The Development and Maturation of the Supracrestal Fibers in Nonhuman Primates

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The role of the supra-alveolar fibers in the postretention movement of orthodontically treated teeth has received attention by many research investigators and clinicians. Transsection of these fibers has been advocated by many orthodontists as a method of preventing postretention rotational relapse.[6,7,9,11,13,21] To better understand this supracrestal network of fibers a longitudinal histologic study was undertaken to show the development of these fibers, their maintenance and alterations in the normal and disease state.

LITERATURE REVIEW

As early as 1904 Waugh[33] believed that gingival fibers resisted tooth movement and that the separation of teeth resulted in the snapping and subsequent degeneration of these transseptal fibers. He did not believe that restoration of the original condition could be expected.

Sicher observed an intermediate plexus with collagenous elements aligned parallel to the long axis of the guinea pig molar.[27] This centrally-situated zone, he postulated, permitted the continuous eruption of these teeth.

Beckwith and Williams[4] demonstrated in cats that orderly regeneration and reorganization of the periodontal fibers after injury and partial destruction was to be expected, rather than the formation of scar tissue.

Marshall noted that, as an extrusive force was applied to a tooth, the transseptal fibers were carried with the tooth resulting in fibers that more nearly paralleled the long axis of the tooth.[19]

Urban and Beisler found that after mechanically separating teeth in dogs the transseptal fibers were stretched and torn on the tension side.[32]

Kronfeld[17] described the transseptal fibers as being confined to the area between two adjacent teeth running from the cementum of one tooth more or less horizontally across the crest of the interdental septum to the cementum of the next tooth. He saw their function as maintaining the mesial-distal relationship between neighboring teeth. He observed the alveolar crest fibers to be a rather variable group of fibers that were sometimes well-developed and at other times missing. These fibers ran from the septal crest to the cementum. Kronfeld also described the "circular ligament" which he saw as horizontal dento-alveolar fibers surrounding the tooth running from cementum to alveolar margin. He believed their function was to prevent displacement of the teeth when lateral stresses were applied.

Sicher expanded the concept of the intermediate plexus to include teeth of limited growth (i.e., human teeth) contending that no alveolodental fiber extended continuously from tooth to bone.[28] Rather, he asserted the fibers intertwined near the middle of the PDL space thus permitting physiologic migration and continuous eruption.

Chase and Revesz showed reestablishment of the transseptal fibers which

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had been broken during extraction and orthodontic procedures on monkeys.[8] They demonstrated that the repair of damaged fibers was accomplished in a relatively short time and the original orderly arrangement and essential function was reestablished.

Erickson, Kaplan and Aisenberg studied the repair phenomenon in humans after the extraction of first bicuspids and retraction of the anterior segments.[12] In histological sections of the previous extraction site they observed the transseptal fibers to be remarkably persistent, even when almost all of the bony support was lost. They also noted that the transseptal fibers were being continuously renewed and, when stretched, tended to pull the tooth to which they were attached in the same direction.

Aisenberg wrote that a differentiation must be made between different types of tissues and their response to orthodontic movements.[1] The fibers of the periodontal membrane that attached tooth to bone were readily adapted and rearranged. The transseptal or subepithelial fibers did not respond as well to tooth movement and were, therefore, implicated as a significant factor in the relapse of orthodontically corrected teeth.

Arnim and Hagerman studied serial horizontal histologic sections of human, monkey and rat jaws.[2] They observed a heavy band of connective tissue that encircled each tooth and extended throughout the dental arch. The connective tissue extended to the depth of the alveolar crest where it decussated with the transseptal fibers. It was found that the fibers were almost entirely destroyed in extensive periodontal lesions, but that they reformed following gingivectomy or curettage.

