A Histological Study of the Exfoliation of Human Deciduous Teeth

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For clarification of the histological details of the shedding of human deciduous teeth, exfoliated and extracted deciduous teeth were examined by light and electron microscopy. After the roots were completely resorbed, the dento-gingival junction migrated along the inner resorbing surface and finally reached the pulpal surface of the crown. At the same time, the gingival epithelium also proliferated and migrated under the crown of the deciduous tooth in such a way that part of it lined the residue of the pulp and another part lined the surface overlying the erupting successional tooth.

This phenomenon took place from various sides of the tooth surface. Therefore, just before exfoliation, the migrated gingival epithelium formed narrow necks of tissue, and the crown was only superficially attached to the gingiva by them. The final shedding of the tooth appeared to occur by a tearing of these narrow tissue regions. The results of the present study suggest that the dento-gingival junction as well as gingival epithelium play important roles in the process of exfoliation of human deciduous teeth.


Introduction.

The histological aspects of the physiological resorption of human deciduous teeth have been well-demonstrated (Ten Cate, 1986). Resorption of the roots of deciduous teeth occurs and continues until the roots are completely resorbed. However, to date, no clear evidence has been reported as to how the deciduous teeth are finally exfoliated.

Clinically, it has been noticed that human deciduous teeth are shed with little bleeding, when the teeth naturally exfoliate. Immediately after teeth are shed, stratified squamous epithelium is frequently found on the underlying tissues. Furthermore, wound healing after exfoliation is usually more rapid than that after extraction. Our hypothesis, therefore, was that the gingival epithelium may play some role in the process of exfoliation.

In the present study, we examined human exfoliated and extracted deciduous teeth by means of light and electron microscopy.

Materials and methods.

Fifteen exfoliated human deciduous teeth (4 incisors, 4 canines, and 7 molars) and 45 extracted deciduous teeth (12 incisors, 16 canines, and 17 molars) that were almost ready to be exfoliated were examined.

The teeth were fixed in a solution of 0.5% glutaraldehyde-4% paraformaldehyde in 0.5% glutaraldehyde buffer (pH 7.3) for 6 to 10 h. The teeth were then washed overnight in 0.5% glutaraldehyde buffer plus 7.5% sucrose (pH 7.3), and then decalcified with 10% ethylenediaminetetraacetic acid (EDTA) in 10 mmol/L cacodylate buffer (pH 7.3) at 4°C for about a month. After decalcification, the teeth were cut into halves labio-lingually or medio-distally and used for either light or electron microscopic observations. For light microscopy, specimens were dehydrated with ethanol and embedded in Technovit 7100 (Kulzer, Germany). Serial sections were cut at 5-μm intervals and were stained with hematoxylin and eosin or with toluidine blue. For electron microscopy, specimens were cut into small cubes, refixed for 2 h in 2.5% glutaraldehyde in 0.5 mol/L cacodylate buffer, and post-fixed with 1% OsO4 for 1 h. After dehydration through a graded series of ethanol, the tissues were embedded in Epon. Ultrathin sections were stained with uranyl acetate and lead citrate, and examined in a JEM-1200 EX electron microscope.

Results.

A medio-distal section of a deciduous molar that was naturally shed is shown in Fig. 1A. The roots of the tooth were completely resorbed. The crown dentin was also partially resorbed, in one area extending from the inner surface of the dentin to the dentin-enamel junction. However, few odontoclasts were observed on the resorption surface. The resorbed regions were mostly covered by cementum-like tissue. The soft tissue remaining attached within the crown showed a dense inflammatory infiltrate, and it was lined on its apical surface by stratified squamous epithelium, probably of gingival origin (Fig. 1A, circular inset). Laterally, this epithelium was continuous with and gave way to thinner epithelium which resembled that of the dento-gingival junction (DGJ) (Fig. 1A, rectangular inset). The latter epithelium was attached to the pulp walls of the crown dentin and/or its cementum-like covering via a basal lamina showing hemi-desmosomes (Figs. 1B and 1C). Adjacent to this junction, inflammatory

Fig. 1.—(A) An exfoliated deciduous lower second molar. The roots are completely resorbed, and coronal dentin (D) has also been resorbed from the inner surface of the pulp (P) chamber. The surfaces of resorbed regions are mostly repaired by deposition of cementum-like tissue (CL). The remaining pulpal tissue shows intense inflammation and is covered with stratified squamous epithelium, probably of gingival origin (circular inset). This stratified squamous epithelium appears to be attached to the inner surface of the pulp chamber (rectangular inset). Micro-organisms (Mo) are present on the resorbed tooth surface that is not covered with pulpal tissue. Stained with hematoxylin-eosin.

