Scanning electron microscope characterization of noncarious cervical lesions in human teeth

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Abstract

Aims: Abfraction is a theoretical process whereby occlusal forces create microfractures in enamel and dentin along the cervical area and predispose it to erosion and abrasion, forming noncarious cervical lesions. However, the theory is not yet proven. The aim of this study was to elucidate the role of abfraction as an etiology of these lesions.

Materials and Methods: Ten human premolars with these lesions from 10 patients requiring tooth extraction, one tooth from each patient, were used in this study. After extractions, all teeth were stored in 10% formalin until required, then prepared routinely for scanning electron microscopy.

Results: In all 10 teeth, at low magnification, noncarious cervical lesions appeared as crescent-shaped lesions. The upper edges of the lesions were on the enamel surfaces and their lower edges were on the cemental surfaces. In four teeth, the lesions showed evidence of microfractures characterized by the presence of fracture lines and fracture surfaces. In addition, in the first tooth of these teeth, the surface was also covered by a network of poorly fixed collagen fibers. In the third tooth, linear scratches, the openings of the dentinal tubules, a dentin matrix which consisted of a network of poorly fixed collagen fibers, and numerous dentinal tubules were also observed. In the remaining six teeth, they showed linear scratches, and the presence of the dentinal tubules or the exposed collagen fibers.

Conclusions: It appears that abrasion and erosion are associated etiologic factors in forming noncarious cervical lesions and an ultrastructural finding that supports the abfraction theory of these lesions is observed.

Keywords: Abfraction, human teeth, noncarious cervical lesion, scanning electron microscopy

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INTRODUCTION

Noncarious cervical lesions are defined as the loss of cervical tooth substance in the absence of dental caries. Erosion, abrasion and attrition have all been associated with their formation. Abfraction is another possible etiology and involves occlusal forces, producing cervical cracks that predispose the surface to erosion and abrasion.[1]

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Clinically, the main features of the noncarious cervical lesions on permanent anterior teeth are "shallow," "concave," "wedge-shaped," "notched" and "irregular."[2] The teeth affected most often are the lower premolars and the prevalence and severity of the lesions increases with age.[3] The number and size of lesions increases with age, lesions are more common on the facial aspects

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of teeth and the formation of lesions appears to be multifactorial with lesion shape not being a predictor of etiology.[4]

There are several etiological factors correlated with noncarious cervical lesions, among which are: Tooth brushing method (abrasion), bruxism (abfraction) and eating behaviors (erosion).[1,5,6] Significant noncarious cervical lesions are created through horizontal brushing with common commercial toothpaste, while brushing with water only did not create these cervical lesions.[7] Romeed *et al*.[8] investigated the biomechanics of abfraction lesions in upper canine teeth under axial and lateral loading conditions using a three-dimensional finite element analysis and found that stresses were concentrated at the cemento-enamel junction in all scenario. Abfraction is a theoretical process whereby occlusal forces create stresses in enamel and dentin along the cervical area and predispose it to erosion and abrasion.[1] However, the theory is not yet proven.[9] The available evidence is insufficient to establish whether abfraction is an important contributor to tooth wear *in vivo*.[6]

The diagnosis of abfraction plays a very important role in the management of the patients.[9] The value of restoring noncarious cervical lesions, where indicated, is unclear and occlusal adjustment to increase the retention of restorations placed to restore these lesions or to halt lesion progression cannot be supported.[4] Clinical aspect importance of noncarious cervical lesions is at most important to be detected for early intervention and treatment modalities as options during the progression of the disease.[10]

Scanning electron microscopy (SEM) may be a better method to apply to elucidate the surface changes of the noncarious cervical lesions in order to understand the etiopathogenetic aspect of the lesions. A review of the literature has revealed that several related studies were reported as follows:

Nguyen *et al*.[11] reported that it appears that abrasion and erosion are common associated etiological factors in the formation of noncarious cervical lesions. Daley *et al*.[12] reported that the cervical wedge is shaped by interactions between acid wear, abrasion and dentinal sclerosis. No histopathologic evidence of abfraction was found. Michael *et al*.[13] and Levrini *et al*.[14] reported that SEM showed a broad range of ultrastructural features of non-carious cervical lesions which were the evidences of abrasion, erosion and abfraction, providing valuable insights into their complex, multifactorial etiology.

