Scanning electron microscope characterization of abrasion in human teeth

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Abstract

Objectives: The purpose of this study was to examine the surface changes of abrasion in human teeth by scanning electron microscopy.

Materials and methods: Ten human premolars with cervical abrasion from 10 patients requiring tooth extraction, one tooth from each patient, were used in this study. The specimens were collected from the Department of Oral and Maxillofacial Surgery, Faculty of Dentistry, Mahidol University and private dental clinics. After extractions, all teeth were stored in 10% formalin until required. The specimens were cut in mesiodistal directions, immersed in 5.25% sodium hypochlorite and then dehydrated using increasing ethanol concentrations (two changes 15 minutes each): 50%, 60%, 70%, 85%, 95%, 100% and dried by leaving the specimens at room temperature for 24 hours, mounted on aluminum stubs, coated with gold, 100-300 Å thick, with an ion sputter coater, and viewed with a JEOL JSM-6610 LV scanning electron microscope, at seven magnifications: X20, X30, X100, X500, X1,000, X3,500, and X10,000. The photomicrographs were described.

Results: In the abraded areas which were limited to the enamel surfaces, most of the enamel surfaces appeared uniformly smooth and showed presence of horizontal, vertical, and oblique scratches. In the abraded areas which were deep and extended into the dentin, dentinal tubules were exposed and could be observed in oblique and longitudinal sections. In some areas, the enamel surfaces showed dissolution of enamel rod ends which gave the enamel surface a honeycomb appearance. In other areas, the dentin surfaces appeared rough with numerous openings of dentinal tubules. Parallel linear scratches arranged in various directions were also noted. Dentinal tubules showed a variation in the diameter of the openings, from patent to completely obliterated. In a few areas, an opening of the dentinal tubule was surrounded by a dentin matrix which consisted of a network of collagen fibers. In one tooth, two vertical fissures were seen in the abraded area.

Conclusions: The abraded enamel surfaces appear smooth with a variable number of parallel scratch marks which are arranged in various directions. The abraded dentin surfaces show linear scratches similar to those of the abraded enamel and contain numerous openings of dentinal tubules. Evidence of erosion and abfraction is found.

Keywords: abfraction, abrasion, erosion, human teeth, non-caries cervical lesion, scanning

Introduction

Abrasion describes the wearing away of a substance or structure through mechanical processes, such as grinding, rubbing or scraping. The clinical term dental abrasion is used to describe the pathologic wearing away of dental hard tissue through abnormal mechanical processes involving foreign objects or substances repeatedly introduced in the mouth and contacting the teeth.1 Probably the most common cause is incorrect or overvigorous toothbrushing, resulting in lesions at the neck of the tooth. This association is supported by studies that have reported an increase in cervical abrasive lesions in individuals who brush their teeth more often, for longer, and use a scrubbing technique rather than a less damaging method.2 Some degree of abrasion was present in 42 percent of the youngest age class (20-29) and in persons of middle age, 76 percent were involved.3 Black classified the abrasions according to their appearance: wedge-shaped, dish-shaped, flattened, irregular and figured areas.4 Dzakovich and Oslak reproduced significant noncarious cervical lesions in vitro via horizontal brushing with common commercial toothpaste.5 Non-carious cervical lesions (NCCLs) involve loss of hard tissue at the cervical third of the dental crown and subjacent root surface, through processes unrelated to caries. NCCLs is commonly multifactorial, with combinations of distinct processes, including abrasion, corrosion (erosion), and possibly abfraction most often operating to varying degrees.6 Using SEM, abrasion was characterized by the presence of horizontal scratch marks while corrosion was characterized by a smooth surface.7 Horizontal, vertical, and irregular scratches are likely to result from abrasion. Cracked areas are likely to be the result of abfraction. Tubule exposure and enamel rod corrosion are possible to be due to corrosion.8 Normal human enamel appeared smooth and structureless under SEM. Linear brushing traces were found. Dissolution of prism cores and boundary regions could be observed after erosion.9 The sclerotic dentin was homogeneous because most tubules had been completely obliterated.10

The surface characteristics of abrasion in human teeth was infrequently reported in the literature. This study aims to examine the surface changes of abrasion in human teeth by scanning electron microscopy (SEM).

Materials and methods

A total of 10 human premolars with cervical abrasion from 10 patients requiring tooth extraction, each tooth from a different patient, was obtained. All teeth had intact surfaces, free of caries or restorations. The specimens were collected from the Department of Oral and Maxillofacial Surgery, Faculty of Dentistry, Mahidol University and private dental clinics. After extractions, all teeth were stored in 10% formalin until required. After the teeth were rinsed under running tap water, each tooth was then sectioned using Micro Cutting Instrument, Struers Accutom-50, Denmark. A section was obtained by cutting each tooth in the horizontal plane above and below the cervical abrasion. Each section was immersed in a 5.25% sodium hypochlorite solution for 24 hours at room temperature to remove soft tissue or organic substances. After that it was rinsed thoroughly in distilled water, and then dehydrated in a series of graded ethyl alcohol (two changes 15 minutes each): 50%, 60%, 70%, 85%, 95%, 100% and dried by leaving the specimens at room temperature for 24 hours. After drying, and before examination in the SEM, the specimen surfaces were rendered conducting by applying thin layers by vacuum evaporation of 100-300 Å gold with an ion sputter coater, and viewed with a JEOL JSM-6610 LV scanning electron microscope, at seven...
magnifications: X20, X30, X100, X500, X1000, X3500, and X10000. The photomicrographs were described. Representative electron micrographs were selected for presentation in this paper.

