Clinical effects of reduction of acid concentration on direct bonding of brackets

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Etching of dental enamel surfaces with phosphoric acid is an accepted and widely used technique, not only in orthodontic treatment, but also in many other fields of dentistry. For many years, the recommended method for clinical use has been acid solutions and gels in concentrations of 35 - 50% applied for 1 minute. However, several recent reports have indicated that a reduction of acid concentration to 5% or less might not have adverse effects on the bonding process.

Soetopo et al.[1] measured the tensile bond strengths after etching with 2 - 60% phosphoric acid solutions and reported about similar values for 2% and 40% solutions. Gottlieb et al.[2] determined no significant differences between the tensile bond strengths after etching with 10 - 60% phosphoric acid solutions. Zidan and Hill[3] also found no significant difference in tensile bond strength after the 1-minute application of 2%, 5%, and 35% phosphoric acid solutions. The loss of enamel, however, was considerably higher at 35% than at 2%. Barkmeier et al.[4] reported that shear bond strengths obtained after etching with 5% acid were comparable to those obtained with a 37% acid gel. Legler et al.[5] found no significant effect of phosphoric acid concentration on the shear bond strengths after use of 37%, 15%, and 5% solutions. Bryant et al.,[6] however, recommended a 30-second application of 15% phosphoric acid for clinical use.

The aim of the present study was to evaluate the clinical results after etching with 37% and 2% phosphoric acid solutions and direct bonding of brackets.

Abstract

A total of 600 metal mesh-backed brackets were directly bonded to the anterior teeth of randomly selected orthodontic patients. Prior to bonding, enamel etching was carried out with 37% phosphoric acid on one side and with 2% phosphoric acid on the other side. The etch duration was 30 seconds. After 1 year no statistically significant difference was found between the failure rates of the two etching procedures. The assessment of the Adhesive Remnant Index (ARI) after debonding, however, revealed that the application of 37% acid resulted in significantly higher amounts of residual adhesive left on the teeth. The present study demonstrates that a phosphoric acid concentration of 2% can be sufficient for bracket bonding on anterior teeth.

Key words

Acid etching • Dental bonding • Dental enamel

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Table 1
Number and localization of brackets bonded and failures after one year

		37%		2%		Total	
		bonded	failed	bonded	failed	bonded	failed
Maxillary	Central	50	0	50	1	100	1
	Lateral	50	1	50	2	100	3
	Canine	50	1	50	1	100	2
		150	2	150	4	300	6
Mandibular	Central	50	0	50	0	100	0
	Lateral	50	0	50	0	100	0
	Canine	50	0	50	1	100	1
		150	0	150	1	300	1
Total		300	2	300	5	600	7

37% versus 2% : $\chi^2 = 1.30 < 3.84 = \chi^2_{0.05;1}$

Maxilla versus mandible : $\chi^2 = 3.61 < 3.84 = \chi^2_{0.05;1}$

Table 2
Number (n), mean ($\bar{x}$), and standard deviation (SD) of ARI values for 37% and 2% acid in maxilla and mandible

	37%			2%		
	n	$\bar{x}$	SD	n	$\bar{x}$	SD
Maxilla	150	2.08	1.14	150	0.49	0.90
Mandible	150	1.99	1.13	150	0.14	0.35
Total	300	2.04	1.13	300	0.31	0.69

Materials and methods

A total of 600 metal mesh-backed brackets (Ultratrimm brackets, Dentaurum, Ispringen, Germany) were directly bonded to the incisors and canines of consecutively treated and randomly selected patients in the author's orthodontic practice, always by the same operator (Table 1). Only patients with hypoplastic or missing anterior teeth were excluded from the study. The majority of the patients were children approximately 11 to 16 years of age. The investigation was limited to anterior teeth because premolars and molars were routinely banded.

The teeth to be bonded were cleaned with a rubber cup and a slurry of pumice and water. In the first 25 cases the teeth on the left side were etched with a 37% phosphoric acid solution and on the right side with a 2% phosphoric acid solution. In the remaining 25 cases, the sides were changed using 2% acid on the left side and 37% acid on the right side. The etching time was always 30 seconds.

