Scientific Article

The effects of acid-etching on enamel from different clinical variants of amelogenesis imperfecta: an SEM study

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Abstract

Purpose: *Successful bonding of resins to teeth affected by amelogenesis imperfecta (AI) may be highly dependent on how the enamel responds to acid etching. The aim of this study was to determine, using scanning electron microscopy (SEM), the types of etching pattern achieved with 37% phosphoric acid on dental enamel of 5 clinical variants of AI, namely, pitted hypoplastic, smooth hypoplastic, X-linked (male), X-linked (female), and hypomineralized.*

Methods: *A normal premolar and primary molar from two healthy patients were used as controls. The enamel was scanned before and after acid etching for 1 min. In the normal, control teeth, the three classical etching patterns were produced: type 1, in which the prism cores are preferentially removed; type 2, in which the prism peripheries are removed, and type 3 in which the removal of enamel does not relate to prism structure.*

Results: *In the normal primary molar, patterns of types 2 and 3 were generally produced. In the AI teeth, the effects of acid etching reflected the clinical variant of AI. All three etch patterns were observed in the enamel surrounding the pits in the pitted type of AI and in the bands of normal enamel in the female with X-linked AI, as well as in the hypomineralized variant. In contrast, no typical etch patterns could be detected in the enamel from the male patient with X-linked variant, as well as from the enamel affected by the smooth hypoplastic variant.*

Conclusions: *The lack of typical etching patterns in these variants may be the result of abnormal prism structure, or the standard etching time and/or acid concentration may be inappropriate for the abnormal enamel. The results of this study may have useful applications in the restoration of teeth affected by AI. (Pediatr Dent 20:1 37–42, 1998)*

Acid etching of enamel to create a surface suitable for bonding resins is now a cornerstone technique of clinical dentistry. Phosphoric acid at a concentration of 37% is now the most widely used acid in bonding techniques for esthetic restorations, fissure sealants, and splinting of teeth.[1-4] Acid etching of enamel results in many surface irregularities, which greatly increases the surface area for mechanical bonding, as well as its wetability, which enhances the flow of resin.[1-4]

The distinct morphological surface changes caused by acid etching have been clearly demonstrated by SEM.[4] In general, the surface modifications may be classified into three types of etching patterns.[4] In the type 1 pattern, a honeycomb appearance is produced by prism core material being preferentially removed, leaving the prism peripherally intact. In the type 2 pattern, a cobblestone effect is produced by the peripheral regions of the prisms being dissolved preferentially, leaving the prism cores intact. In the type 3 pattern, surface loss occurs without exposing the underlying enamel prisms. Although the relative significance of the etching patterns to bond strength is still unclear, it is likely that all three types contribute to clinical bonding on any one surface.[1]

While the etching patterns produced in normal enamel have been well described, little is known regarding the changes produced in abnormal enamel, and in particular, for developmental abnormalities such as amelogenesis imperfecta (AI). AI is a heterogenous group of inherited conditions affecting enamel, and shows prevalence rates ranging from 1:4000 to 1:14,000.[5-7] As the diagnosis and classification of AI based on molecular criteria[8-10] are yet to be determined, diagnosis of AI is usually based on clinical and inheritance criteria.[11-13] Witkop[7] suggested four broad categories of AI in his classification, namely, hypoplastic, hypocalcified, hypomaturation, and hypomaturation/hypoplastic with taurodontism, and included several subtypes dependant on inheritance patterns. In clinical practice, however, the lack of clear familial histories in the majority of patients often prevents definitive diagnosis of affected individuals into a particular subtype. Furthermore, extensive overlap of clinical pre-

sentations of the hypocalcified and hypomaturation types often make it extremely difficult to distinguish clinically between these two types of AI. Hence, for practical purposes, three broad clinical variants are generally recognized, namely, 1) hypoplastic, in which the enamel is deficient in quantity, 2) hypomineralized/hypomaturation in which mineralization/maturation of enamel is altered, and 3) X-linked, in which females classically display vertical striping of enamel, and males show an even loss of enamel.

