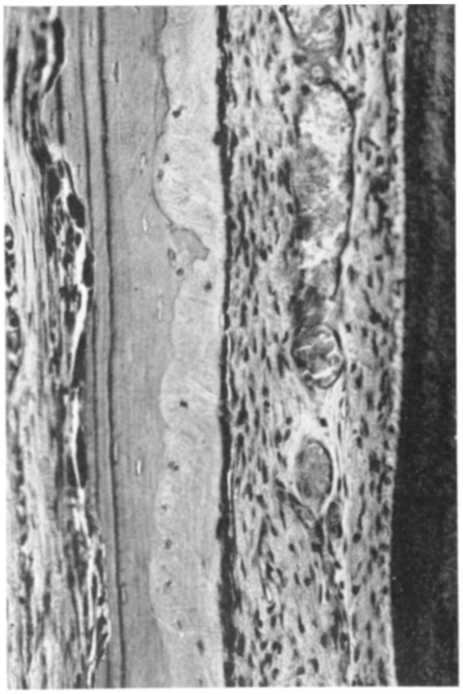


Fig. 3B. Resorption of bone on the labial side of the alveolar process and newly formed bone on the periodontal membrane side of the alveolar bone. Dilated blood vessels. Periodontal fibers mainly parallel to the surface of the bone and the root. Actual width of the periodontal space: 0.08 — 0.10 mm. Case 3. Magnification X275.

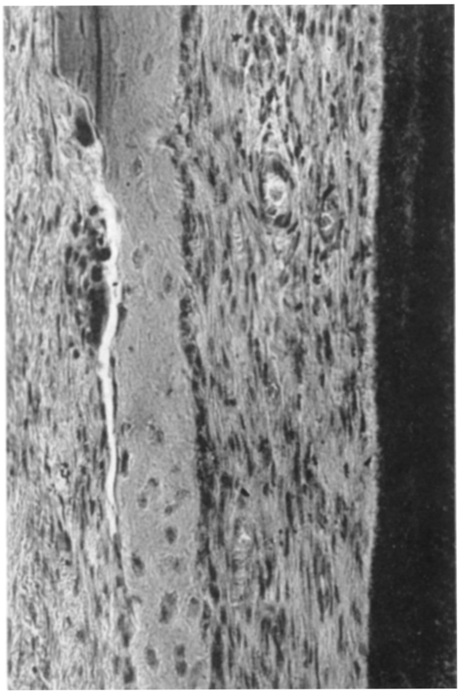


Fig. 3C. From same specimen as Figs. 3A and B. Close to the area where the alveolar bone plate is missing. Primitive type of new bone formed in an attempt to bridge the described defect in the labial aspect of the alveolar process. The Collagen fibers are parallel to the surface of the bone and the root. Magnification X275.

pey's fibers can be seen entering the cementum (Fig. 2 B), and a well defined layer of precementum is present on the root surface (Fig. 2 C). The alveolar crest fibers are arranged in a well defined functional pattern, and most of the principal fibers are made up of normally appearing collagenous fibers. Only in small areas in the middle of the periodontal membrane can beginning degeneration of the collagen fibers be observed (Fig. 2 C). A few inflammatory cells (Fig. 2 D), mainly plasma cells, appear in a scattered distribution extending from the bottom of the gingival crevice into the periodontal membrane proper for a distance of 3-4 millimeters apically to the alveolar crest.

Case Number 3

Rapidly progressing osteogenesis can be observed at the alveolar crest and along the periodontal membrane surface of the alveolar bone (Fig. 3 A). Bone resorption is evident on the labial aspect of the alveolar process (Fig. 3 B). The labial bone plate of the alveolar process is absent from a point 5 millimeters apically to the free gingival margin to the border of the specimen for a distance of 3 millimeters. On the root surface corresponding to the area of missing alveolar bone, resorption has extended into the dentin and the defects have been only partially repaired by deposition of new cementum. A narrow zone of precementum is present on the remainder of the root surface, but only in focal areas can cementoblastic activity be observed with certainty. The alveolar crest fibers exhibit a well defined functional arrangement. The attachment of the principal fibers appears to be much weaker to the alveolar bone than to the cementum. Small areas of slight degenerative changes

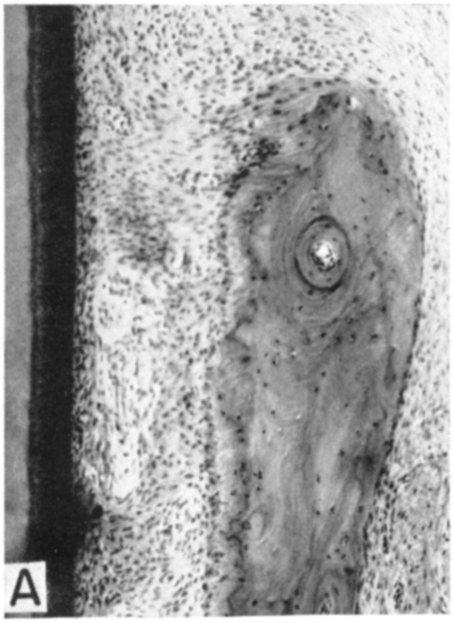


Fig. 4A. Newly formed bone at the margin of the alveolar crest and along the surface of the alveolar bone. Actual width of periodontal space in crestal area: 0.15 — 0.20 mm. Case 4. Magnification X266.

