Organic Tissue Characteristics on the Pressure Side of Human Premolars Following Tooth Movement

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INTRODUCTION

Connective tissue components on the pressure side of the root are usually undergoing certain changes in number and shape during orthodontic tooth movement with hyalinization of fibrous tissue as the end result.[1,7,8] During the hyalinization period, tooth movement is delayed,[5] and resorption of the tooth surface may occur.[10] In practical orthodontics the understanding of these changes is essential, especially with regard to the magnitude, type and duration of the forces applied. Many of the studies dealing with hyalinization have been based on light microscopy study of teeth and supporting tissue from animal specimens. Earlier investigations have disclosed that the tissue characteristics of various species are reflected in the tissue reaction.[7] Consequently it may be concluded that information of clinical value primarily can be obtained from studies of human tissue.

It has been established that the normal morphology of organic structures remaining on the root after extraction may be studied in the scanning electron microscope (SEM).[3] The purpose of the present investigation was to observe organic tissue alterations on the pressure side of extracted teeth which had been moved continuously by means of fixed orthodontic appliances.

MATERIALS AND METHODS

The material comprised forty premolars obtained from individuals aged 10-12 years. None of them had received orthodontic treatment previously. Oral x-ray films, study models and clinical examination revealed only normal teeth. Twenty-three teeth were moved with fixed, orthodontic appliances, fifteen teeth were provided only with orthodontic bands, and two teeth were untreated. In every case one control tooth from the same individual was available for comparison, and when possible the observation period of the experimental tooth and the tooth provided only with a band were kept similar. Two control teeth were left without bands.

Orthodontic procedure.

A stainless steel spring (.016") was attached to the first molar exerting a force of 50 grams and moving the experimental tooth in a buccal direction. This latter tooth was provided with a twin arch bracket. The force exerted by the spring was measured with a Correx gauge. The experimental periods were 5, 10, 15, 20, 25, 30, 35, 45, and 76 days; each observation group included three premolars except the last group which consisted of only two teeth.

Laboratory procedure.

After extraction the teeth were fixed in 4% buffered formaldehyde (pH 7.3) for 24-48 hours at room temperature. The apex of the tooth was cut off and the tooth divided in one buccal and one lingual half each containing the marginal and middle root portion. The buccal halves used in the present study were postfixed in 2% OsO_4 for 12 hours at 4° C, dehydrated in graded series of ethyl and ether, mounted on metal holders (brass or aluminum) with colloidal silver and air-dried for 24 hours. The specimens were coated in a vac-

uum evaporator under continuous tilting and rotation.[2] The marginal buccal portion of the roots was studied in a scanning electron microscope usually operated at 45°, 20 kV and 100 mA.

Findings

On the pressure side the presence of compressed, irregular round or ovoid areas was the most noticeable alteration of the organic tissue as compared with sham-operated or untreated teeth. These areas were fairly well-outlined and located close to the supra-alveolar tissue (Fig. 1). The tissue within these areas was fairly flat and homogeneous as compared with the surrounding tissue or the surface of the control teeth. Although the same magnitude of force was used for all teeth, the extent of the pressure areas varied markedly in groups with the same observation time, and frequently more than one such zone was observed on the pressure side (Fig. 2). Whereas usually the presence of compressed areas could be readily determined, other areas were so small that only a close examination at high magnification revealed their existence.

Also the tissue characteristics of various areas varied. Frequently the central portion of the compressed tissue of these zones was completely structureless showing only an amorphous substance (Figs. 3 and 4). In other teeth principal fiber bundles without the usual, structural organization were observed (Fig. 5). The coalesced fiber bundles had no periodic cross-striation.

Part of the homogeneous substance was frequently absent, and thus the mineralized tooth surface was exposed (Fig. 6). Such removal of the structureless substance was first observed in the second group after a period of ten days. In the portion surrounding some of the compressed areas, disorganized fiber bundles containing fibrils still exhibiting cross-striation were observed (Fig. 7).

Resorption processes of cementum and dentin were observed close to pressure areas containing the homogeneous substance (Fig. 8). Such processes were particularly present in groups representing an observation time of between twenty and thirty-five days.

Numerous erythrocytes of normal shape and size were regularly found, and in the pressure areas disorganized blood cells significantly reduced in size were also present (Fig. 9). These cells differed markedly from normal erythrocytes located outside the pressure areas of the same specimens (Fig. 10).