Because a significant complication of AI is poor esthetics, an important aspect of clinical management is improvement of the appearance using bonded resins.[12–15] However, in many patients with AI, adhesive restorations may show high failure rates that are associated with inadequate bonding between the restorations and enamel. This area of restorative dentistry for AI has not been well investigated. As the bond between enamel and restoration is highly dependent on the enamel surface changes after acid etching, the examination of these surfaces may provide clues as to the potential success of the acid etch technique on the different types of enamel surfaces in AI variants. The aim of this investigation was to use SEM to examine the effects of acid-etching on teeth from patients with different variants of AI compared with normal teeth.

Methods

Naturally exfoliated primary teeth, as well as premolar teeth extracted for orthodontic reasons, were donated by patients. All the AI patients had been previously diagnosed by Dr. Seow using clinical and radiographic criteria.[12, 13] The teeth had been kept dry by the patients until the time of study. One tooth from a patient of each of the following clinical variants of AI was randomly selected for study: 1) pitted hypoplastic, 2) rough hypoplastic, 3) X-linked hypoplastic (female), 4) X-linked hypoplastic (male), and 5) hypomineralized. A total of five AI-affected teeth and two normal control teeth were used for the study.

The teeth were cleaned in an ultrasonic bath containing 0.5% sodium hypochlorite solution for 30 min to remove surface debris, and dried with compressed air. Half the facial surface of each tooth was masked with masking tape and the unmasked half treated with 37% phosphoric acid for 1 min, thoroughly washed with distilled water for another minute, and dried with compressed air. The teeth were then vacuum coated with 50 mm of silver and prepared for SEM in a Phillips 505 scanning electron microscope (Phillips Electronic Eindhoven, Netherlands).

Results

Control Teeth

A premolar extracted for orthodontic reasons from a healthy female was used as a control tooth for the AI-affected premolar. A naturally exfoliated mandibular primary first molar from a healthy male was used as a comparison for the AI-affected primary teeth.

Normal maxillary premolar–untreated

Low-power SEM showed a generally uniform surface with distinct perikymata showing as wave-like horizontal bands. Higher magnification showed the surface to be covered with many shallow depressions and a few micropits.

Normal maxillary premolar–acid etched

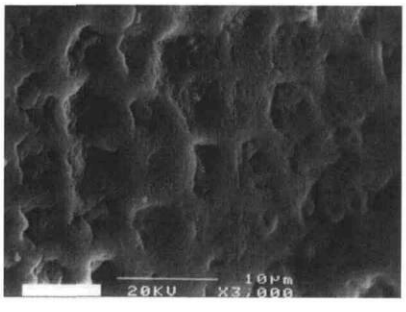
After treatment with acid, the etched area generally showed a type 1 pattern with the prism cores preferentially removed (Fig 1). However, in small, isolated areas the etching pattern was similar to that of type 2, i.e., prism peripheries were preferentially removed. A type 3 etching pattern (general removal of tooth structure without exposing prism structure) was also observed in other isolated areas.

Normal primary mandibular molar–untreated

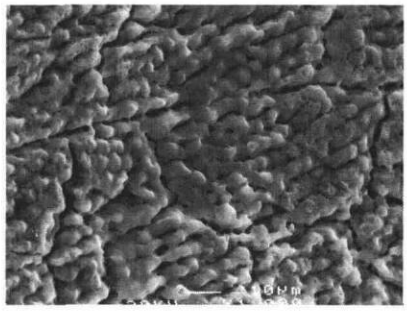
Rounded enamel rod endings were faintly visible on the surface of the normal primary molar, and gave it a uniformly speckled appearance. Apart from a few scratches, the untreated enamel surface was generally unremarkable.

Normal primary mandibular molar–acid etched

Acid etching generally produced a type 2 pattern.



◄ **Fig 1. Facial surface of normal premolar after treatment with phosphoric acid. Type 1 etch pattern in which the prism cores were preferentially removed was generally observed. Mag. x3000**



► **Fig 2. Facial surface of normal primary molar treated with phosphoric acid. Type 2 etch pattern was predominantly present. Mag. x1000**

In some isolated areas, the removal of tooth mineral around the prism borders appeared more extensive, leaving behind irregular clumps of fractured sheets of enamel prisms.