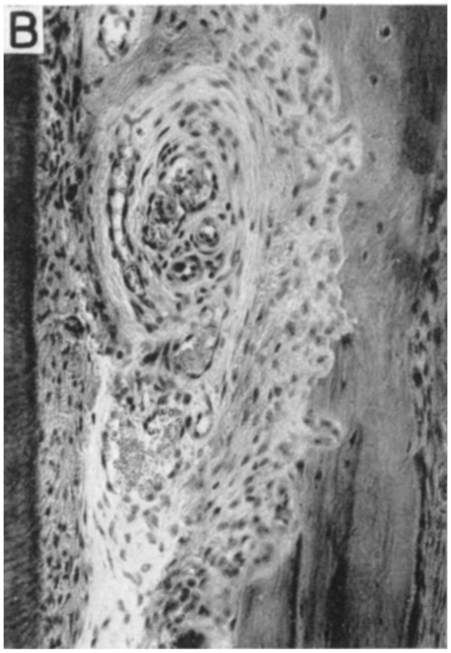


Fig. 4B. Resorption of the alveolar bone. Vascular granulation tissue in the periodontal membrane. Note intact fibers parallel to and attached to the surface of the cementum. Case 4. Magnification X310.

can be found in the periodontal membrane. The principal periodontal fibers are arranged mainly parallel to the surface of the root and the alveolar bone (Fig. 3 C). A few plasma cells and lymphocytes are present in the periodontal membrane, especially in the areas of degeneration.

Case Number 4

Osteogenesis is evident at the margin of the alveolar crest (Fig. 4 A). Several areas of active resorption and repair can be observed on the periodontal membrane side of the alveolar bone (Fig. 4 B). On the labial aspect of the alveolar process there is evidence of fairly rapid osteogenesis, but the osteoblasts derived from the periosteum of the alveolar process are much smaller and more squamous in character than the osteoblasts on the periodontal membrane side of the alveolar bone. Numerous cementoblasts and a well defined zone of precementum can be observed on the root surface. There is a marked widening of the periodontal space in the cervical area. The functional pattern of the collagen fibers is well defined, especially in the area of the alveolar crest. The oblique fibers run nearly parallel with the surface of the tooth and alveolar bone. There are numerous large vascular channels present in the periodontal membrane, and areas of vascular granulation tissue can be seen (Fig. 4 B).

Case Number 5

Apposition of new bone is evident on the labial aspect of the alveolar crest and the alveolar process (Fig. 5 A). On the periodontal membrane side the alveolar bone is undergoing resorption. The labial plate of the alveolar process is very thin, and in some areas there has been loss of the continuity of the alveolar process because of resorption from the periodontal membrane side of the alveolar bone. Many areas of resorption can be observed on the root surface. In some places the resorption extends into the dentin. Very little repair can be

Fig. 5A. The entire alveolar crest is made up of newly formed bone. Root resorption extending into the dentin. Case 5. Magnification X97.

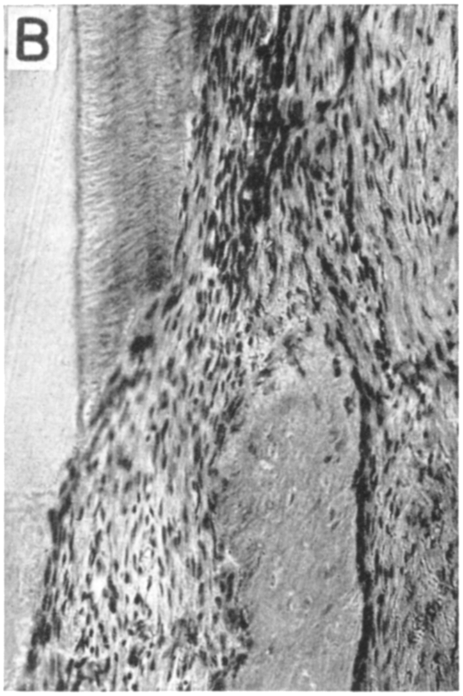


Fig. 5B. High magnification (X280) from Fig. 5A. Compression of the periodontal membrane (actual width 0.06 mm.). The fibers are arranged parallel to the surface of the tooth and the alveolar bone. Active resorption of the alveolar bone.

found in the areas of root resorption. There is a marked compression of the periodontal membrane (width 0.06 mm.) corresponding to the root resorption (Fig. 5 B). This patient appears to have a marked tendency for resorption of cementum and dentin corresponding to compression and increase in pressure within the periodontal membrane. A large number of dilated blood vessels engorged with blood can be observed in both the free and attached gingiva (Fig. 5 C). The reason for this increase in blood supply is not apparent from our sections. The clinical picture is included to show the gingival recession and the heavy occlusion (Fig. 5 D).

Case Number 6

Several layers of newly formed bone are found on the periodontal membrane side of the alveolar bone (Fig. 6). Resorption of bone can be observed on the labial side of the alveolar process. There is fibrosis of the bone marrow. A well defined layer of precementum is evident on the root surface. The alveolar crest fibers exhibit a well defined functional pattern. In the remainder of the periodontal membrane the fibers are oriented parallel to the root surface. Focal areas of mucoid degeneration can be seen in the central part of the periodontal membrane. The mild chronic gingival inflammation extends into the periodontal membrane, slightly apical to the alveolar crest, where a focal area of inflammation apparently has produced a notch in the alveolar bone.

Case Number 7

The alveolar crest appears very thick and a slow apposition of new bone is evident at the crestal margin. On the periodontal membrane surface of the alveolar

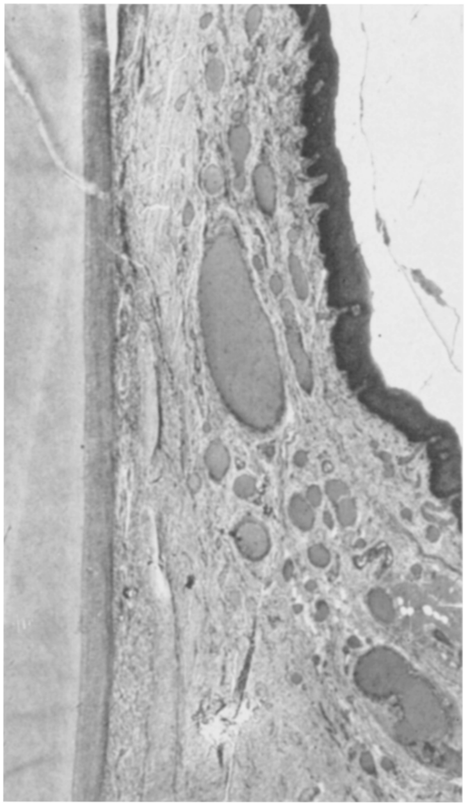


Fig. 5C. Large dilated blood vessels with a thin endothelial lining seen in the free and attached gingiva. No apparent connection with the compressed periodontal membrane. Case 5. Magnification X31.