(B) and (C) Electron micrographs of the epithelium attached to the lateral surface wall of the pulp (P) chamber. Epithelial cells (Ep) are attached to the surface of the deposited cementum-like tissue (CL) via the internal basal lamina (arrowheads) and hemi-desmosomes (arrows) in a manner similar to that present in junctional epithelium.
cells were frequently observed in the connective tissue of the pulp. Resorbed surfaces that were not covered with pulpal tissue were overlaid by micro-organisms (Fig. 1A), indicating that these parts of the dentin surface had been exposed to the oral cavity.

Similar histological features were observed in all other classes of teeth, especially when they had naturally exfoliated. The remaining pulp of the latter group of teeth was usually completely covered basally by gingival-like epithelium (Fig. 2).

Various earlier stages from extracted deciduous teeth that were almost ready to exfoliate are illustrated in Fig. 3. This shows extracted teeth for which the roots were mostly resorbed. The DGJ epithelium had proliferated downward and was usually found adjacent to the margin of the resorbed tooth (Fig. 3A). Moreover, the gingival epithelium appeared to have proliferated inward for a short distance into the pulp from where it reflected backward to join the DGJ epithelium connected to the tooth margin. The gingival epithelium and DGJ epithelium were otherwise separated (Fig. 3A). At a later stage of shedding, the cementum on the external surface of the root had completely resorbed, and the DGJ epithelium became detectable on the resorbed surface of the inside of the crown (Figs. 3B-D). In the tooth where shedding appeared to be imminent, a part of the DGJ epithelium had reached the inner surface of the pulp chamber (Figs. 3B and 3C). By serial sectioning of the tooth, however, it was noticed that the migration of the tooth. In some extracted teeth, for example, while most of the DGJ epithelium was detected on the resorbed surface of the inside of the crown, the rest was still found on the resorbed root surface. The inequality of the migration of the DGJ epithelium seemed to be more pronounced in the extracted deciduous incisors and canines than in the molars (data not shown).

In the exfoliated deciduous teeth, the DGJ epithelium was usually found on the newly deposited cementum-like tissue on the resorbed dentin surface of the pulp chamber (Figs. 1A-C). However, in some extracted teeth, the DGJ epithelium was detected on the resorbed dentin surface, where no cementum-like tissue deposition could be found (Figs. 4A and 4B). Ultrastructurally, the epithelial cells attached directly to the resorbed dentin surface in the same manner as junctional epithelium (Fig. 4C).

Concomitant with the migration of the DGJ epithelium prior to exfoliation, the gingival epithelium also appeared to have proliferated and migrated beneath the coronal pulp so that at first the remaining pulp was partially covered with gingival epithelium and later completely covered by it (Fig. 3C). This phenomenon occurred unevenly at various sides of the tooth surface, but in late stages, the migrating gingival epithelium bounded narrow connective tissue bridges under the crown just before shedding (Figs. 3D and 3E).

**Discussion.**

The evidence presented in this study indicates that in human deciduous teeth, migration of the DGJ epithelium as well as of gingival epithelium takes place prior to shedding, and suggests that this phenomenon may play an important role in the process of exfoliation.

**Migration of the DGJ epithelium.**—The apical migration of the DGJ epithelium to the resorbing surfaces of the deciduous teeth during the process of shedding has been demonstrated in dogs (Urban, 1931), monkeys (Bernick et al., 1951; Johnson, 1961), and humans (Kronfeld, 1932; Bernick et al., 1949, 1951; Soskolne and Bimstein, 1977; Rölling, 1981). Whereas Bernick et al. (1951) assumed that apical migration of the DGJ epithelium might be

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**Fig. 2**—Naturally exfoliated deciduous canine crown. Note the gingival epithelium covering the remaining pulp tissue (arrow). Stained with toluidine blue. Dentin (D), Pulp (P).