Numerous investigations contended that transsection of the dentogingival and transseptal fibers prevented relapse following orthodontic tooth movement.[6,7,9-11,13,21,22,30,31]

Thompson stated that the function of the supra-alveolar fibers was not to create good tooth alignment, but rather to maintain the teeth in place. He concluded that the supra-alveolar fibers had great regenerative and reparative qualities, exhibited great resistance, and were difficult to control. He viewed them as a considerable factor in the relapse phenomenon of orthodontically rotated teeth.[30]

Reitan noted that stretching of the periodontal fibers that occurred in treatment on dogs could be observed at a considerable distance from the particular tooth that was being moved.[22-26]

Orban, Wentz, Everett and Grant described the gingival fibers as being functionally arranged into several groups.[20] The dentogingival fibers extended from the cementum beneath the epithelial attachment laterally into the lamina propria of the gingiva and were usually the most numerous group of fibers. The alveologingival fibers arose from the alveolar crest and inserted into the lamina propria. Small groups of circular fibers encompassed the tooth. The accessory fibers were prominent horizontal fibers extending interproximally between adjacent teeth. They were also called transseptal fibers. On the oral and vestibular surfaces of the jaws a fiber group extended from the periosteum of the alveolar bone to the tooth and were called dentoperiosteal fibers.

Bernick described the organization of the periodontal fibers in the developing molars of rats.[5] His study demonstrated that the transseptal fibers which pass from the cementum of one tooth across the interproximal space to attach to the cementum of the approximating teeth did not become organized until both approximating teeth were in clinical occlusion. At this stage the fibers from one tooth passed toward the middle of the interproximal space to interdigitate with the fibers arising from the cementum of the adjacent tooth. After the teeth were in functional occlusion, the transseptal fibers became thicker, and the interlacing fibers appeared to become cemented at the midline giving the appearance that these fibers passed from one tooth to another.

Fullmer did a comparative histochemical study of elastic, pre-elastic, and oxytalan fibers.[14] He concluded that oxytalan fibers were part of the elastic-like connective tissue and that they represented an immature or specially modified elastic fiber.

Sicher stated that there was no area of adjustment or intermediate plexus in the gingiva. Without the plexus he suggested adjustment may take years to accomplish.[29]

Grant and Bernick studied the developmental sequence of periodontal ligament formation in teeth with and without predecessors in marmosets.[16] They concluded that while the chronology differed, the sequence of principal periodontal fiber formation was the same for teeth with and without predecessors. In each the developmental pattern occurred as follows: (1) Fibers first emanated from cementum. The osteoblast-lined alveolar bone showed no fiber extrusions or only a rare, isolated fiber. The greatest part of the periodontal ligament space was occupied by the collagenous elements similar in appearance to those of the dental sac. (2) Fibers, thicker and more widely spaced than those from cementum, emerged from bone and extended briefly toward the tooth and then splayed out at their ends. The central three fourths of the periodontal ligament space was occupied by loosely structured collagenous elements. (3) Bony fibers extended into the central zone to join lengthening cemental fibers and obliterated the "intermediate plexus." (4) With occlusal function the principal fibers became classically organized, thicker, and apparently continuous between bone and cementum.

Furstman and Bernick noted that transseptal fibers did not become organized until both approximating teeth were in clinical occlusion. At this stage, fibers from one tooth passed toward the middle of the interproximal space to interdigitate with fibers arising from the cementum of the adjacent teeth.[15]

Materials and Methods

The cotton ear marmoset (Callithrix jacchus) and spider monkey (Saimire sciureus) used in this study ranged in age from young animals in the mixed dentition stage (5), young adults in the permanent dentition (10) and old animals (10). At necropsy the heads were removed and fixed in either 10% formalin or an alcoholic acetic acid-formalin solution. The maxillae and mandibles were decalcified in 10% nitric acid in 10% formalin, dehydrated and infiltrated in the routine manner for nitrocellulose embedding. Half of each jaw was sectioned either in a mesiodistal and/or buccolingual plane. Some horizontal sections were also taken. Alternate sections cut at 15-25 micra were stained with Mallory's connective tissue stain, iron haemetoxylin-picro fuchsin, and silver nitrate impregnation.