Fig. 5D. Clinical picture of case 5 immediately prior to the removal of the specimen. Gingival recession and heavy occlusion with spreading of the maxillary anterior teeth.

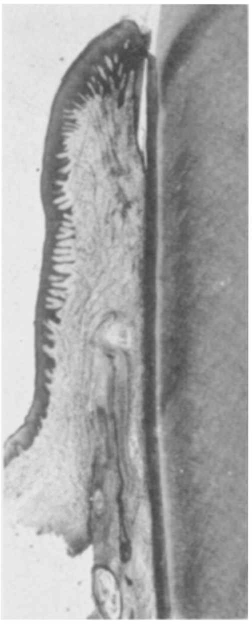


Fig. 6. Notch in the alveolar bone, slightly below the alveolar crest, associated with granulation tissue and inflammatory cells. Only mild gingival inflammation. Case 6. Magnification X10.

bone alternating areas of resorption and repair can be observed. The bone marrow is slightly fibrotic. A distinct layer of precementum is present on the root surface. The alveolar crest fibers are heavy and they exhibit a well defined functional pattern. The horizontal and oblique periodontal fibers have a very compact functional arrangement which closely resembles the tendon-like character of the periodontium in dogs. Only a few blood vessels are present in the periodontal membrane, and a very limited amount of interstitial loose connective tissue can be observed.

Case Number 8

Apposition of new bone is progressing at a rapid rate on the alveolar crest and along the periodontal membrane side of the alveolar bone. There is evidence of active bone resorption on the labial surface of the alveolar process. The bone marrow is partially fibrotic. Only a narrow zone of precementum can be observed. The cementoblasts are few and squamous in char-

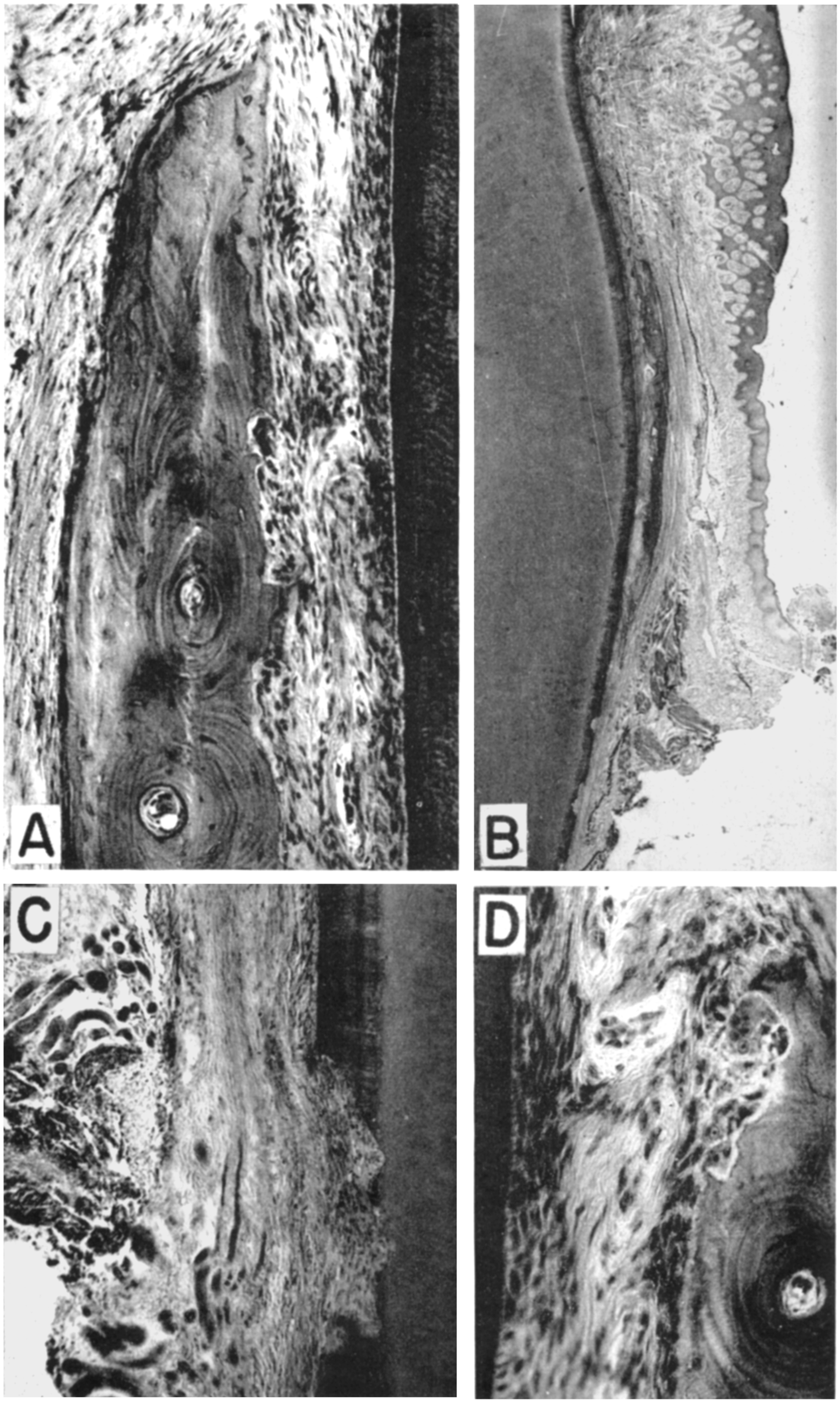
Fig. 7. (Left). Newly formed alveolar crest. Instead of normal horizontal fibers, the fibers are oriented parallel to the surface of the root and the alveolar bone. Oblique fibers can be seen at the bottom of the photomicrograph. Case 9. Magnification X170.