**Fig. 3**—(A-E) Various stages of the migration of the dentogingival junction (DGJ) epithelium and gingival epithelium in the process of exfoliation. Stained with toluidine blue.

(A) The DGJ epithelium is found adjacent to the margin of the resorbed tooth. The cementum (arrow) can be found on the resorbed root surface. Deciduous canine.

(B) The DGJ epithelium passed over the margin of the resorbed tooth, and migrated toward the inside of the crown. A part of the DGJ epithelium can be detected on the resorbed dentin surface in the pulp chamber (arrow). The gingival epithelium migrating from both sides of the tooth surface covers the underlying tissue of the crown. A narrow neck-like connective tissue region can be found between the migrated epithelium (arrowhead). The cementum on the root surface was completely resorbed. In some regions (*), undermining resorption of coronal dentin reaches the dentin-enamel junction. Deciduous canine.

(C) The DGJ epithelium reached the inner surface of the pulp chamber. Deciduous molar.

(D) The migrated gingival epithelium under the crown. The migrated gingival epithelium forms a narrow neck of tissue region under the crown. Deciduous molar. Micro-organism (Mo).

(E) The area outlined in (C). Cementum-like tissue (CL). Dentin
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A \[ \text{Ep} \]
B \[ \text{D} \]
C \[ \text{P} \]
D \[ \text{Mo} \]
related to exfoliation, the participation of the migration of the DGJ epithelium in exfoliation has not been clarified. Soskolne and Bimstein (1977) mentioned that the migration of the DGJ epithelium appeared to be due to resorption of the root rather than to apical migration of the DGJ epithelium.

In this study, apical migration of the DGJ epithelium was found in extracted deciduous teeth that were almost ready to exfoliate. Furthermore, it was also revealed that the DGJ epithelium of the deciduous teeth did not detach from the tooth surface throughout the process of shedding. The migration of the DGJ epithelium continued until the tooth had exfoliated. At first, it migrated toward the inside of the crown along the resorbed dentin surface, and eventually reached the inner surface of the pulp chamber. In fact, the DGJ epithelium was found on the wall of the pulp chamber even in exfoliated teeth. Our findings demonstrate that the DGJ epithelium of the deciduous teeth would protect the underlying connective tissue from bacterial invasion until the teeth finally exfoliate, if it did not detach from the surfaces of the teeth by mechanical injury during the process of exfoliation.

Bernick et al. (1951) and Soskolne and Bimstein (1977) suggested that inflammatory processes and irritation would stimulate the apical migration of the DGJ epithelium. In this study, it was found that an inflammatory process accompanied the migration of the DGJ epithelium, since lymphocytic infiltration gradually increased in the connective tissue adjacent to the DGJ. Especially, after the DGJ epithelium had reached the margin of the resorbed tooth, the migration appeared to be further stimulated as a result of chronic irritation by micro-organisms present adjacent to the DGJ. By the continuous infiltration of the inflammatory cells, the remaining pulpal tissue showed intense inflammation just before exfoliation.

It is of interest to clarify how the DGJ epithelium migrates toward the inside of the crown along the resorbed dentin surface. As reported in our previous study (Sahara et al. 1992)...

Fig. 4—(A) Light micrographs of the surface of resorbed dentin. The epithelial cells attached to the resorbed dentin surface of the crown. Toluidine blue. Dentin (D), Epithelium (Ep), Pulp (P).