Although degenerative resorptive processes and coalesced fibrils were typical features on the pressure side, formative tissue changes were also observed in the form of thin fibers forming a plexus different from those observed in the sham-operated teeth (Fig. 11). Such tissue tended to cover the resorption lacunae in observation groups of longer duration. In a few cases cells resembling fibroblasts were located close to the hyalinized tissue (Fig. 12).

Discussion

In sectioned tissue the hyalinized portion of the periodontal membrane is mostly homogeneous and consists of coalesced fiber bundles.[1,5,8,9] Following tooth movement with forces acting continuously, this alteration is regularly observed and has certain characteristic, morphologic features. The structureless substance observed in studies with SEM must be considered to consist of hyalinized tissue of the periodontal membrane. The present study indicates that the formation of hyalinized areas is initiated by a loss of the regular arrangement of the fiber bundles, disappearance of the periodic cross-striation, subsequently followed by a unification

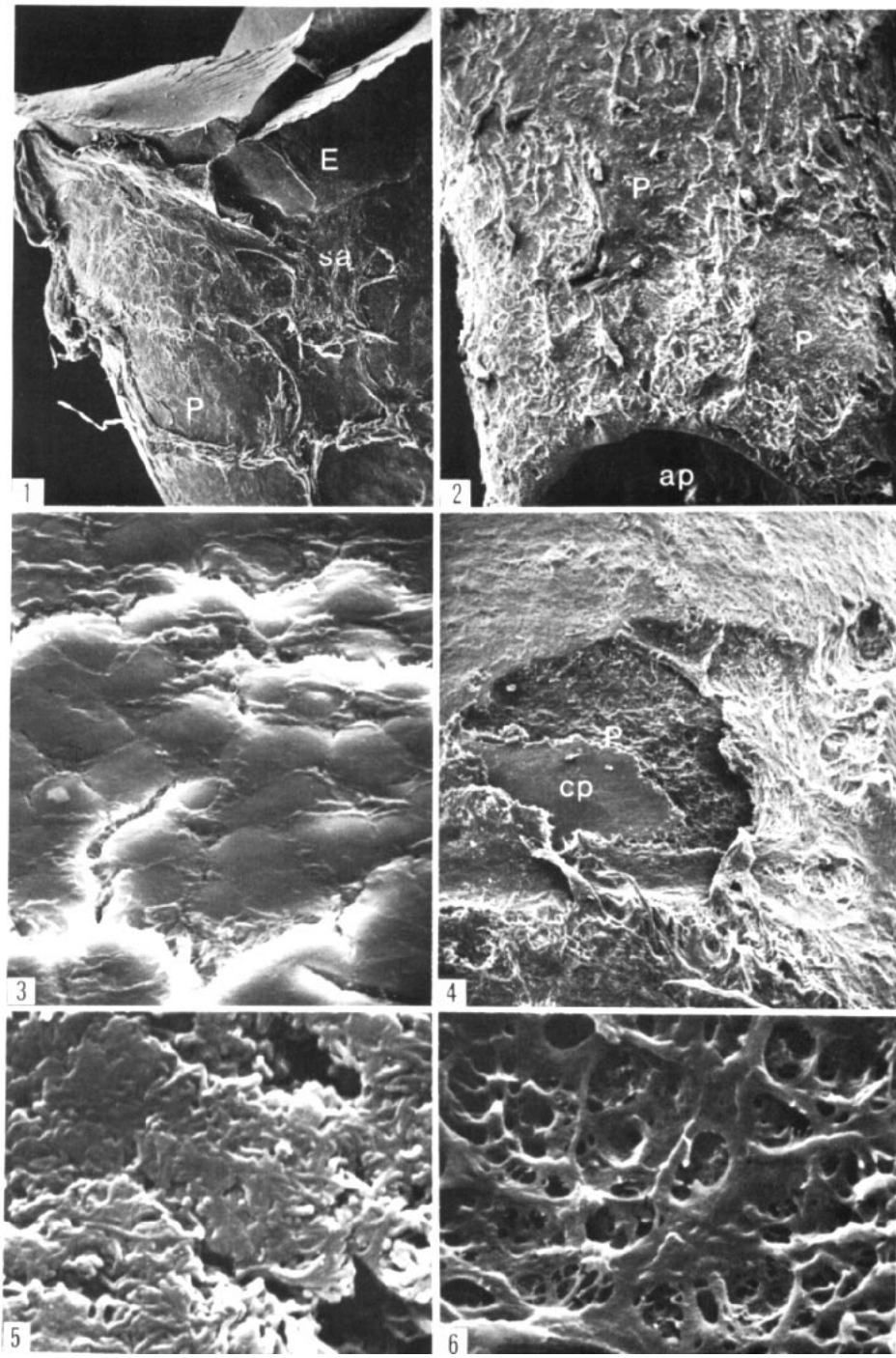

Fig. 1 Scanning electron micrograph of marginal portion of pressure side of young premolar, E, enamel; P, pressure area covered by a compressed, homogeneous substance; Sa, supra-alveolar tissue. Observation time: 25 days, x 26.