Fig. 8. (Right). Mucoid degeneration and a few lymphocytes and plasma cells in the periodontal membrane. Note the well defined layer of fibrous connective tissue on the surface of the root and the undisturbed pattern of the Sharpey's fibers, while the area of degeneration extends to the surface of the alveolar bone. Actual width of the periodontal space in this area: 0.12 mm. Case 11. Magnification X210.

acter in contrast to the numerous large osteoblasts and the wide zone of newly formed bone on the surface of the alveolar bone. A functional arrangement of the alveolar crest fibers is apparent, but there is evidence of beginning degeneration of the principal periodontal fibers with focal areas of mucoid degeneration and a few lymphocytes and plasma cells. In other areas within the periodontal membrane young granulation tissue is replacing the collagenous periodontal fibers. This granulation tissue is characterized by numerous newly formed vascular channels. The old collagen fibers have very long and narrow spindle shaped nuclei, and even the nuclei exhibit a slightly wavy pattern. Under high magnification one can observe a large number of fine Sharpey's fibers attached into the cementum, and there is absolutely no evidence of degeneration or atrophy along the root surface. The distance between the individual bundles of Sharpey's fibers is much greater on the alveolar bone surface than on the cemental surface. But the individual fiber bundles entering the bone is much thicker than the fibers that enter the cementum.

Case Number 9

Apposition of new bone is evident at the alveolar crest and along the periodontal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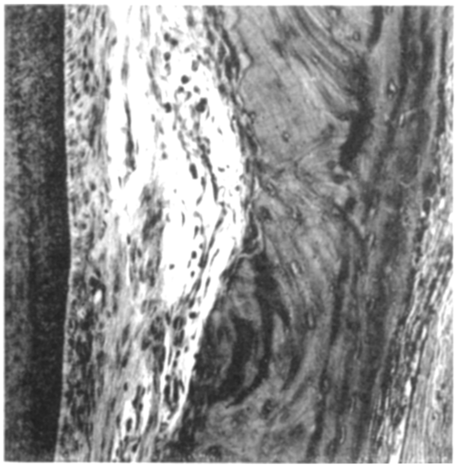


Fig. 9E. High magnification (X250) of area 3 mm. below the alveolar crest from same case as Figs. 9A, B, C, D. Mild mucoid degeneration of the periodontal membrane associated with slight resorption of the alveolar bone. Note the intact root surface and Sharpey's fibers. A few lymphocytes and plasma cells in the area of degeneration. Apposition of bone on the labial surface of the alveolar process.

membrane side of the alveolar bone (Fig. 7). Resorption is seen on the labial surface of the alveolar process. A fairly wide zone of precementum is present on the root surface, but only a few active cementoblasts can be seen. Most of the collagen fibers of the periodontal membrane run parallel to the root surface. There is evidence of diffuse areas of beginning mucoid degeneration of the periodontal membrane. In one such area of mucoid degeneration, about 5 millimeters apically to the alveolar crest, a considerable number of inflammatory cells are found.

Case Number 10

A wide zone of newly formed bone can be observed at the alveolar crest. There also is evidence of new bone formation along the periodontal membrane side of the alveolar bone. Active resorption is found on the labial side of the alveolar process. The labial bone plate which constitutes a fusion between the alveolar bone and the cortical bone on the alveolar process is very thin and without marrow spaces. A well defined zone of precementum is present on the root surface, and by careful study one can observe numerous areas of resorption and complete repair of the cementum. The alveolar crest fibers exhibit a well defined functional pattern. The remainder of the periodontal membrane is rather vascular, and there is evidence of beginning disuse atrophy and degeneration. Old collagenous fiber bundles characterized by very narrow long spindle shaped cells still have a functional orientation, while the young fibroblasts appear parallel to the root surface or frequently without any pattern of functional arrangement.

Case Number 11

Active bone apposition can be observed at the alveolar crest and along the periodontal membrane side of the alveolar bone. There is evidence of bone resorption on the labial side of the alveolar process. A relatively wide zone of precementum is apparent on the root surface. The periodontal fibers exhibit a functional arrangement at the alveolar crest. Areas of mucoid degeneration (Fig. 8) and a few lymphocytes and plasma cells can be seen scattered throughout the periodontal membrane. Most connective tissue cells of the periodontal membrane are arranged parallel to the root surface.

Fig. 9A. Alternating areas of resorption and apposition of alveolar bone. Slight hyalinization of the periodontal fibers. Intact fibers and attachment on the surface of the cementum. Actual width of periodontal space: 0.09 — 0.10 mm. Case 12. Magnification X157.

Fig. 9B. The alveolar bone plate is absent in the lower one-third of the photomicrograph. Case 12. Magnification X13.

Fig. 9C. Area of resorption extending into the dentin. Higher magnification (X78) of the area of missing alveolar process Fig. 9B. Muscle attachment into periosteum-like periodontal membrane.

Fig. 9D. Slight hyalin degeneration in the middle of the periodontal membrane and resorption at the alveolar crest. Different section from same area as Fig. 9A. Magnification X250.

Case Number 12

Lamellated newly formed bone is present on the labial aspect of the alveolar crest and along the labial surface of the alveolar process. Alternating areas of resorption and repair can be seen on the surface of the alveolar bone (Fig. 9 A). The labial bone plate is missing for a distance of 3 millimeters (Fig. 9 B) starting 4 millimeters apically to the alveolar crest and extending 7 millimeters apically to the alveolar crest where the alveolar bone again is present. Corresponding to this area of missing alveolar process, there is evidence of root resorption which in some instances extends into the dentin (Fig. 9 C). A well demarcated zone of precementum can be observed on the root surface. There is compression of the periodontal membrane in the cervical area with evidence of slight hyalin degeneration in the middle part of the periodontal membrane (Fig. 9 D). Mucoid degeneration can be found in other areas of the periodontal membrane (Fig. 9 E). The periodontal membrane has the appearance of periosteum where the labial bone is missing. The connective tissue cells are arranged parallel to the surface of the root and the muscle fibers are attached to this periosteal-like periodontal membrane.