In the present study, the surface characteristics of noncarious cervical lesions were examined to elucidate the role of abfraction as an etiology of these lesions by SEM.

MATERIALS AND METHODS

A sample of 10 extracted human premolars with noncarious cervical lesions were used in this study. These teeth showed various features of noncarious cervical lesions. Based on the morphologic classification of the noncarious cervical lesions proposed by Michael *et al*.[2] the tooth specimens were composed of one tooth with a concave lesion, two teeth with shallow lesions, three teeth with wedge-shaped lesions, two teeth with notched lesions and two teeth with irregular lesions [Figure 1].

The tooth specimens were derived from 10 patients requiring tooth extraction, one tooth from each patient, were used in this study. The teeth were collected from 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, IsoMet low-speed saw, Buehler, Illinois, USA. The teeth were cut in mesiodistal directions, immersed in 5.25% sodium hypochlorite solution, rinsed thoroughly in distilled water and then dehydrated in a series of graded ethyl alcohol (2 changes, 15 min each): 50%, 60%, 70%, 80%, 95%, 100% and dried by leaving the teeth at room temperature for 24 h. After drying, the teeth were mounted on aluminum stubs, coated with gold, thickness of 100–300 Å, with an ion sputter coater, and viewed with a JEOL JSM-6480 LV scanning electron microscope, Japan, at seven magnifications: ×40, ×200, ×1000, ×3000, ×5000, ×10,000 and × 20,000. The photomicrographs were described. Representative electron micrographs were selected for presentation in this paper.

Figure 1: Clinical picture of extracted premolars with noncarious cervical lesions. The lesions show various features at the cervical areas on the labial surfaces of the teeth: (1) Concave lesion. (2) Shallow lesion. (3) Wedge-shaped lesion. (4) Notched lesion. (5) Irregular lesion

RESULTS

In all ten teeth, at low magnification, noncarious cervical lesions appeared as curved shapes that were wide in the middle and pointed at each ends or crescent-shaped lesions and were concave with varying depths and sizes. The upper edges of the lesions were on the enamel surfaces and their lower edges were on the cemental surfaces [Figure 2].

In the first tooth, at low magnification, a buccal concave cervical lesion was observed. The floor of this lesion was smooth with some scattered nondescript granular debris. The surface of the enamel along the upper curved enamel edge appeared rough and irregular with a horizontal fracture line. The lower cemental edge was curved and flakes of cementum had fractured away to leave an irregular shallow depression at the right end of this edge. The fracture surface of the cementum appeared rough and irregular [Figure 3a]. At higher magnification, a granular lumpy texture was seen on the surface [Figure 3b and c]. In addition, at even higher magnification, the surface appeared to be covered by a network of poorly fixed collagen fibers of the cementum matrix [Figure 3d]. In the second tooth, at low magnification, a buccal wedge-shaped cervical lesion was seen. The floor of this lesion was smooth with some scattered nondescript granular debris on the surface. The surface of the enamel at the central part of the upper curved enamel edge appeared rough and irregular due to the fracture of the enamel. Two horizontal fracture lines were seen at left and right of this enamel edge. The fractured enamel surface appeared rough and irregular [Figure 4a]. At higher magnification, several horizontal fracture lines were seen on the surface of the enamel and the fracture surface appeared granular and lumpy [Figure 4b and c]. At even higher magnification, the surface was composed of the hydroxyapatite crystallites of the fractured ends of the enamel rods [Figure 4d]. In the third tooth, at low magnification, the wedge-shaped cervical lesion showed a smooth surface with a few oblique fracture lines [Figure 5a]. At higher magnification, one of the fracture lines was irregular and extended deep into the dentin and the adjacent enamel. Furthermore, the surface of the cervical lesion was smooth with numerous horizontal linear scratches which appeared to be parallel to one another [Figure 5b]. At even higher magnification, the linear scratches were arranged in various directions. There were scattered round to ovoid microholes that were the openings of the dentinal tubules [Figure 5c]. The surface of the lesion was covered by a dentin matrix which consisted of a network of poorly fixed collagen fibers [Figure 5d]. In another area of the lesion of this tooth, the surface of the lesion showed presence of linear scratches arranged in various directions. The linear scratches intersected with numerous dentinal tubules which were cut in longitudinal sections. The surface also contained some scattered nondescript granular debris [Figure 5e and f]. At higher magnification, the surface was covered by a network of poorly fixed collagen fibers of the dentin matrix [Figure 5g and h]. In the fourth tooth, at low magnification, the enamel edge of the buccal notched cervical lesion had fractured away to leave two small fragments which were still attached to the fracture plane. The fracture surface was rough and granular. The cervical lesion contained several vertical

