Air abrasion of enamel

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Enamel / Acid-etching / Air abrasion / Ultrastructure

ABSTRACT – Enamel conditioning (elimination of dental plaque and creation of an irregular surface) is an essential step before bonding of orthodontic brackets. The most popular procedure in our practice is bonding with resin which requires enamel etching in order to get enough shear bond strength. Many studies have tried to evaluate the effects of enamel bonding using the acid-etching procedure as well as the changes caused by detachment of brackets. Thanks to the development of other adhesives such as glass ionomer cements which chemically bind to the enamel, new enamel conditioning methods appeared, in particular sandblasting with aluminium oxide particles. This technique is a mechanical preparation of the tooth that avoids the harmful effects of acid products. By suitably choosing the parameters of sandblasting (pressure, time and quantity of powder), enamel loss is lower than with the acid-etch procedure and the surface of the enamel seems less affected. However the bond strength remains superior to the values required for treatment. The presented results indicate that enamel sandblasting can be considered as an alternative for the acid-etching technique currently used in orthodontic practice because it creates sufficient strength and respects enamel thickness better.

1. Introduction

In orthodontics, just as in restorative dentistry, preparation of enamel has become an indispensable stage before any bonding procedure can be carried out; in this step the dentist can remove the film that has become adhered to the tooth and create the micro-grooves in the enamel surface that are needed for good attachment of the bonding agent. Many studies have been devoted to determining what are the best methods and conditions for obtaining effective bond strength while preserving the integrity of the affected tooth.

Currently acid-etching is the most widely used technique to prepare enamel for bonding. However the strength of the acid agent can sometimes cause irreversible damage to the enamel surface. Various laboratories have devised and developed other methods of preparing enamel whose objective is to transform the enamel into a platform compatible with an effective outcome of bonding while causing as little harm to the dental organ as possible.

In this article we plan to evaluate one of those techniques: air abrasion. At the start it is important to outline the available information on the effects of etching with different acids on enamel surface. Then we shall review the results of a study analyzing the different parameters of air abrasion and the variations of its action on and depth of penetration of enamel. Finally, we shall examine the force of the bond strength achieved with resin-modified glass ionomer cement (RMGIC) in different types of enamel preparation in order to determine whether or not enamel air abrasion constitutes a credible alternative to acid-etching.

2. Effects of enamel preparation using demineralizing agents

Because dental enamel is a highly mineralized substance it is quite susceptible to attack by solutions like orthophosphoric acid. And, owing to the heterogeneity of its surface the extent to which enamel dissolves varies widely. As a result the irregularity of the transformed field encourages solid anchorage of the bonding resin. For several years...
Researchers have attempted to obtain equally effective bonding results with new methods while conserving a maximum amount of dental tissue. In this framework, proposals for pre-treatment with maleic, polyacrylic and other acid solutions as well as for air abrasion have abounded.

But for every suggested method, the objective is the same, to create retentive micro-indentations from 5 to 10 μm deep, which will allow the bonding agent to penetrate into the enamel enough to achieve mechanical retention by imbrication between the enamel and the bonding material thus forming a hybrid layer.

Researchers have experimented with a variety of acids, including hydrochloric, citric and formic, for use in etching enamel but orthophosphoric remains the most widely used.

Buonocore [3] was the first to describe this technique in 1955 when he used it to seal enamel pits and fissures to protect them from becoming sites of decay. Because these organic plastic sealants did not establish a chemical bond with the enamel, he proposed etching the enamel with acid so as to create adhesion based on mechanical attachment. However the major impact of this work was its application to the development of adhesive restorative techniques. Later, in 1964, Newman [12] proposed extending the acid-etching technique to orthodontics as a means of bonding brackets directly to teeth.

2.1. Effect of etching with orthophosphoric acid on the enamel

We shall review four aspects of the consequences of applying this acid to enamel:

– the ultrastructure,
– the depth,
– the effects on pulpal tissue,
– the strength of adhesion and the tearing away of enamel substance during the removal of attachments.

2.1.1. Ultrastructure

Silverstone [16] described three types of the histological architecture of enamel:

– Type 1 is the architectural type most frequently encountered. With it, acid primarily reaches the heart of the enamel prisms leaving the periphery and the inter-prismatic substance unaffected. The zones that are dissolved have a diameter of 3 μm. The resultant over-all appearance of treated surface resembles a bee hive (Fig. 1).

– Type 2 is the type where the periphery of the prisms is altered by acid action while the intra-prismatic substance is left intact. The acid works along the entire length of certain prisms thus creating variation in shape from prism to prism (Fig. 2).

– Type 3 corresponds to a chaotic mode of acid dissolving where the inter- and the intra-prismatic substances are both altered. Here the enamel surface is very little changed, adopting neither of the configurations of the first two types.
Figure 3
Enamel structure after acid-etching. (a) 10 μm lost (aprismatic); (b) 20 μm dissolved prisms; (c) 20 μm porous enamel; (d) healthy enamel.