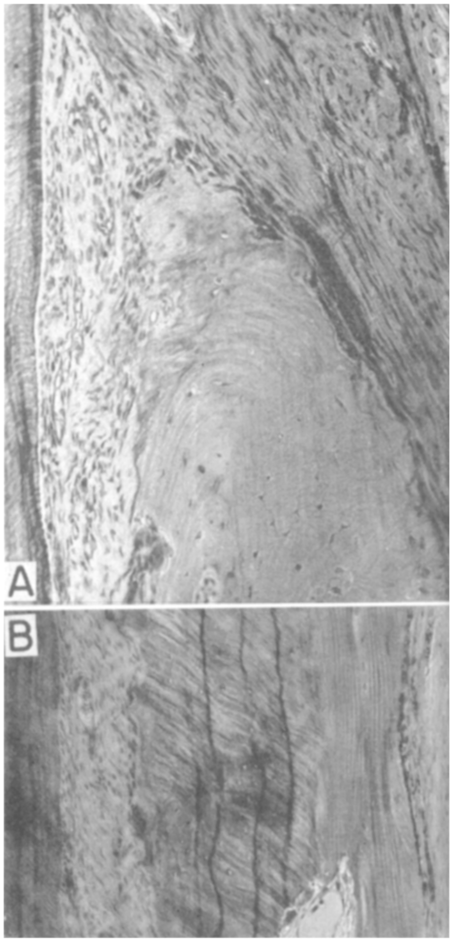
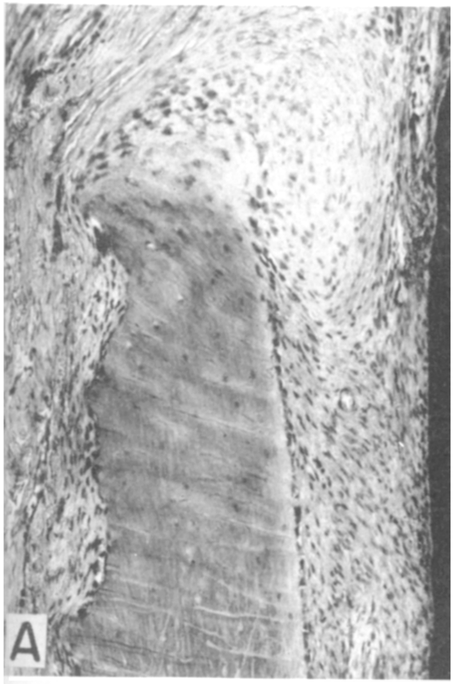


Fig. 10A. Compression of the periodontal membrane (actual width 0.08 — 0.09 mm.). Slight hyalinization in the periodontal membrane. Alternating resorption and apposition of alveolar bone. Case 13. Magnification X182.

Fig. 10B. Photomicrograph from about 4 mm. below the alveolar crest. The same specimen as Fig. 10A. Fusion between labial cortical bone and alveolar bone. Actual width of the periodontal space in this area: 0.13 — 0.15 mm. Magnification X100.

Case Number 13

At the labial aspect of the alveolar crest there is evidence of new bone formation (Fig. 10 A). Alternating areas of resorption and apposition of bone can be observed on the periodontal membrane side of the alveolar bone. The alveolar process is thick and alternating areas of resorption and new bone formation can be observed on its labial surface. The marrow spaces are very small, and the line of fusion can be observed between the cortical layer of the alveolar process and the alveolar bone (Fig. 10 B). There is moderate fibrosis of the bone marrow. A very narrow zone of precementum can be seen under high magnification. There is no evidence of cemental resorption. The periodontal membrane appears slightly compressed at the alveolar crest, and beginning hyalinization can be observed in the middle of the periodontal membrane. Close to the area of hyalinization, the blood vessels appear enlarged. The collagen fibers in the rest of the periodontal membrane appear very compact and they exhibit an easily recognizable pattern.



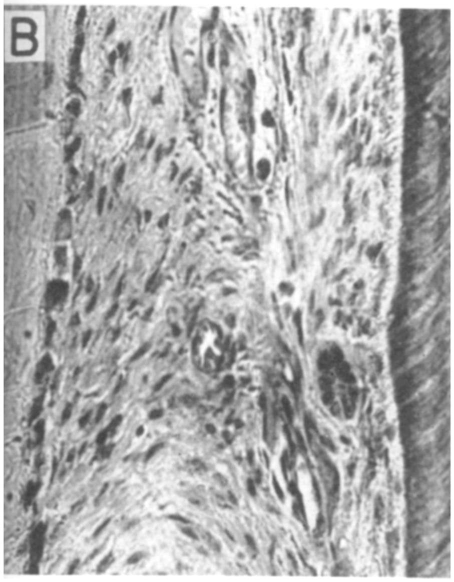


Fig. 11A. Rapid apposition of bone at the alveolar crest and along the inner surface of the alveolar bone. Resorption on the labial surface of the alveolar process. Width of periodontal space: 0.10 — 0.14 mm. Case 14. Magnification X150.

Fig. 11B. High magnification (X347) of the periodontal membrane 3-4 mm. below the alveolar crest from the same case as Fig. 11A. Beginning disorganization of the periodontal fibers in the central portion of the periodontal membrane. Note osteogenesis and cementogenesis.

Case Number 14

Marked osteoblastic activity can be observed at the alveolar crest and along the periodontal membrane side of the alveolar bone (Fig. 11 A). Resorption is taking place on the labial side of the alveolar process. A well defined layer of precementum is present on the root surface. Beginning atrophy and degeneration of the periodontal fibers can be recognized in part of the periodontal membrane (Fig. 11 B), but well defined bundles of oblique periodontal fibers are still present. A few plasma cells and lymphocytes are found in focal areas of mucoid degeneration. Numerous evenly distributed small Sharpey's fibers enter the cementum, while only a few heavy bundles of Sharpey's fibers are inserted into the alveolar bone.