Hypoplastic pitted AI

Clinically, all permanent teeth of the patient showed many round, pin head-sized pits, which were concentrated mainly on the occlusal half of the facial and lingual surfaces.

Maxillary premolar–untreated

In the untreated surface, the pits appeared round or elongated oval under low-power SEM, arranged linearly, and surrounded by apparently normal enamel (Fig 3a). At high magnification, the pits were clearly demarcated as depressed areas containing rough, dysplastic enamel and organic material. The enamel surface in the cervical parts of the tooth appeared to be normal, although containing a few pits.

Maxillary premolar–acid etched

After acid etching, the enamel surrounding the pits generally showed mixture of either type 1 or type 2 patterns (Fig 3b). In other isolated areas, the pattern of etching was generally that of type 3.

Smooth, hypoplastic AI

In this patient, the entire primary dentition showed thin enamel which appeared extremely abraded.

Primary mandibular first molar–untreated

The untreated tooth surface of the primary first molar tooth showed a generally unremarkable and relatively smooth surface (Fig 4a).

Primary mandibular first molar–acid etched

After acid etching, the enamel showed a generally uniform fibrillar surface, without any of the classical features of etched enamel (Fig 4b).

X-linked Hypoplastic (Male)

Clinically, the entire primary dentition of the patient showed thin enamel, of normal color, and appeared smooth on the surface.

Primary maxillary incisor–untreated

Low-power SEM of a primary maxillary incisor from this patient showed extensive surface loss of enamel from abrasion. Higher magnification showed the intact parts of the enamel surface to be relatively smooth (Fig 5a).

Primary maxillary incisor–acid etched

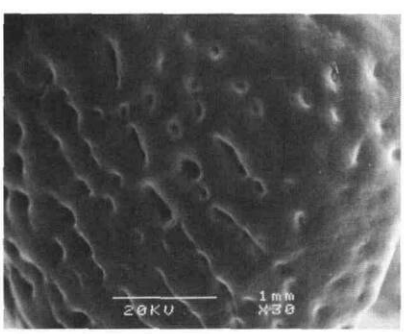
In the areas where intact surface enamel was present, acid etching showed patchy loss of surface tooth structure without evidence of etching patterns (Fig 5b).

X-Linked Hypoplastic (Female)

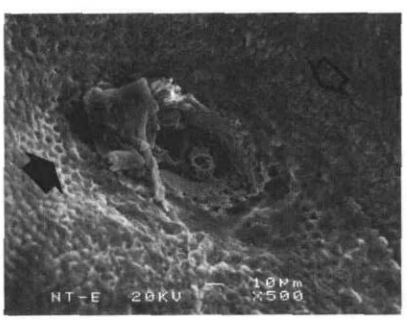
The primary dentition of this patient was heavily restored with amalgam and showed areas of extensive breakdown. The enamel appeared rough and grooved.

Primary maxillary first molar–untreated

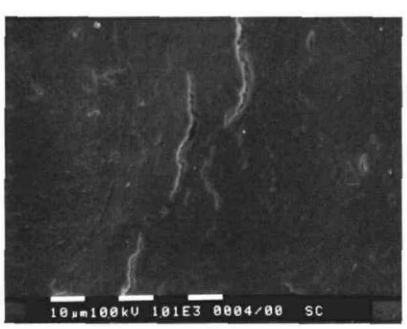
Low-power SEM showed alternating bands of relatively smooth, normal-appearing enamel inter-



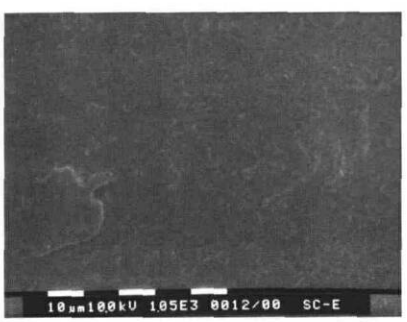
◀ Fig 3a. Untreated facial surface of premolar affected with pitted hypoplastic AI. The pits were mainly concentrated on the occlusal halves of the facial and lingual surfaces. Mag. x30