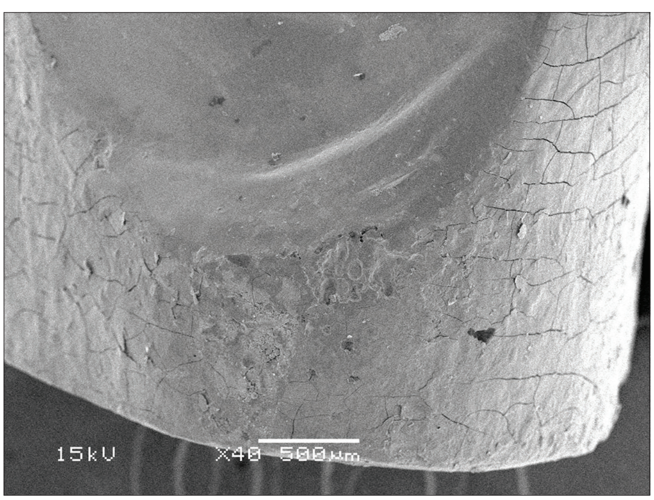

Figure 2: At low magnification, each noncarious cervical lesion appears as a curved shape that is wide in the middle and pointed at each end or a crescent-shaped lesion. The upper edge of the lesion is on the enamel surface and its lower edge is on the cemental surface

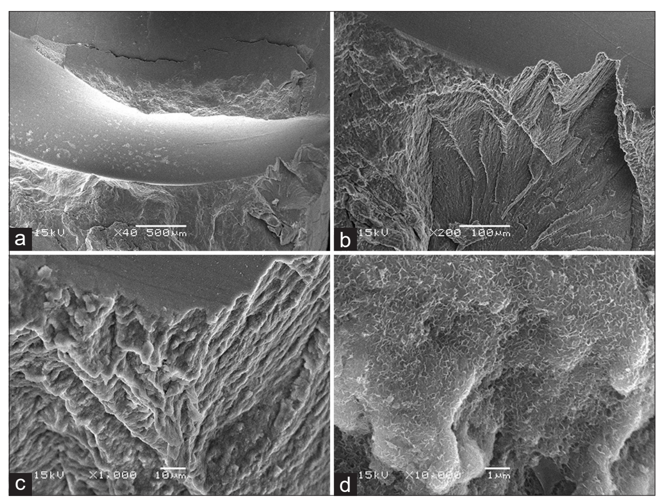

Figure 3: (a) At low magnification, a premolar tooth with a buccal concave cervical lesion. The floor of this lesion is smooth with some scattered granular debris. Along the upper curved enamel edge, the surface of the enamel appears rough and irregular with a horizontal fracture line. The lower cemental edge is curved and at right of this edge, flakes of cementum have fractured away to leave an irregular shallow depression. (b) The fractured cemental surface appears rough and irregular. (c) At higher magnification, a granular lumpy texture is seen on the surface. (d) At even higher magnification, the surface is covered by a network of poorly fixed collagen fibers