Case Number 15

Resorption is evident at the margin of the alveolar crest. Alternating areas of resorption and repair can be observed on the periodontal membrane surface of the alveolar bone (Fig. 12 A), while new bone formation is taking place on the labial aspect of the alveolar process. The labial bone plate is very heavy and made up of almost solid bone with only a few small marrow spaces present. A well demarcated zone of precementum can be observed on the root surface, and there is no evidence of cemental resorption. There is evidence of compression of the periodontal membrane at the alveolar crest (width 0.1 mm.) and beginning hyalinization of periodontal fibers in this area. Beginning hyalinization of the periodontal membrane is evident also several millimeters apically to the alveolar crest. Relatively large blood vessels with a thick endothelial lining can be seen at the alveolar crest and at the periphery of other areas of hyalinization. The periodontal fibers at the alveolar crest appear folded and compressed. In the periodontal membrane the fibers are arranged parallel to the root surface. The clinical picture of this case (Fig. 12 B) is included to illustrate the occlusal relations.

DISCUSSION OF FINDINGS

The histological findings were similar in the eight maxillary specimens where the opposing teeth were extracted. In all of these cases a remodeling of the alveolar process could be observed associated with a lingual incisal movement of the teeth. Apposition of bone appeared at the alveolar crest and along the periodontal membrane surface of the alveolar bone, while resorption was evident on the labial aspect of the alveolar process. The layer of alveolar bone that apparently had been deposited after the extraction of the opposing teeth was measured microscopically and the measurements are listed in Table II.

In case number 14 the entire labial bone wall in our specimen consisted of new bone, so the thickness of the newly deposited bone could not be measured, but it must have exceeded the present thickness of the alveolar process (0.25 mm.). Other cases showed complete replacement of the crestal portion of the alveolar process with new bone following the loss of the antagonist. Of course, it cannot be stated with absolute certainty that these measurements were obtained from reliable lines of reference. However, under the microscope the newly formed bone appeared to be easily distinguishable from the rest of the alveolar process, both in staining quality and in structural pattern (Fig. 2 A). From Table II it appears that the interval of time elapsed since the extraction of the antagonists and the variation in occlusal stress influenced the amount of bone apposition to a greater extent than the age of the patient. It was remarkable that the cervical 3-4 millimeters of the labial alveolar process was completely rebuilt over a period of 169 days in a patient 64 years old (case number 14). This histologic observation confirms the clinical impression and experience that orthodontic movement of teeth can be accomplished with a satisfactory result in relatively old individuals.

TABLE II

Case No.	*Days Without Antagonist*	*Apposition of Alveolar Bone in Millimeters*
2	14	0.05—0.07
3	15	0.06—0.08
10	75	0.10—0.12
6	98	0.11
8	112	0.15—0.20
9	112	0.14—0.17
11	146	0.08—0.10
14	169	more than 0.25

The rapid apposition of alveolar bone in several of these experimental cases obviously necessitated a reorganization of the attachment of the periodontal fibers. Relatively widely separated heavy coarse fiber bundles were observed to enter the alveolar bone with one to five large cuboidal osteoblasts lined up between the individual fiber bundles. The attachment of the periodontal fibers to the cementum appeared unaltered. Very little cementoid or new cementum could be observed on the root surfaces except in areas of repair following previous traumatic injuries.

The gingival and alveolar crest fibers had maintained a distinct functional orientation during the limited time (up to 169 days) that has elapsed following the loss of the oppposing teeth. Several areas of well defined oblique fibers also could be observed in the periodontal membrane, but more often the fibers were oriented parallel to the surface of the root and the alveolar bone. Invariably the thin spindle shaped older connective tissue cells were lined up in a typical functional arrangement, while the young fibroblasts had a non-functional arrangement. Inconspicuous changes of early degeneration and atrophy in some instances could be observed in the subcrestal fibers. Fragmentation and partial disintegration of the collagen fibers occasionally could be observed. This was seen best in sections stained with Azan connective tissue stains. In some instances the collagen fibers were replaced by a meshwork of reticulum-like fibers in a seemingly edematous environment representing areas of so-called "mucoid degeneration" (Fig. 8). A few plasma cells and lymphocytes commonly were

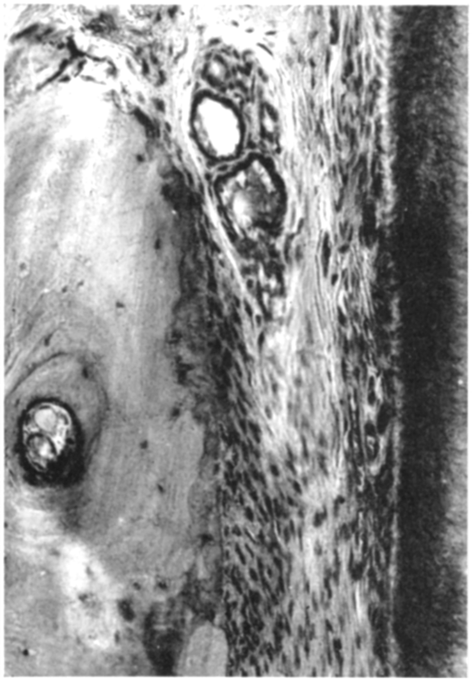


Fig. 12A. Compression and slight hyalinization of the periodontal membrane at the alveolar crest. Width of periodontal space: 0.10 mm. Note blood vessels with thick endothelial lining. Case 15. Magnification X250.

found within the periodontal membrane in areas of beginning disuse atrophy and degeneration. In none of these instances did the atrophy and degeneration approach in severity the changes of disuse atrophy that have been found in autopsy material when teeth have been without functional contacts for several years. Therefore, it can be assumed that disuse atrophy of the periodontal membrane progresses slowly in adult individuals. The relative stability of the collagen fibers in the fully developed adult periodontium also has been borne out in animal research on nutritional deficiencies[5].