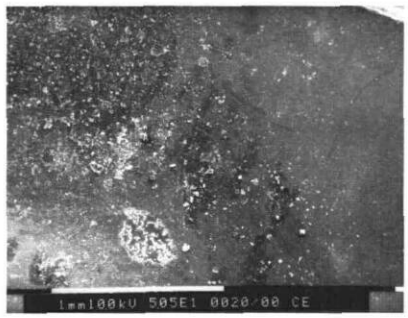
▶ Fig 3b. Facial surface of premolar affected with pitted hypoplastic AI after treatment with phosphoric acid. In the center is a large oval pit. Filled arrow shows area of type 1 etch pattern. Open arrow shows area of type 2 etch pattern. In the areas immediately adjacent to the pit, a type 3 etch pattern was found. Mag. x500



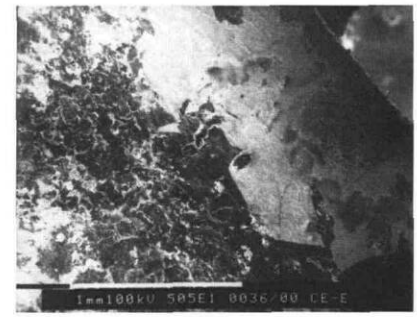
◀ Fig 4a. Untreated facial surface of primary molar affected with the smooth hypoplastic variant of AI. Apart from a few narrow linear depressions, the surface was generally unremarkable. Mag. x1000



▶ Fig 4b. Facial surface of primary molar affected with the smooth hypoplastic variant of AI after treatment with phosphoric acid. The enamel shows a uniform fibrillar surface without any of the classical features of etching. Mag. x1000



◀ **Fig 5a. Untreated facial surface of a primary incisor from a male affected with X-linked AI. The right side of the figure depicts an area of relatively smooth, intact surface, wheras the left side shows areas of abrasion with a granular appearance and shallow grooves and pits. Mag. x500**



▶ **Fig 5b. Primary incisor from a male affected with X-linked AI after phosphoric acid treatment. On the right, there was patchy loss of surface enamel with no etch pattern. On the left, which had partial loss of surface enamel, there was irregular removal of tooth structure (type 3 etch pattern). Mag. x100**

spersed with abnormal, granular, and rough enamel. Higher magnification of the abnormal areas showed a complex pattern of interconnecting rounded ridges separated by furrows (Fig 6a) containing rough granular enamel and small pits (Fig 6b).

Primary maxillary first molar–acid etched

Acid etching of the surface revealed a variety of etching appearances. In the bands of smooth normal enamel, a type 2 etching pattern predominated (Fig 6c). In areas of abnormal granular enamel, there was irregular removal of tooth structure without definite etching patterns.

Hypomineralized AI

A premolar was available from a female who had been diagnosed as having hypomineralized variant AI. Clinically, both primary and permanent teeth of the patient appeared yellow-brown, and showed areas of posteruptive fracture and abrasion.

Maxillary premolar–untreated

Fig 7a shows the intact areas of the facial surface. Higher magnification of this area showed the presence of many irregular, shallow pits and fine cracks.

The mesial half of the facial surface showed a large area of partial enamel loss. SEM of the fractured enamel in this area revealed a rough surface containing irregular patches of rough, granular enamel (Fig 7b). In the vertical parts of the fractured enamel surface, irregular, longitudinal prism structure was observed (Fig 7c).

Maxillary premolar–acid etched

Acid etching of the enamel surface with phosphoric acid produced a random mixture of the three classical etching patterns.

Discussion

As the failure rates of adhesive restorations in AI may be high, the question often arises as to whether this type of dental enamel may be successfully etched. The present study addresses this important clinical issue in five clinical variants of AI, namely, pitted hypoplastic, smooth hypoplastic, X-linked (female), X-linked (male), and hypomineralized, using extracted premolar and exfoliated primary teeth.