fracture lines [Figure 6a]. The fractured enamel showed enamel rods arranged in a fairly parallel fashion [Figure 6b]. At higher magnification, the fractured enamel was composed of enamel rods exposed longitudinally. Rods and interrod enamel were observed to contain hydroxyapatite crystallites [Figure 6c and d].

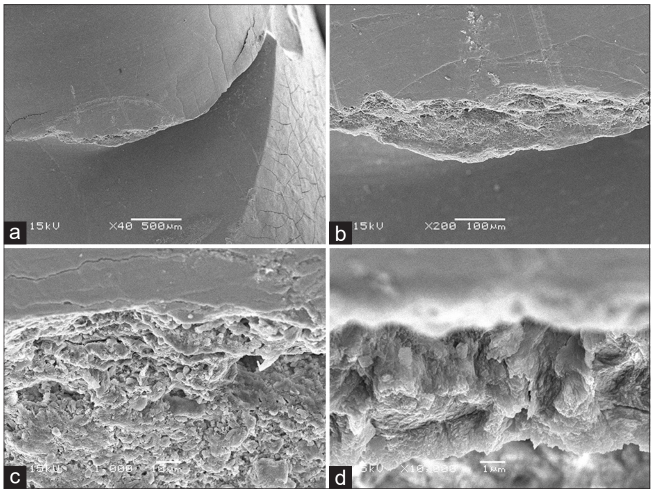

Figure 4: (a) At low magnification, another premolar tooth with a buccal wedge-shaped cervical lesion. The floor of this lesion is smooth with some scattered granular debris. At center of the upper curved enamel edge, the surface of the enamel appears rough and irregular due to the fracture of the enamel. A horizontal fracture line is seen at left of this enamel edge. (b) The fractured enamel surface appears rough and irregular. Several horizontal fracture lines are seen on the surface of the enamel. (c) At higher magnification, the surface appears granular and lumpy. (d) At even higher magnification, the surface shows the fractured ends of the enamel rods which are composed of hydroxyapatite crystallites

In the remaining six teeth, they showed linear scratches and the presence of the dentinal tubules or the exposed collagen fibers.

DISCUSSION

In four teeth of this study, in the first tooth, at low magnification, along the upper curved enamel edge, the surface of the enamel appeared rough and irregular with a horizontal fracture line and at the right end of the lower curved cemental edge, flakes of cementum had fractured away to leave an irregular shallow depression. The fracture surface of the cementum appeared rough and irregular [Figure 3a]. In this tooth, a microfracture was obviously seen. In addition, at higher magnification, the fracture cemental surface was granular and lumpy [Figure 3b and c]. The fractured cemental surface is covered by a network of poorly-fixed collagen fibers of the cementum matrix, indicating that it is the result of erosion or resulting from dissolution of inorganic matrix of the cementum and the erosion process apparently occurs in the oral cavity before this tooth was extracted. In the second and fourth teeth, the fractures of the enamel edges with fracture lines were also observed. The fractured enamel surfaces appeared