Results

In the interdental space of two premolar teeth in which one tooth has erupted, fibers from the erupted tooth passed across the crest to terminate freely in the lamina propria covering the crypt of the adjacent developing tooth. Free gingival fibers were only demonstrable in the erupted tooth (Fig. 1).

The orientation of the supracrestal fibers in erupted teeth depended upon

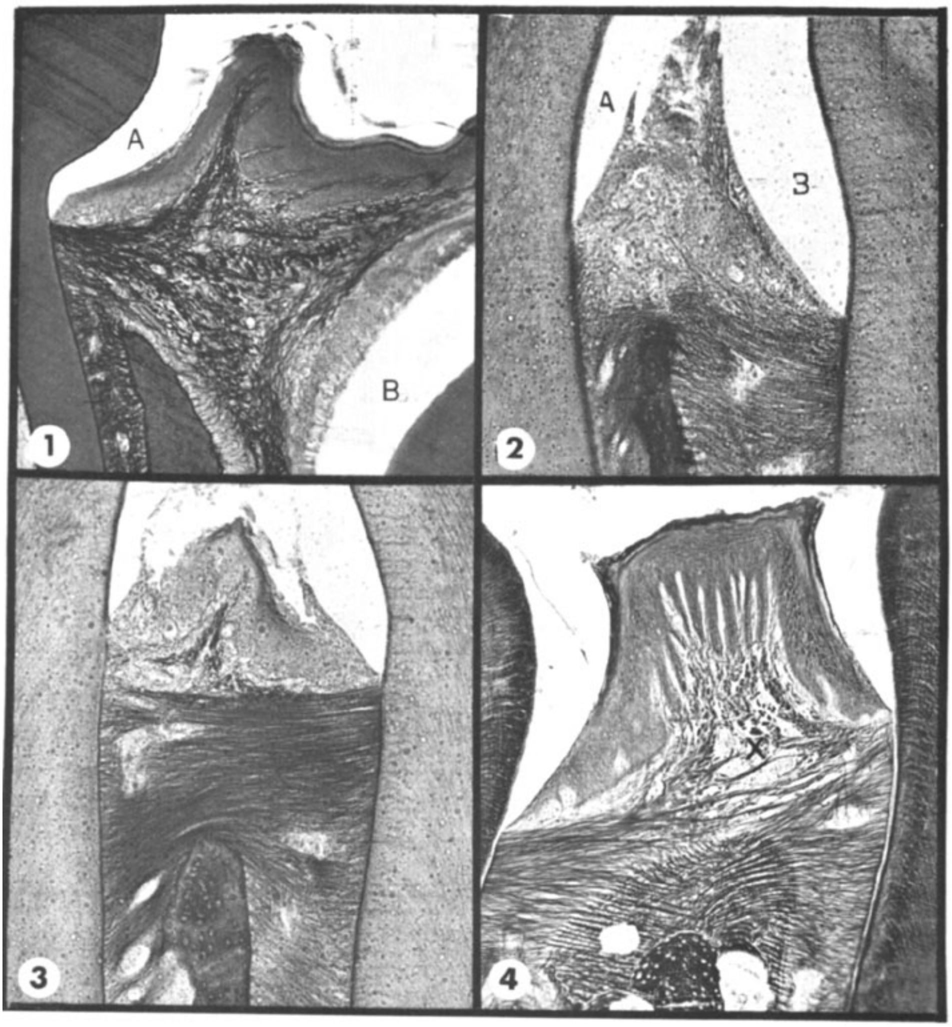

Fig. 1 Interdental space between first and second maxillary molars. The first molar (A) has erupted into the oral cavity whereas the second molar (B) is unerupted. Note that the fibers arising from the cementum of the first molar pass across the crest to end among the fibers of the lamina propria covering the unerupted second molar. Mallory's connective tissue stain, × 120.