No indication could be found of a so-called "intermediate plexus" of the periodontal membrane (Sicher [19], Orban[16]). Blood vessels and surrounding interstitial tissues commonly were located in the middle portion of the periodontal membrane, and it is conceivable that repair of the periodontal membrane following injury may originate in these tissues; but whenever functionally oriented periodontal fibers were observed, they exhibited a distinct continuity in their pattern or orientation from the surface of the cementum to the surface of the alveolar bone. Reorganization of attachment of the fibers seemed to take place on the surface of the alveolar bone and at the alveolar crest in response to changes in functional stress on the teeth. The intricate interwoven pattern of the periodontal fibers is obvious when cross sections and longitudinal sections through the root of a tooth and its surroundings are studied simultaneously. It is therefore virtually impossible to follow the entire length of a fiber bundle in the plane of any one section prepared for microscopic study. But the general pattern of orientation of the collagen fibers at the alveolar crest, the horizontal fibers, and the oblique periodontal fibers in this material did not indicate any seam or structural variation in the middle portion of the periodontal membrane. Neither were the early degenerative changes consistently localized to the middle portion of the periodontal membrane.

Fig. 12B. Clinical picture of case 15. The maxillary right lateral incisor was the experimental tooth. The occlusal stress on this tooth was heavy following extraction of the posterior teeth.

The most stable part of the periodontal membrane appeared to be the attachment to the cementum and the immediate vicinity of this attachment. Repair of the periodontal structures following trauma from occlusion is well illustrated in case number 3 (Fig. 3 C). The experimental tooth had been in traumatic occlusion up to 15 days prior to the removal of the specimen when the opposing teeth were extracted. Rapidly progressing repair of alveolar bone and cementum could be observed in this case.

The once case of a tooth from the mandible (case number 1) without antagonist followed the pattern of changes in the periodontal membrane already described for the eight cases from the maxilla, but there was no evidence of resorption on the labial aspect of the alveolar process. One would expect that the lower anterior teeth would move labially following loss of antagonist in contrast to the maxillary teeth that moved lingually. The lack of remodeling resorption on the labial aspect of the alveolar process in this case therefore can be understood. The lack of labial resorption furthermore was of great interest since a flap operation had been performed 14 days prior to the removal of the specimen. The lack of resorption following the flap operation in this case helps to exclude the surgical trauma as the cause of resorption on the labial aspect of the alveolar process in the previously described eight cases in the maxilla.

As could be expected, the periodontal findings in the six cases with increased occlusal stress varied considerably from the nine cases without antagonists. A process of remodeling of the alveolar process was observed also in the cases of increased occlusal stress, but here the remodeling represented an attempt to compensate for a labial movement of the teeth subsequent to the increased labial component of the occlusal stress. Apposition of bone was found on the labial aspect of the alveolar ridge and along the labial surface of the alveolar process. On the periodontal membrane side of the alveolar bone there was evidence of alternating areas of resorption and repair with the resorption dinstinctly dominating over the new bone formation. In four cases the labial bone plate was thick and made up of almost solid bone, but in two cases the labial alveolar process was perforated apically to the alveolar crest (Fig. 9 B). These perforations might have been caused by labial movement of the teeth. A similar perforation of the alveolar process also was found in case number 3 where the experimental tooth had been in traumatic occlusion until two weeks prior to the removal of the specimen.

Some areas of root resorption, occasionally extending into the dentin, were found associated with heavy occlusal stress. In some instances there was a marked tendency toward root resorption (Fig. 5 A), while in most instances (Figs. 10 A and 12 A) the root did not show any reaction to compression of the periodontal membrane. The zone of cementoid and newly formed cementum appeared slightly thicker on the teeth that had been subjected to heavy occlusion than on the previously discussed teeth with decreased occlusal function. But the cementoblasts appeared distinctly squamous in all instances and never were any cementoblasts observed that even approached the cuboidal appearance of the osteoblasts on the surface of the alveolar bone.

Normal functional arrangement of the periodontal fibers seldom was found in these cases with increased pressure from the occlusal forces. In some cases the periodontal space appeared widened; in other cases a definite compression of the periodontal membrane was evident at the cervical area with the fibers arranged parallel to the surface of the tooth and the alveolar bone. A beginning hyalinization at the middle portion of the periodontal membrane (Figs. 9 D and 12 A) was observed associated with the compression. As described by Oppenheim[12], dilatation of vessels (Fig. 12 A) could be found adjacent to the areas of hyalinization. In other areas vascular granulation tissue was observed in association with bone resorption (Fig. 4 B).

In areas where the labial bone plate was missing, the periodontal membrane assumed the morphological characteristics of periosteum (Figs. 9 B and 9 C). Attachments of muscle fibers into this area very closely resembled muscle attachment to regular periosteum. The osteoblasts associated with periosteum in any area were squamous and never approached the size and cuboidal appearance of the osteoblasts that were seen on the surface of the alveolar bone. It may be assumed that the large size and cuboidal shape of these latter osteoblasts is an indication of the rapid rate by which bone can be deposited on the surface of the alveolar bone.

It was also interesting and thought provoking to note how vulnerable the root surface is to resorption following compression of the periodontal membrane. The midportion of the periodontal membrane seems to be most vulnerable to increase in pressure as evident by the early hyalinization and vascular changes in this area. Azan stains for connective tissue also revealed an alteration in staining quality in these areas of hyalinization as described recently by Stahl, et al.[20]

The stability of the Sharpey's fibers inserted into the cementum and the persistence of the alveolar crest fibers in the presence of great changes in the other periodontal structures were the two most striking observations in this study. These structures also were found to be very resistant to changes associated with scurvy in an investigation by Waerhaug[22]. The biologic stability of these structures appear to be of great significance in prevention of downgrowth of the epithelial attachment and pocket formation both in relation to traumatic and systemic periodontal changes.