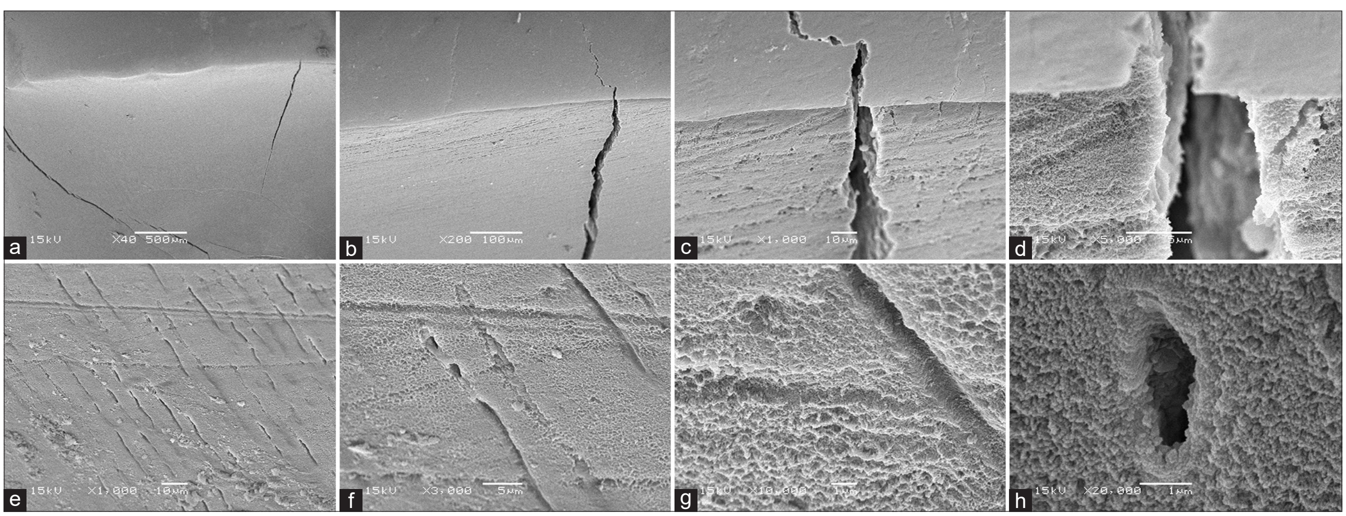

Figure 5: (a) At low magnification, the concave cervical lesion of another premolar tooth shows a smooth surface that contains a few oblique fracture lines. (b) One of the fracture lines is irregular and extends deep into the dentin and the enamel. The surface of the lesion is smooth with numerous horizontal linear scratches which appear to be parallel to one another. (c) At higher magnification, the linear scratches are arranged in various directions. There are microholes which are the openings of the dentinal tubules. (d) At even higher magnification, the surface of the lesion is covered by a dentin matrix which consists of a network of poorly fixed collagen fibers. (e) In another area of the lesion, the surface of the lesion shows presence of linear scratches arranged in various directions. At top, three horizontal linear scratches run parallel to one another. Numerous dentinal tubules in longitudinal sections are clearly seen. The surface also contains some scattered granular debris. (f) The linear scratches run from left to right and the longitudinally cut dentinal tubules run obliquely from top left to bottom right. The surface of the lesion is covered by a network of poorly fixed collagen fibers. (g) At even higher magnification, the poorly fixed collagen network is more clearly seen. (h) At highest magnification, an opening of a dentinal tubule is surrounded by a dentin matrix which consists of a network of poorly fixed collagen fibers