The common features of normal enamel, as well as the abnormal enamel in AI, have been described in previous publications.[15–23] Our results on the untreated surfaces of the different variants of AI showed many of these abnormalities. However, there have been no previous studies comparing the effects of acid

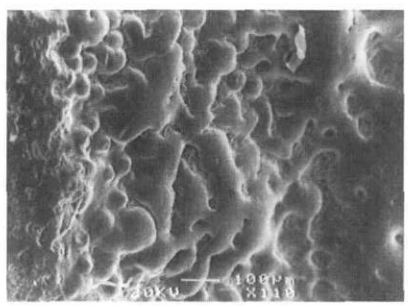


Fig 6a. Untreated facial surface of a primary first molar from a female affected with the X-linked variant of AI. The surface showed a complex pattern of interconnecting, rounded ridges separated by grooves. Mag. X110

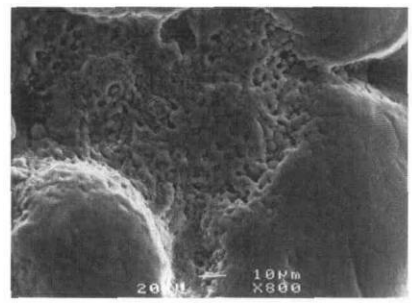


Fig 6b. Untreated facial surface of a primary first molar from a female affected with the X-linked variant of AI. Higher magnification of a furrow between two bands of normal enamel showed the presence of rough, granular enamel and small pits. Mag. X800

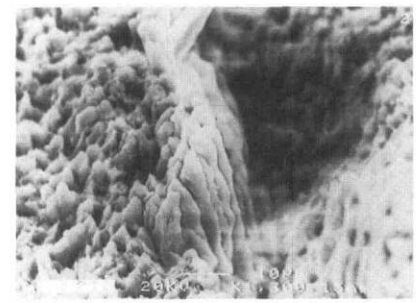


Fig 6c. Facial surface of a primary first molar from a female affected with the X-linked variant of AI after treatment with phosphoric acid. A type 2 etch pattern was generally observed in the bands of normal enamel depicted in Fig 6a. Mag. 1300

etching on enamel from different AI variants.

Our study shows that the three classical acid-etching patterns found in normal enamel may be produced in most of the clinical variants of AI, although each variant tended to show a predominant etch pattern. In the case of the pitted hypoplastic variant, the predominant etch pattern was that of type1, in which the prism cores were preferentially removed. In contrast, in the X-linked (female) variant, the main etching pattern was type 2, in which the peripheral boundaries of the prisms were dissolved. In the X-linked (male) variant, the etched enamel generally showed a type 3 pattern, in which the pattern of prism dissolution was irregular and did not appear to be related to prism structure. In the hypomineralized type of AI, all three types of etching patterns were found to be distributed equally.

In contrast, the enamel surface of the smooth hypoplastic variant did not change significantly after etching with phosphoric acid. It is possible that removal of a thin surface layer of enamel had occurred without production of etch patterns because of abnormalities in prism structure, such as the presence of a prismless layer. Alternatively, it is also likely that, because of smaller or weaker prisms, the length of time of the acid etch or the concentration of etchant may not be optimal to produce the classical etch patterns. These hypotheses are based on findings of previous studies which found abnormalities of prism structure, as well as reduction in enamel thickness by more than half compared with normal enamel in the smooth hypoplastic variant of AI.[18]

In the hypomineralized variant, the findings on the untreated surface such as micropits and cracks are similar to those noted in a previous report.[17] The fact that acid etching produced all the three classical etch patterns suggested that the prism structure in this variant may be generally normal, a finding which had been observed in a previous ultrastructural study on this AI variant.[19]