Fig. 2 Interdental space between the maxillary third premolar (B) and the first molar (A) in a young animal. The height of the alveolar crest is at the C-E junction of the third premolar. Notice that the fibers appear to terminate at the midline. Mallory's connective tissue stain, × 75.

Fig. 3 Interdental space between two maxillary premolar teeth that have just erupted into clinical occlusion. Note that the transseptal fibers interlace at the midline and appear to be uninterrupted. Mallory's connective tissue stain, × 75.

Fig. 4 Interdental space between two maxillary premolar teeth in an adult animal. Note that the transseptal and alveolar crest fibers are well-demonstrable, and that many of the fibers (X) in the tunica propria are in the cross-section plane. Silver nitrate impregnation, × 125.

the height of the crest. When both teeth had erupted into the oral cavity, and the height of the crest was at the cemento-enamel junction of one tooth, the transseptal fibers rising from one premolar crossed the ligament space above the alveolar crest. The fibers originating from the mesial of the first molar coursed to and appeared to terminate at the midline above the crest. At this stage there appeared no interlacing of the fibers which extended from the cementum of both surfaces (Fig. 2).

The termination of the transseptal fibers from each tooth appeared to interlace at the midline giving the impression that the transseptal fibers of one tooth passed uninterrupted to the cementum of the adjacent tooth when the two adjacent teeth were in clinical occlusion (Fig. 3).

The appearance of the supracrestal fiber bundles was related to the morphology of the interdental space. Figure 4 illustrates the crestal area between two upper premolars. Alveolo-gingival fibers appeared to pass into the connective tissue papillae of the gingiva. However, there were large bundles of fibers in cross section that passed in a buccolingual direction. The transseptal fibers from both surfaces terminated in the midline in a loose interlacing network.

In contrast, the interdental space between the mandibular premolar and first molar teeth appeared very wide, and the transseptal fibers from the adjacent teeth seemed to intermingle at the midline. The three distinct fiber bundles of the supracrestal group (free gingival, transseptal, alveolar crest) are clearly demonstrable (Fig. 5).

The interdental space between the two maxillary premolars of the marmoset was narrow in width and the transseptal fibers appeared to run from the cementum of one tooth to the cementum of the adjacent tooth without any interruption (Fig. 6).

In gingival inflammation the initial loss of the transseptal fibers appeared to be at the interlacing zone (Fig. 7). The free gingival fibers as well as the buccal-lingual fibers appeared lysed.

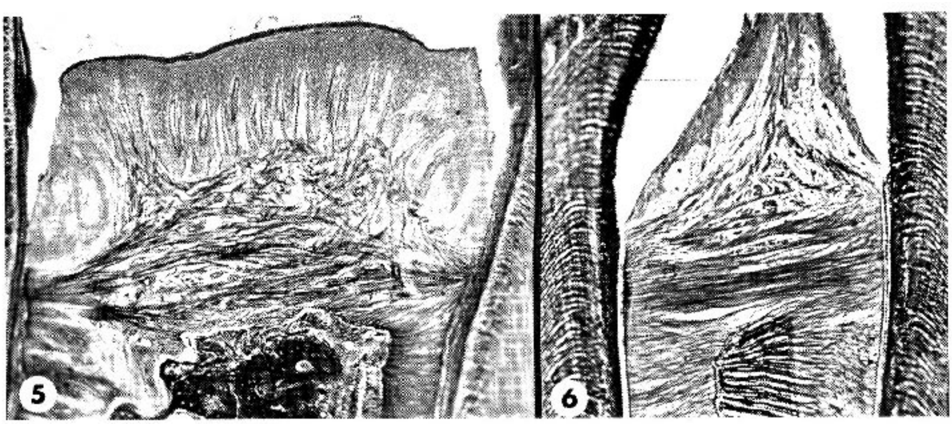

Fig. 5 Interdental space between the mandibular third premolar and first molar. Note the width of the space due to mesial drift and the separation of the fibers at the midline due to this drifting. Silver nitrate impregnation, × 125.