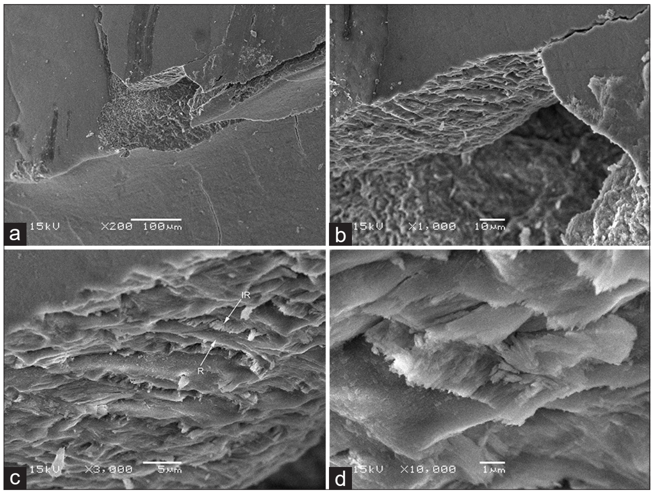

Figure 6: (a) At low magnification, the enamel edge of the buccal cervical lesion of another premolar tooth has fractured away to leave two small fragments which are still attached to the fracture plane. The fracture surface is rough and granular. The lesion contains several vertical fracture lines. (b) The fractured enamel consists of enamel rods arranged in a fairly parallel fashion. (c) At higher magnification, the fractured enamel is exposed longitudinally. Rods (R) and interrod (IR) enamel are observed. (d) At even higher magnification, the hydroxyapatite crystallites in rod and interred enamel are more clearly seen

rough and irregular [Figures 4a, b and 6a, b]. At higher magnification, the fracture surfaces showed fractured enamel rods which were composed of hydroxyapatite crystallites [Figures 4c, d and 6c, d]. Therefore, these two teeth show only ultrastructural evidences of microfractures. In the third tooth, at low magnification, the noncarious cervical lesion was notched with a smooth surface and the microfracture characterized by the presence of a few oblique fracture lines was clearly observed [Figure 5a and b]. At higher magnification, the surface of the cervical lesion was smooth with numerous linear scratches that were arranged in various directions associated with scattered small round to ovoid openings of the dentinal tubules [Figure 5c]. The surface of the lesion was covered by a dentin matrix which consisted of a network of poorly fixed collagen fibers [Figure 5d]. In another area of the lesion of this tooth, the linear scratches intersected with numerous dentinal tubules which were cut in longitudinal sections [Figure 5e]. The surface of the lesion was covered by a dentin matrix which consisted of a network of poorly fixed collagen fibers [Figure 5f-h]. In this tooth, the linear scratches result from abrasion. Horizontal scratches can result from horizontal toothbrush movements and vertical scratches can result from vertical toothbrush movements.

Oblique scratches are the result of oblique toothbrush movements. These findings agree with those of Nguyen *et al*.,[11] Michael *et al*.,[13] and Levrini *et al*.[14] The presence of the openings of the dentinal tubules and the longitudinally sectioned dentinal tubules is due to the erosive process that is in agreement with the findings of Michael *et al*.,[13] and Levrini *et al*.[14] In this study, the exposed dentin matrix on the surface of the lesion is found, this results from erosion or the dissolution of the inorganic matrix of the dentin and the exposure of the organic matrix (collagen fibers) of the dentin. In the remaining six teeth, the presence of the linear scratches results from abrasion and the presence of the dentinal tubules or the exposed collagen fibers results from erosion.

Microfractures characterized by the presence of fracture lines and fracture surfaces as observed in this study [Figures 3-6] are likely to be the result of abfraction. It is also possible that they may result from forces related to extraction, or alternatively, it can represent drying artifact.[13] However, in one tooth in this study [Figure 3], it shows ultrastructural evidence of a combination of a microfracture and erosion and it appears that the erosion process apparently occurs after the microfracture when the tooth is still in the oral cavity before the extraction of the tooth. Therefore, it is possible that abfraction may play a role in the formation of the noncarious cervical lesions.

CONCLUSIONS

A limitation of this work is the relatively small number of tooth specimens. Further studies are needed to establish whether abfraction is an etiology of noncarious cervical lesions. However, based on scanning electron microscopic assessment of a sample of ten extracted teeth in this study, it appears that abrasion and erosion are associated etiologic factors of noncarious cervical lesions. This study also shows an ultrastructural finding that supports the abfraction theory of noncarious cervical lesions, involving occlusal stress that produces cervical cracks that predispose the surface to abrasion and erosion. The occlusal stress may need to be taken into account to make a clinical diagnosis and give treatment to the patient with this lesion.

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Conflicts of interest

There are no conflicts of interest.

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