Thus, based on the findings of this study, acid etching for bonded restorations may be possible in hypomineralized AI despite the presence of hypomineralization abnormalities and morphological changes detected at the crystallite level.[19] In this regard, pretreatment of enamel with 5% sodium hypochlorite had been shown to be effective in removing excess protein from teeth affected by the hypomineralized AI, with enhancement of clinical bonding.[21] Of further interest is the recent finding of Wright et al.[24] that decreased mineral content and increased protein was found not only in hypomineralized AI, but also in the hypomaturation and hypoplastic variants. This suggests that pretreatment with sodium hypochlorite is likely to be of value in enhancing the effect of acid etching in cases of AI in general. However, our use of only 0.5% sodium hypochlorite in the ultrasonication bath was mainly for the removal of gross plaque and other organic debris present on the tooth surface. This low concentration of the reagent would be unlikely to have affected the tooth surface to significantly alter the effects of the acid etching as reported by Venezie et al.[21]

Our study thus showed that the presence or absence of useful etch patterns for bonding largely reflects the preoperative clinical appearance/morphology of the AI-affected teeth. In this regard, it is of interest to note the differences between male and female teeth in the X-linked variant. Because of the homozygous AI gene defect in the males, the tooth from the male patient showed uniformly abnormal enamel. When treated with acid, classical etch patterns did not appear, suggesting abnormal prism structure on the entire surface. In contrast, in the female patient, the untreated enamel presented in al-

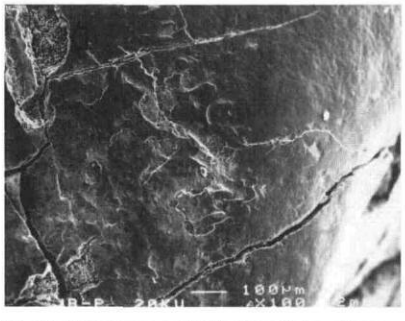


Fig 7a. Low-power SEM of facial surface of unteated premolar of patient affected by hypomineralized AI. A few cracks were present, most likely the result of extraction. On the left side (arrow) are areas of shallow depressions containing rough, granular enamel. Mag. X100

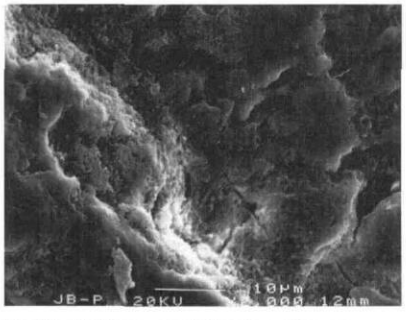


Fig 7b. Higher magnification of area showing surface loss of enamel in Fig. 7a. The surface showed rounded ridges and depressions which appear to contain shallow, irregular honeycomb outlines resembling a developing enamel morphology. Mag. X2000

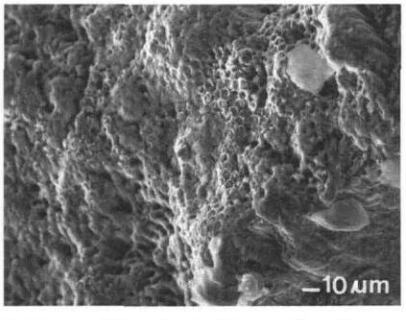


Fig 7c. Facial surface of premolar of patient affected by hypomineralized AI after treatment with phosphoric acid. A mixture of the three clasical etch patterns were observed on the surface. Mag. X2000

ternating bands of normal and abnormal enamel as a result of the Lyonization phenomenon which may be observed in X-linked conditions.[21] After treatment with acid, only the bands with normal enamel showed the typical etch patterns, suggesting that enamel with normal prism structure was found only in the bands containing normal enamel.

From a clinical viewpoint, the presence of the typical etch patterns in most variants of AI suggests that bonding of composite resins may be feasible in most patients with AI. High failure rates of adhesive restorations on AI-affected teeth compared with normal teeth could be due to factors other than bond failure, such as fractures within weak enamel or dentin supporting the restorations. Alternatively, total or partial loss of enamel may have occurred prior to placement of restorations, so that reduced areas were available for bonding.

Conclusions

1. In the pitted hypoplastic and hypomineralized variants of AI, classical etch patterns as seen in normal, control enamel may be produced after treatment with phosphoric acid
2. In the smooth hypoplastic and male X-linked variants, classical etch patterns are generally not observed, and in the female X-linked variant, these are seen only in the bands of normal enamel which alternate with the abnormal bands.

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