of these fibrous elements into a homogeneous substance where no structural arrangement remains.

The hyalinized tissue persists for a time which has been termed the hyalinization period. During this period removal of the coalesced fibers occurs,[1] whereafter the tooth again starts to move. Provided the force is acting continuously, processes denoted as secondary hyalinization of the periodontal membrane may occur.[5] In addition to the experimental force, intermittent forces caused by function of the teeth may influence the tissue reaction, particularly when the experimental tooth has attained a changed intercuspation. The effect of such factors may be reduced by grinding the occlusal surfaces of the experimental teeth. During routine orthodontic treatment such forces are present and it was therefore decided to include the effect of such factors. Some of the differences in the extent, number and location of the pressure areas can be ascribed to such factors, and the variability in the character of the areas indicates that the initial tissue reaction may have been influenced by the subsequently changed intercuspation.

Measurements of the rate of tooth movement in humans have shown that during the primary hyalinization from five to twenty-five days only minor tooth movement occurs.[5] The frequency of hyalinized areas in the present investigation corroborates these findings, confirming that more than one area may account for the delay of tooth movement initially.[6] The present study also shows that a force of fifty grams, acting continuously, is strong enough to create secondary hyalinization regularly in human premolars, a finding which also may be influenced by the architecture of the bone surface.

The connective tissue cells on the pressure side play an essential role during the reorganization of the periodontal membrane. In SEM studies, fibroblasts located on the root surface may be identified, but they are not regularly seen on the surface of extracted teeth.[3] The determination of the occurrence and location of pressure areas must therefore be based on other tissue changes. However, blood cells were regularly observed in all regions as a result of the bleeding produced during the extraction. It can also be stated that the size and shape of erythrocytes are influenced by the preparation of the material before examination in the SEM, but erythrocytes similar to those

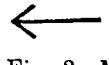

Fig. 2 Middle root portion with apex (ap) of the tooth removed. Two irregular areas (P) were characterized by compressed tissue. Observation time: 15 days, x 27.

Fig. 3 Homogeneous, structureless substance from central portion (cp) of Figure 4. Observation time: 35 days, x 2000.

Fig. 4 Compressed area (P) with structureless substance located central (cp). Some of this substance is absent exposing the cementum. The area, which was surrounded by organic tissue, was located closely beneath the supra-alveolar tissue. Observation time: 35 days, x 50.

Fig. 5 High magnification of coalesced fiber bundles in compressed area. The outline of smaller fibers can still be discerned. Observation time: 76 days, x 12500.

Fig. 6 High magnification of mineralized cementum surface surrounding central portion of compressed area showing numerous trabeculae in a resorbed lacunae. Observation time: 35 days, x 12000.