Results

The abraded areas appeared as cervical notches or depressions with smooth surfaces and fairly well-defined margins. In some teeth, horizontal furrows were noted and generally appeared smooth (Figure 1). In the abraded areas which were limited to the enamel surfaces, most of the enamel surfaces appeared uniformly smooth and showed presence of horizontal, vertical, and oblique scratches (Figure 2). In the abraded areas which were deep and extended into the dentin, dentinal tubules were exposed and could be observed

![Figure 1](image1.png)

**Figure 1** The abraded area is characterized by a horizontal cervical notch with a sharply defined margin and a smooth surface. Note two horizontal furrows (X20).

![Figure 2](image2.png)

**Figure 2** An enamel surface appears uniformly smooth and shows presence of horizontal, vertical and oblique scratches (X500).
in oblique and longitudinal sections (Figure 3). In some areas, dissolution of enamel rod ends gave the enamel surface a honeycomb appearance (Figure 4). Dissolution of prism cores and boundary regions could be clearly observed at higher magnification (Figure 5). In other areas, the dentin surfaces appeared rough with numerous openings of dentinal tubules. Parallel linear scratches arranged in various directions were also noted (Figure 6). Dential tubules showed a variation in the diameter of the openings. Some of the openings were patent, some were narrowed and some were completely obliterated (Figure 7 to Figure 10).

Figure 3  In the upper half of the field, an enamel surface appears smooth. In the lower half of the field, a large and deep area shows dentinal tubules in oblique and longitudinal sections (X30).

Figure 4  An area shows a honeycomb appearance due to dissolution of enamel rod ends. Dentinal tubule exposure is seen at the bottom of the field (X500).
In a few areas at low magnification, the dentin surface had a globular appearance, and holes from the openings of dentinal tubules (Figure 11). At higher magnification, the opening of the dentinal tubule was surrounded by a dentin matrix which consisted of a network of collagen fibers (Figure 12). In one tooth, two vertical fissures were seen in the abraded area (Figure 13 and Figure 14).

**Discussion**

In this study, the abraded enamel surfaces...
appeared uniformly smooth and showed presence of horizontal, vertical, and oblique scratches (Figure 2). These scratches are likely to result from abrasion. Horizontal scratches can result from horizontal toothbrush movements and vertical scratches can result from vertical toothbrush movements. Oblique scratches are likely to be the result of oblique toothbrush movements. It is possible that furrows result from prolonged unidirectional abrasion or a combination of abrasion and erosion. These findings are in agreement with previous reports. In this study, in the abraded areas which were deep and extended into the dentin, dentinal tubule exposure was seen (Figure 3). In some areas, enamel rod ends were

![Figure 7](image-url)  
**Figure 7** Numerous openings of dentinal tubules are seen at top. No openings of dentinal tubules are seen at bottom. Note several parallel oblique scratches (X500).

![Figure 8](image-url)  
**Figure 8** Dentinal tubules show variation in the diameter of the openings, some of which are patent and some are occluded (X1,000).
dissolved and the enamel surfaces showed honeycomb appearances (Figure 4 and Figure 5). In other areas, the dentin surfaces appeared rough with numerous openings of dentinal tubules (Figure 6). These findings show evidence of erosion which are similar to those reported in the literature.\textsuperscript{9,10} Parallel linear scratches arranged in various directions were also noted in the rough dentin surfaces (Figure 6). This finding indicates a combination of abrasion and erosion. Dentinal tubules showed a variation in the diameter of the openings, from patent to completely obliterated (Figure 7 to Figure 10). This finding agrees with the literature.\textsuperscript{10} In one area at high magnification, an opening of the dentinal tubule was surrounded by a dentin matrix, consisting of a network of collagen fibers, which were retained after

**Figure 9** Most of the dentinal tubules show narrowed to completely occluded openings. Note several parallel oblique scratches (X1,000).

**Figure 10** Patent, narrowed and completely occluded openings of dentinal tubules are clearly seen (X3,500).
erosion, or resulting from dissolution of inorganic matrix of the dentin (Figure 12). This study shows evidence of microfractures characterized by presence of two vertical fissures (Figure 13 and Figure 14). Cracked areas, as observed in this study, have been reported to be the result of abfraction. It is also possible that these cracks result from forces related to extraction, or alternatively, they can represent drying artefacts. The term abfraction is used to describe a special form of wedge-shaped defect at the cementoenamel junction of a tooth. Such lesions are hypothesized to be the result of eccentrically applied occlusal forces leading to tooth flexure rather than to be the result of

Figure 11 In some area, the dentin surface has a globular appearance, and holes from the openings of dentinal tubules (X3,500).

Figure 12 The opening of the dentinal tubule is surrounded by a dentin matrix which consists of a network of collagen fibers (arrow) (X10,000).
abrasion alone. As the scientific basis of the tooth flexure theory is not yet sufficiently explored, more research is needed for a better understanding of this process.¹

In this study, based on ultrastructural assessment of a sample of extracted teeth, it appears that abrasion, erosion, and abfraction are common associated etiologic factors in the formation of NCCLs.

This study was a SEM study of abrasion. A limitation of this work is the relatively small number of specimens. Further studies are needed to confirm the etiologies of the various features observed in this investigation.

This study showed that the abraded enamel surfaces appear smooth with a variable number of parallel scratch marks which are

![Figure 13](image13.png)

**Figure 13** Two vertical fissures (arrows) are seen in the abraded area (X100).

![Figure 14](image14.png)

**Figure 14** A few scattered openings of dentinal tubules (arrows) and a linear fissure due to separation of dentin are clearly seen (X1,000).
arranged in various directions. The abraded dentin surfaces show linear scratches similar to those of the abraded enamel and contain numerous openings of dentinal tubules. Evidence of erosion and abfraction is found.

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