SUMMARY AND CONCLUSIONS

1. Periodontal changes associated with functional decrease and increase in occlusal stress on 15 human teeth have been described.

2. The most stable periodontal structure with regard to functional changes in occlusal stress appear to be the Sharpey's fibers entering the cementum and the periodontal fibers coronally to the margin of the alveolar crest.

3. Most of the adaptation of the periodontal fibers to change in functional demand seemingly takes place at the surface of the alveolar bone and the middle zone of the periodontal membrane.

4. Disuse atrophy of functionally oriented periodontal fibers in adults is a slow process.

5. Loss of posterior teeth may lead to traumatic occlusion with such sequellae as resorption of the surface of the root extending into dentin, and resorption of the alveolar bone with perforation of the labial wall of the alveolar process.

6. Remodeling and partial rebuilding of the alveolar process in response to changes in functional occlusal stress occurred in all of the patients regardless of the variation in age from 16 to 68 years of age.

BIBLIOGRAPHY

1. Bhaskar, S., and Orban, B.: Experimental Occlusal Trauma. J. Periodont. 26:270, 1955.

2. Black, G. V.: The Periosteum and Peridental Membranes. D. Rev. 1:57, 113, 169, 233, 289, 353, 411. 1886-1887.

3. Box, H. K.: Studies in Periodontal Pathology. Canad. Dent. Res. Foundation, Toronto, 1924.

4. Coolidge, E. D.: Traumatic and Functional Injuries Occurring in the Supporting Tissues of Human Teeth. J.A.D.A. and Dent. Cos. 80:343, 1938.

5. Goldman, H. M.: The Effects of Dietary Protein Deprivation and of Age on the Periodontal Tissues of the Rat and the Spider Monkey. J. Periodont. 24:135, 1953.

6. Gottlieb, B., and Orban, B.: Die Veränderungen der Gewebe bei übermässiger Beanspruchung der Zähne. Leipzig, Georg Thieme, 1931.

7. Häupl, K., und Lang, F. J.: Die Marginale Paradenitis. Berlin, Hermann Meusser, 1927.

8. Häupl, K., und Psansky, R.: Histologische Untersuchungen die Wirkungsweise der in der Funktions-Kiefer-Orthopädie verwendeten Apparate. Dtsch. Zahn-Mund-Kieferhk. 5:214, 485, 641, 1938.

9. Kohler, C. A., and Ramfjord, S. P.: Healing of Gingival Muco-Periosteal Flaps. In press. J. O. Surg., O. Med., O. Path.

10. Kronfeld, R.: Histologic Studies of the Influence of Function on the Human Periodontal Membrane. J.A.D.A. 18:1242, 1931.

11. Kronfeld, R.: Histologic Analysis of the Jaws of a Child with Malocclusion. Angle. Orth. 8:21, 1938.

12. Oppenheim, A.: Human Tissue Response to Orthodontic Intervention of Short and Long Duration. Am. J. Orth. and Oral Surg. 28:263, 1942.

13. Orban, B.: Resorption and Repair on the Surface of the Root. J.A.D.A. 15:1768, 1928.

14. Orban, B.: Tissue Changes in Traumatic Occlusion. J.A.D.A. 15:2090, 1928.

15. Orban, B.: A Contribution to the Knowledge of the Physiologic Changes in the Periodontal Membrane. J.A.D.A. 16:405, 1929.

16. Orban, B.: Periodontics. The C. V. Mosby Co., St. Louis, 1958.

17. Reicbnorn-Kjennerud, I.: Funktionell-prothetische Behandlung und Prophylaxe der Zahnlockerung und der Dysgnathien. In Häupl, K. Die Zahn-, Mund-und Kieferheilkunde, Vol. 4, München, Berlin, Urban and Schwartzenberg, 1956.

18. Reitan, K.: The Initial Tissue Reaction Incident to Orthodontic Tooth Movement as Related to the Influence of Function. Acta Odont. Scand. Suppl. 6, Oslo, 1951.

19. Sicher, H.: The Principal Fibers of the Periodontal Membrane. Bur. 55:2, 1954.

20. Stahl, S. S., Sandler, H. C., and Suben, E.: Histochemical Changes in Inflammatory Periodontal Disease. J. Periodont. 29:183, 1958.

21. Waerhaug, J.: Pathogenesis of Pocket Formation in Traumatic Occlusion. J. Periodont. 26:107, 1955.

22. Waerhaug, J.: Effect of C-Avitaminosis on the Supporting Structures of the Teeth. J. Periodont. 29:87, 1958.

23. Wentz, F. M., Jarabak, J., and Orban, B.: Experimental Occlusal Trauma Initiating Cuspal Interferences. J. Periodont. 29:117, 1958.

Periodontosis—Associated with Gingival Lesions—in a Child

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THE following case is described rather for the sake of its peculiar features than for any light that it sheds upon disorders of the gingivae or of the supporting tissues of the teeth. The striking features of the case are the multiple discrete lesions of the gingival margins and the areas of gross resorption of alveolar bone without appreciable pocketing or suppuration.

History: The patient, a girl of 11 years, complained of painful ulcers in the mouth of about one week's duration. The ulcers had occurred at irregular intervals for two years, and each ulcer lasted about a week before healing. Nothing was known that precipitated the disorder and there was no history of ulcers in any other sites than the mouth. There was no complaint of any other symptoms.

Examination: The patient was rather pale. She was of normal development for her age and showed no obvious abnormalities. Within the mouth there was a healing aphtha on the buccal mucous membrane, and this was the source of the complaint. Much more conspicuous than this, however, were the lesions on the gingivae.

Gingivae and Mucous Membrane: The mucous membrane was of normal colour, but there was a mild chronic gingivitis with hyperplasia of the gingival margins especially in the upper and lower incisor regions.

Distributed along the gingival margins were nine discrete lesions: five were on the upper gingivae and four on the lower. The lesions were rounded in outline, varied from about 0.5 cm. to 0.75 cm. across and extended from the gingival margin towards the buccal sulcus (see Fig. 1). They were

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