2.1.2. Depth
According to Goldberg [7], enamel is composed of three zones (Fig. 3):

- a first zone approximately 10 μm deep which contains aprismatic enamel,
- a second zone underlying the first about 20 μm in depth, which is porous, and whose histological variability accounts for the different changes in shape produced by etching that Silverstone [16] described,
- a third zone, also some 20 μm deep, which is porous but does not have the histological variations of the region above it into which prolongations of the bonding resin can penetrate.

2.1.3. Effects on pulpal tissue
According to Auther [1], after acid application and the chemical demineralization it causes, changes occur not only in the enamel but also in underlying dentinal and pulpal tissues. Chemical disturbances characterized by a phosphorous wave are set up that reaches the pulp thirty days later. After 36 days, equilibrium is re-established on the etched surface while the deeper areas continue to be affected.

2.1.4. Bond strength and enamel loss in removal of attachments
Bond strength can be defined as resistance of attachments to a dislodging force exerted by appliance activations during treatment and the impact of mastication and of pernicious habits. At the end of treatment, orthodontists attempt, of course, not to inflict any iatrogenic harm to dental tissues as they remove appliances that could affect enamel prisms or ceramic substrates.

Osorio, et al. [14] cites the work of Reynolds in asserting that a minimal adhesive strength of 6 to 8 MPa is necessary and sufficient. However, all recent studies testing bond strength of composites or of resin-modified glass ionomer cement (RMGIC) after enamel preparation with acid-etching showed values considerably higher than what is needed during orthodontic treatment carried out under normal conditions. Hitmi et al. [9], for example, have reported work that demonstrates such findings as can be seen in Figure 4.

Furthermore, it is possible to measure the amount of enamel still clinging to the backs of brackets after their detachment as well as the quantity of bonding agent remaining on tooth surfaces and, by
assessing these two indices, determine the true extent of enamel loss caused by bracket removal:

– Qualitative and quantitative analyses of debonding from an enamel base can provide measurements to key into the Enamel Detachment Index (EDI) as shown in Figure 5a. The EDI presents the quantity of enamel remaining on the back of the bracket.

– An analysis of the tooth bonding interface calculates the amount of bonding residue in the Adhesive Remnant Index (ARI) as shown in Figure 5b. The more bonding residue is found, the higher the ARI reading will be.

In his work, Sorel, et al. [19, 22] examined the bases of Discovery brackets (Fig. 6a) removed from initially etched enamel surfaces after having been placed with composite resins. Their photographs show enamel adhering to the bases of the debonded brackets they examined (Fig. 6b). Note that these debonding zones frequently consist of a mixture of enamel/bonding agent, ruptured adhesive, and adhesive adhering to bracket bases.

Summing up, we can assert that acid-etching is accompanied by these undesirable side effects:

– an increased risk of caries development,
– adverse effects on the dentino-pulpal complex,
– an irreversible loss of enamel structure,
– debonding zones with residue, often mixed,
– long-term persistence of bonding agent on tooth surface.

Dentists are urged to follow these recommendations for the preservation of enamel integrity:

– adhere to the bonding protocol precisely,
– educate patients to oral hygiene,
3. Effects on the enamel of other acids used in etching

3.1. Maleic acid

Maleic acid [8], a relatively mild organic compound, when used in 10% solutions removes significantly less enamel than the frequently employed 35% orthophosphoric acid. The bond strength [10] after etching of 15 s with 35% orthophosphoric acid or 10% maleic acid, that is 15.3 MPa ± 5.5 and 15.8 MPa ± 5.9, is comparable.

Even though maleic acid causes considerably less demineralization of enamel during etching than orthophosphoric acid does, it still weakens enamel quality by its especial noxious effect on the superficial layer where fluoride is most highly concentrated.

3.2. Polyacrylic acid

It was Smith and Cartz, cited by Farquhar, et al. [5], who had the idea, in 1973, of creating retention on the enamel surface not by invading its integrity to create toe holds but by bonding chemically to it. When they tried this method after they applied a solution of polyacrylic acid containing sulfates to enamel they observed surface deposits of a white crystalline material that they identified as gypsum. From this discovery they formulated a crystal bonding technique that was based on a micromechanical interlocking of the gypsum crystals with the resin thus minimizing enamel damage in a method that paralleled the protocol of the orthophosphoric acid technique. In 1979 Smith and Maijer [17] began to sell a commercial polyacrylic solution that was withdrawn from the marketplace in 1986 because of studies that pronounced it unsuitable for routine clinical use. Since then, however, other commercial polyacrylic products have been introduced and are still being offered for sale (Fig. 7a and 7b).

In 1986 Smith and Maijer [18] conducted experiments that showed by chemical analysis of the calcium ions liberated after acid-etching with polyacrylic acid that the resultant enamel loss was one sixth of that caused by etching with a 50% solution of orthophosphoric acid. This can be accounted for by the rapid formation of crystals of hydrated calcium sulfate which reduce acid penetration and limit the liberation of calcium ions on the enamel surface. In addition, because it has a much lower atomic weight polyacrylic acid penetrates far less deeply into etched sites than orthophosphoric acid does.