The 37% acid was derived from Concise Orthodontic Bonding System (3M Dental Products, St. Paul, Minn). The 2% solution was obtained by diluting liquid 85% phosphoric acid.

The acid was applied to the teeth with a minisponge, and slightly agitated during the etching period. The adhesive used was Concise. After careful rinsing and drying, equal amounts of the two sealant components (resin A and B) were mixed and a thin film was applied to the etched enamel surface with a minisponge. Pastes A and B of Concise adhesive were mixed in a ratio 1 : 2 to allow a prolonged working time. Usually three brackets were bonded with one adhesive mixture to a canine and two incisors. Excess adhesive around the brackets was removed immediately.

The acid concentration of each case was recorded separately so that neither during the treatment nor at the time of debonding was operator aware of the concentration. The brackets used in this study were preangulated, pretorqued, and with a .018 inch slot. The test period was 1 year.

If a patient presented with a loosened bracket, the tooth, date, cause of failure (if known), and the Adhesive Remnant Index (ARI) were recorded. After removal of any remaining composite, a new bracket was bonded using 37% phosphoric acid for 15 seconds.

At the end of treatment, the brackets were debonded using an ETM bracket-removal plier (ETM Corporation, Monrovia, Calif) applied between the bracket base and the tooth. The amount of residual adhesive left on the tooth was assessed using the Adhesive Remnant Index (ARI) of Artun and Bergland.[7] This index is a four-point scale: 0 = no adhesive left on the tooth; 1 = less than half of the adhesive left on the tooth; 2 = more than half of the adhesive left on the tooth; 3 = all adhesive left on the tooth.

Differences in failure rates and ARI distributions were analyzed statistically by Chi-square tests.

Results

The number of brackets lost within the first 12 months is shown in Table 1. The difference between the failure rates of the two etching procedures was not statistically significant ($\chi^2 = 1.30 < 3.84 = \chi^2_{0.05;1}$). There were more loose brackets in the maxilla than in the mandible, but this difference was also without statistical significance ($\chi^2 = 3.61 < 3.84 = \chi^2_{0.05;1}$).

Figures 1 and 2 demonstrate the frequency distributions of ARI values in maxillary and mandibular teeth after bracket removal or bond failure. Debonding of the brackets from surfaces etched with 37% acid commonly resulted in considerable

amounts of adhesive left on the teeth, which is expressed by the prevalence of high ARI scores. On the other hand, debonding of brackets from the 2% group resulted mainly in ARI scores of 0 or 1, indicating little or no adhesive remained on the teeth. The differences are statistically highly significant in both the maxilla and mandible (χ^2 = 121.20 > 16.27 = $\chi^2_{0.001;3}$ and χ^2 = 177.69 > 16.27 = $\chi^2_{0.001;3}$).

Discussion

Successful bonding of orthodontic attachments depends on several factors: 1) conditioning of the teeth, 2) bonding material,[7,8] 3) size, shape, and quality of the attachment, 4) type of the teeth to be bonded,[9-12] 5) bonding procedure,[13,14] and 6) experience of the operator.[8,11] If one factor is reduced, the efficiency of the others becomes more important.

The present study demonstrates that a phosphoric acid concentration of 2% can be sufficient for the direct bonding of metal brackets to anterior teeth. The results are in accordance with the tensile bond strength measurements of Soetopo et al.[1] and Zidan and Hill,[3] which showed no significant differences between the 60-second etching with 35-40% and 2% phosphoric acid solutions. However, these in-vitro tests cannot be compared directly to the clinical situation, where bonded attachments are submitted to a variety of forces. Furthermore, bond strength measurements are usually carried out on ground, flat surfaces, which will produce values different from those of unground teeth.[15-16]

Assessment of the Adhesive Remnant Index[7] revealed remarkable differences in bond strength between the two acid solutions (Table 2). Bennett et al.,[17] Oliver,[18] and Kinch et al.[12] reported that the method of bracket removal influences the quantity of residual composite left on the teeth. In the present study, debonding was carried out by applying a shear force with a bracket removal plier at the bracket base/composite/enamel interface.