Fig. 6 Interdental space between two maxillary premolars taken at the center of the crest exhibiting a dense accumulation of transseptal fibers giving the impression that the fibers pass uninterrupted from cementum of one tooth to the cementum of the adjacent tooth. Silver nitrate impregnation, × 125.

The lysis of the transseptal fibers in the midline accentuates the interrelationship between the mesial and distal transseptal fibers. The origins of these fibers adjacent to the cementum of both teeth were intact.

With progressive periodontal disease including the resorption of the bony crest, the transseptal fibers and the alveolar crest fibers are destroyed at the midline (Fig. 8).

In the reparative stage following crestal resorption the reformation of the transseptal fibers takes place in the midline and follows the contour of the alveolar crest (Fig. 9).

A section of the "col" region or interproximal space best illustrated the course of the gingival fibers that were seen in cross section in the mesial and distal views. A dense fiber bundle passing from the buccal to the lingual gingiva above the crest was demonstrable. The fibers appeared to spray into the lamina propria of the buccal and lingual gingiva (Fig. 10).

The orientation of the fibers in the buccal gingiva as well as the lingual gingiva varied between these two surfaces. On the buccal (Fig. 11) fibers originating from the cementum passed occlusally into the lamina propria of the gingiva with only a few fibers terminating in the papillae. A denser bundle was seen passing over the bony crest to terminate in the connective tissue of the attached gingiva. The mass of the lamina propria consisted of interlacing fibers appearing in cross section view. The lingual or palatal gingival area, on the other hand, appeared to consist mostly of dense alveologingival fibers which pass from the cementum into the connective tissue of the gingiva and palate. Fibers that appear in cross section were minimal (Fig. 12).

In observing a cross-sectional area just above the cemento-enamel junction a wide band of transseptal and alveolar crest fibers can be seen extending interproximally. Also fibers which originate in the interproximal area can be observed coursing circumferentially around the labial and lingual surface. They appeared to occur in a larger proportion than those alveologingival fibers which originated labially and lingually (Fig. 13).

Discussion

The histogenesis of the supracrestal fibers was studied from a late preeruptive stage through maturity in health and disease (Fig. 1). Free gingival fibers, which were only demonstrable in the erupted tooth, passed across the crest to terminate in the loosely-structured collagenous fibers surrounding the unerupted adjacent tooth. As the adjacent tooth erupted into the oral cavity, fibers which subsequently became the transseptals coursed toward the interdental bony crest to meet the fibers extending from the adjacent tooth. At this stage the fibers did not meet or interlace at the midline. As the tooth continued to erupt into the oral cavity the dentogingival fibers became more numerous. They interlaced at the midline and appeared to form a thick bundle stretching from one tooth to another. These fibers may be cemented together at the midline by a mucopolysaccharide complex which could allow these fibers to slide over one another without tearing as occurs in mesial-distal movement. The density of the transseptal fibers appeared to be inversely related to the size of the interdental space. As the interdental space became larger, the fibers were more loosely arranged at the midline. This appears to help preserve the integrity of the remaining arch as Kronfeld has suggested.[17]

In gingivitis and periodontitis an interesting finding of this study was the apparent lysing of the dentogingival

