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. 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.

The distinct morphological surface changes caused by acid etching have been clearly demonstrated by SEM. In general, the surface modifications may be classified into three types of etching patterns. 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.

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 heterogeneous group of inherited conditions affecting enamel, and shows prevalence rates ranging from 1:4000 to 1:14,000. As the diagnosis and classification of AI based on molecular criteria are yet to be determined, diagnosis of AI is usually based on clinical and inheritance criteria. Witkop 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 Al. Hence, for
practical purposes, three broad clinical variants are gen-
erally 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 Al is poor
esthetics, an important aspect of clinical management
is improvement of the appearance using bonded res-

ins.12,13 However, in many patients with Al, adhesive
restorations may show high failure rates that are asso-
ciated with inadequate bonding between the restora-
tions and enamel. This area of restorative dentistry for
Al has not been well investigated. As the bond between
enamel and restoration is highly dependent on the
enamel surface changes after acid etching, the exami-
nation of these surfaces may provide clues as to the
potential success of the acid etch technique on the
different types of enamel surfaces in Al 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 Al compared with normal teeth.

Methods

Naturally exfoliated primary teeth, as well as pre-
molar teeth extracted for orthodontic reasons, were do-
nated by patients. All the Al patients had been
previously diagnosed by Dr. Seow using clinical and ra-
diographic 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 Al
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 Al-affected teeth and two normal con-
trol teeth were used for the study.

The teeth were cleaned in an ultrasonic bath con-
taining 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
Al-affected premolar. A naturally exfoliated mandib-
ular primary first molar from a healthy male was used
as a comparison for the Al-affected primary teeth.

Normal maxillary premolar–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 maxillary premolar–acid etched

Acid etching generally produced a type 2 pattern.
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 AL**

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 AL**

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-
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 post-eruptive 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.15–22 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 etching on enamel with hypomineralized variant AI.
etching on enamel from different Al 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 Al, 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 type 1, 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 Al, 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 Al.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 Al variant.19

Thus, based on the findings of this study, acid etching for bonded restorations may be possible in hypomineralized Al 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 Al, 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 Al, 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 Al 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 Al-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 Al 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-

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Fig 7a. Low-power SEM of facial surface of untreated premolar of patient affected by hypomineralized Al. 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 Al after treatment with phosphoric acid. A mixture of the three classical 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. 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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References