The removal of brackets bonded to surfaces etched with 2% acid resulted predominantly in ARI scores 0 and 1. The small amounts of adhesive left on the enamel could usually be scraped off with a scaler, followed by polishing of the teeth with a rubber cup and a paste of pumice and water. The clean-up procedure was thus much easier than in the 37% group, where the composite remnants had to be removed with a tungsten carbide bur under air cooling. The use of low phosphoric acid concentrations seems especially appropriate for bonding ceramic brackets where bond strength is higher than with metal brackets.[19-21]

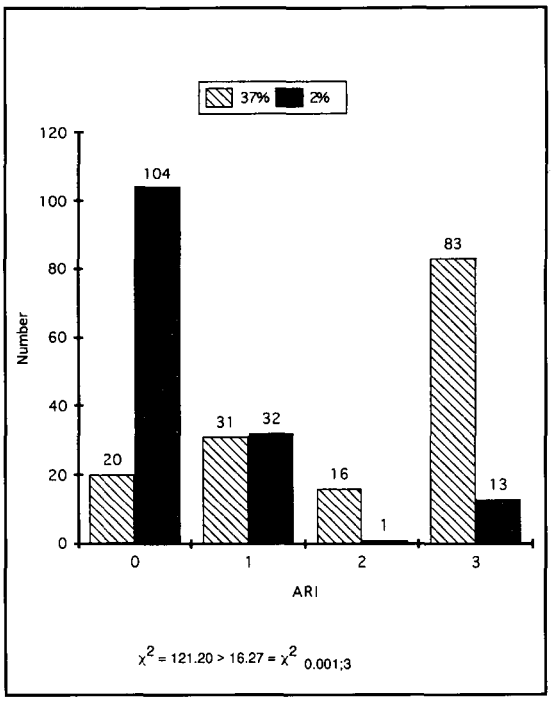

Figure 1

Figure 1 Frequency distribution of ARI values for 37% and 2% in the maxilla

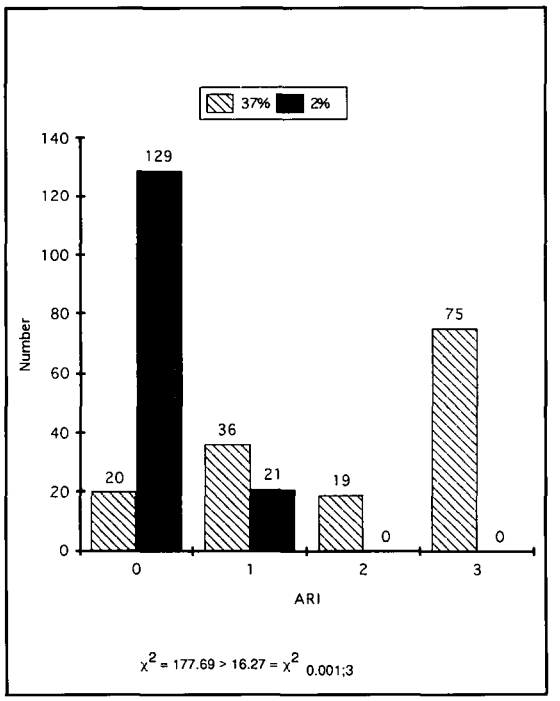

Figure 2

Figure 2 Frequency distribution of ARI values for 37% and 2% in the mandible

A recent study by Carstensen[22] illustrated the differences in the effects of various phosphoric acid concentrations on enamel surface morphology. Two percent acid was found to create considerably less roughening of the enamel in comparison with a 40% solution. The present investigation shows that the lower acid concentration resulted in lower ARI scores after debonding. Denys and Retief[23] concluded that adequate superficial rough-

ness and increased wettability of the etched enamel surface are more important in the bonding mechanism than resin penetration into the deeper porous zone.

Etching with 2% or 5% phosphoric acid seems to reduce the total loss of superficial enamel,[3,16,24,25] which is especially rich in fluoride.[26] Furthermore, the depth of acid penetration into deeper enamel layers seems to be reduced at low acid concentrations.[1] This could be favorable in preventing enamel decalcification around the attachments.

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