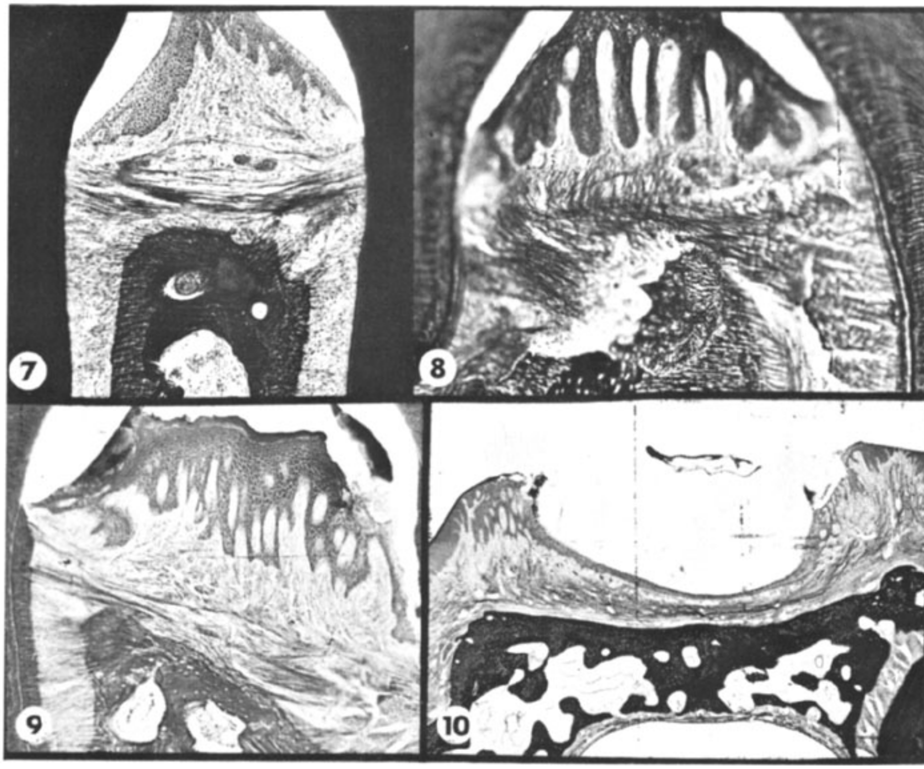

Fig. 7 Interdental space between two maxillary premolars. Note the inflammation of the gingival papilla and underlying connective tissue and loss of fibers in the lamina propria and at the midportion of the transseptal fibers. Silver nitrate impregnation, × 75.

Fig. 8 The interdental space between two mandibular molars which exhibits periodontitis. Note the destruction of the crestal bone due to periodontal disease and the loss of fiber attachment above and at the region of resorption. Silver nitrate impregnation, × 200.

Fig. 9 Interdental space between two mandibular molars of an older animal. Loss of bone was due to periodontal disease. Note the subsequent healing and reformation of fibers above the crest. Silver nitrate impregnation, × 75.

Fig. 10 "Col" area between two maxillary premolars. Note the dense band of fibers extending from buccal gingiva and terminating in the lingual gingiva. Silver nitrate impregnation, × 30.

fibers at their weakest point, the midline. Chase and Revesz showed that with healing these fibers reorganized rapidly to their original orderly arrangement.[8] This reorganization probably occurs because only the reaggregation of the collagen molecules is needed in the center to restore the integrity of the fibers.

Collagen fibers are continuously being formed and replaced and it may be that the fibers, surrounding teeth that have been rotated, have been twisted (as described by Reitan[24]) and reformed in the same pattern continuing the tension. However, no studies appeared to document this view and this opinion must be considered a construct.

The "col" region demonstrated a completely separate band of fibers which ran from labial gingiva to lingual gingiva. This band probably serves