(B) and (C) Electron micrographs of the epithelial cells on the resorbed dentin surface. The epithelial cells are attached directly to the surface of the resorbed dentin by attachment structures. Dentin (D), Dentinal tubules (DT), Epithelial cells (Ep), Hemi-desmosomes (arrowheads).
teeth, the internal surface of the resorbed dentin in the pulp chamber is usually repaired by deposition of cementum-like tissue. In fact, for most exfoliated teeth examined, the DGJ epithelium was found on the surface of the newly deposited cementum-like tissue rather than in dentin. However, in some teeth, the epithelial cells of the DGJ were attached directly to the resorbed dentin surface via hemi-desmosomes. These findings suggest that the DGJ epithelium can migrate on the resorbed dentin surface whether or not it has been repaired by cementum-like tissue deposition.

Movement of the gingival epithelium.—Some investigators (Urban, 1931; Kronfeld, 1932; Johnson, 1961; Sosolne and Bimstein, 1977) mentioned that the gingival epithelium also proliferated and migrated toward the resorbing areas during the process of exfoliation. Urban (1931) and Kronfeld (1932) suggested that this epithelium could unite with the enamel epithelium of the permanent tooth germ. On the other hand, Johnson (1961) reported that the epithelium does not unite with the enamel epithelium and does not participate in the formation of the alveus of the permanent tooth. However, the ultimate fate and participation of gingival epithelium in the process of exfoliation have not been established. The most interesting finding of this study was the evidence that in the exfoliated tooth the remaining pulpal space was covered by stratified squamous epithelium, and that the epithelium was attached to the inner surface of the pulp chamber in a manner similar to that present in the DGJ. This histological configuration suggests that the gingival epithelium also proliferated and migrated toward the inside of the crown, and eventually ended under the deciduous crown (Fig. 5).

Smith (1958) reported that, in the healing of experimental extraction wounds, the epithelial proliferation was directed toward the concentration of inflammatory cells in the isolation and exfoliation of root fragments. A similar phenomenon would occur in the process of exfoliation of deciduous teeth.

With the apical migration of the DGJ epithelium, the remaining pulp became inflamed because of the chronic irritation by micro-organisms present adjacent to the DGJ. Thus, the gingival epithelium proliferated toward the inflammation in the remaining pulp. As mentioned above, however, the DGJ epithelium did not detach from the tooth surface throughout the process of exfoliation. Therefore, the migrated epithelium might be present under the crown to isolate the areas of inflammatory infiltration in the remaining pulp. It is assumed that the presence of the gingival epithelium under the crown might play an important role in exfoliation. The upper part of the epithelium would isolate the inflamed pulpal tissue from the underlying oral tissues. The lower part of the epithelium might function not only to isolate the inflammatory infiltration but also to protect the underlying oral tissue, including the permanent tooth germ, from invasion by micro-organisms. It is also assumed that at the time of shedding, the upper part of the migrated gingival epithelium that covered the remaining pulpal tissue would come off with the deciduous tooth.

A possible mechanism of final shedding.—Fig. 5 shows schematic representation of the possible migration of

Fig. 5—Schematic representation of migration of the DGJ epithelium and gingival epithelium in the process of exfoliation of a human deciduous tooth. After the roots are completely resorbed, the DGJ epithelium gradually migrates toward the resorbed surface, and finally reaches the surface of the pulp chamber wall. Accompanying this migration, the gingival epithelium also proliferates and migrates toward the resorbed regions, and eventually is present under the crown. Therefore, the migrated gingival epithelium makes nar-
The DGJ epithelium as well as gingival epithelium begin to migrate toward the inner surface of the crown along the resorbed surface. This phenomenon would take place at the various sides of the tooth surface, so that migrating gingival epithelium comes to form narrow strips of that epithelium under the crown. Just before exfoliation, the remaining pulpal tissue would be connected with underlying oral tissues by only these narrow tissue regions. Then, actual exfoliation will be accomplished by tearing of these narrow neck-like portions under the deciduous crown. At the time of shedding, minimal bleeding would occur, because only the blood vessels passing through these narrow necks of tissue would be broken. After exfoliation, the migrated gingival epithelium, the lower part of epithelium, would rapidly cover the wound areas caused by exfoliation.

Although we could not obtain any information about the relationship between deciduous and successor permanent teeth during the later stage of exfoliation, the present findings provide a histological basis for the minimal bleeding at exfoliation and the rapid wound healing.

REFERENCES