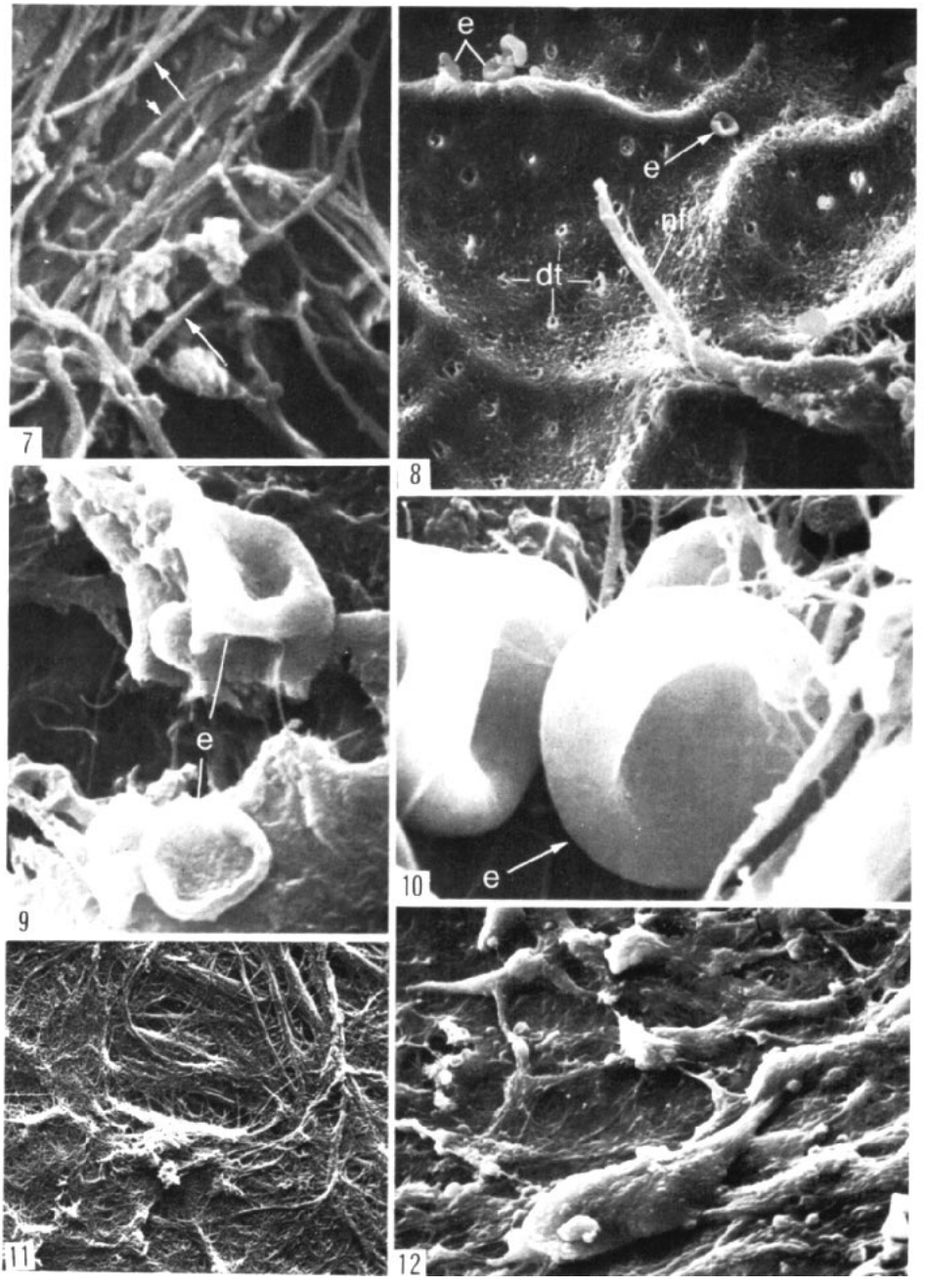

Fig. 7 High magnification of fibers with periodic cross-striation (600 A) in fibers with a diameter of 500 A, located peripherally in a compressed area. The structural organization of the fiber bundles was lost. Observation time: 30 days x 24000.
Fig. 8 Resorbed dentin with dentin tubules (dt). Note presence of erythrocytes (e), and of nerve fiber (nf). Observation time: 25 days, x 1250.

observed in the pressure areas of the present study were never observed.[3] In addition, erythrocytes located close to the pressure areas were of a size and shape entirely different from the appearance of the remnants of such cells that persisted in cell-free areas. Removal of fibrous structures located circumferentially and around the hyalinized tissue could be observed from ten days after the experiment had been initiated. After thirty-five days formative changes occurred, whereby a plexus of thin fibers tended to cover the resorbed lacunae of the root surface. The incidence of root resorption could, therefore, not be recorded in all specimens and will be dealt with separately in a study in which the organic tissue components observed in the present investigation had been removed so that the cementum of the root became denuded.

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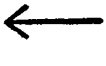

Fig. 9 Collapsed erythrocytes (e) localized in compressed area. The cell size is significantly reduced but a biconcave appearance is maintained. Observation time: 20 days, x 12500.

Fig. 10 Erythrocyte (e) of normal shape and size, from same specimen as Figure 9, but located outside the compressed area. Observation time: 20 days, x 12500.

Fig. 11 Network formed by numerous fibers in cell-free zone. Observation time: 35 days, x 2350.

Fig. 12 Cells (c) located in the peripheral portion of a compressed area. Observation time: 20 days, x 1250.