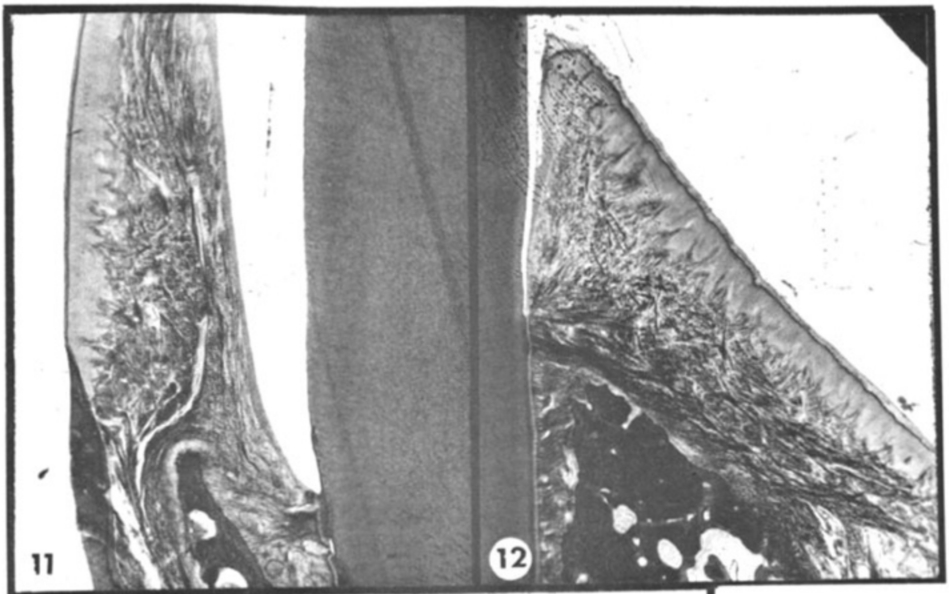

Fig. 11 Section of the labial gingiva of a maxillary premolar. Note the supracrestal fibers passing over the bony crest into the attached gingiva. Note only a few fibers terminate in the free margin of the gingiva and that the mass of collagen fibers are viewed in cross section. Mallory's connective tissue stain, × 75.

Fig. 12 The lingual gingiva and palate exhibit supracrestal fibers that pass into the palatal mucosa as well as fibers terminating in the connective tissue papillae. Mallory's connective tissue stain, × 75.

Fig. 13 Cross-sectional view of a maxillary premolar. Note the circumferential extension of the interproximal fibers to the buccal and lingual gingiva. Mallory's connective tissue stain, × 30.

to tie the labial and lingual gingiva together. Although these fibers are not attached to any teeth it is possible that they also contribute to the rotational relapse phenomenon. If the rotation of a tooth causes twisting of the gingivodental fibers as Reitan has suggested, causing displacement of the labial gingiva as Edwards[11] has shown, it is likely that this band of fibers is then placed under tension. The return of these fibers to a relaxed state would then appear to influence the other alveolodental fibers in the same vicinity contributing to rotational relapse. It would seem then that in any surgical procedure involving the transsection of the alveologingival fibers this labial-lingual band would be freed and devoid of tension.

If possible it would seem that early correction of rotations as suggested by Furstman and Bernick is advisable in light of the fact that the supracrestal are not fully formed until the teeth are in clinical occlusion.

Summary and Conclusions

1. The transseptal fibers appear to develop independently in adjacent teeth and course toward each other meeting at the midline.

2. Correction of rotations should be accomplished if possible before the teeth are in clinical occlusion.

3. The thickness of the band of transseptal fibers depends on the anatomy of the interproximal space.

4. The fibers are not continuous but interlace at the midline.

5. In disease the transseptal fibers are destroyed first at the midline and appear to reorganize at that point.

6. A thick fiber bundle was demonstrated to run buccolingually in the interdental space which served to connect the buccal and lingual gingiva. It was independent of the dentogingival fibers.

7. Circumferential fibers which extend from the interproximal to the labial and lingual gingiva were also noted.

8. Poor hygiene which contributes to the formation of gingivitis and in extreme cases periodontitis causes the lysing of the gingival fibers.

9. This study does not answer the problem of why certain rotations reoccur even after surgical transsection of the fibers.

10. Further morphologic studies in a time sequence during rotation correction and retention are needed to determine which fibers play an exact role in the rotational relapse phenomenon.

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