Even though bond strength values of polyacrylic acid techniques are weak they do exceed or at least match those required for routine use without posing any risk to the integrity of enamel. They would, therefore, appear to be an attractive alternative for bonding of attachments to upper anterior teeth where high shearing bond strength is not routinely required. But as Reynolds, cited in the Osario paper [14], points out their minimal acceptable shearing bond strength would make them poor candidates for use in situations where attachments will be subjected to more intense forces.
As a result of these constraints, the use of polyacrylic bonding techniques is now usually limited to the placement of ceramic attachments and to improve the bond strength of glass ionomer cements.

By using polyacrylic acid practitioners can be assured they will damage the superficial enamel layer, which is rich in fluoride ions, as little as possible and risk little, or even no, long time retention of bonding residue on the tooth surface. They can also be confident that they will obtain bonding strength adequate for clinical purposes provided dislodging forces are not too high and that at the close of treatment they will be able to remove attachments easily and rapidly. In addition, at some time in the future polyacrylic acid bonding may offer the benefit of incorporating fluoride ions in its composition as an anti-plaque agent that would suppress caries development.

Still, polyacrylic acid shares the risk characteristics that are inherent in the employment of any acid, risks that would not accompany a purely mechanical retentive bonding approach. And it is this absence of a risk factor that makes the air abrasion preparation for bonding technique so attractive.

4. Preparing the enamel surface with air abrasion

4.1. History of the procedure

Using air abrasion to prepare enamel surfaces is by no means a recent concept. Robert Black, cited by Goldstein and Perkins [6], first proposed it in 1943, as a component of cavity preparation in restorative dentistry. Because it was a technique for adjusting internal dental tissues that was far more acceptable to patients, as well as dentists, than the time honored way of accomplishing the task with low speed rotary drills, air abrasion enjoyed considerable success in the forties and early fifties but was largely discarded with the introduction of the high speed air turbine handpiece.

But in 1993 Zachrisson [24] proposed the re-introduction of air abrasion as a preparatory step in bonding to gold, amalgam, and porcelain surfaces.

4.2. Principles and parameters of the use of air abrasion

4.2.1. Principles

Air abrasion is a technique for preparing enamel and other tooth surfaces that is mechanical, unlike acid-etching, which chemically dissolves some enamel hydroxyapatite crystals.

Air abrasion, or sand blasting, is the operation of forcibly propelling a stream of abrasive particles in a stream of dry air or water spray at high speed against a surface to roughen it or remove contaminants.

This technique is based on the theory of kinetic energy as defined in the formula:

$$Ec = \frac{1}{2}mv^2$$

– $m$: mass of particles so that $m = \varnothing v$, with $\varnothing$: density of the particle, $v$: volume of the particle so that $v = \frac{4}{3}\pi r^3$,
– $V$: velocity of ejection force (in relation to the pressure).

The harder the treated substance is, the higher is the velocity of the stream.

And, conversely, the softer the treated substance is, the lower is the velocity.

4.2.2. Working parameters

– The projected particles

These projected particles can be of different types and different sizes:
– small laboratory glass beads,
– aluminum oxide in three commercially available sizes, 29 μm, 50 μm, and 90 μm (Fig. 8a and 8b),
– sodium bicarbonate (baking soda) (Fig. 8c).
– Pressure

The pressure is usually regulated manually with the bar as the gradation scale.

– The quantity of powder

This is also regulated manually in most appliances.

– The nozzle (Fig. 9)

Nozzles with different size apertures are available. The smaller the ejection site or aperture is, the greater is the velocity of the stream, and, of course, the smaller and more concentrated the stream is, the greater are its power and its precision. In our clinical practice we use 0.8 mm nozzles, one with greatest opening, so that its surface action will be spread out and not pin-pointed.
The time length of application

Timing is of utmost importance in air abrasion. A study with a profilometer after abrasion application will show that the desired irregularities do not increase with increased time of blasting. However, with increased time there is an augmentation of damage to enamel crystals. Accordingly we recommend limiting air abrasion to 2 to 3 s per tooth.

4.3. Ultrastructure and depth obtained after air abrasion application

An in vitro study of the effects of air abrasion on surface enamel ultrastructure as well as the depth of the micro-indentations created, carried out for a doctoral thesis by Mehdi and Lurquin [11], is presented below. It analyzes the results of air abrasion with 29 \( \mu \text{m} \) particles of aluminum oxide.

4.3.1. Methods and materials

The buccal surfaces of eighteen recently extracted, restoration free bicuspid teeth that had been kept in a water bath were sectioned with a carborundum separating disc so these buccal surfaces would lie in planes parallel to the planes of the lingual surfaces. The eighteen teeth were divided into two groups:

- The surfaces of the teeth of the first group were planed with an abrasive disc and then polished with a rubber tip.
- The surfaces of the teeth of the second group were not adjusted in any way.

The surfaces of the teeth of the two samples were then covered with a lead leaf that had a 14 mm\(^2\) square central cut-out corresponding to the size of the base of a bracket. Then the surfaces of the two groups were subjected to air abrasion with aluminum oxide powder made up of 29 \( \mu \text{m} \) particles (Fig. 10). The nozzle of the instrument was held perpendicular to the surface at a 1 mm distance and moved back and forth across the buccal surface to sweep it in its entirety.

The sand blastings varied in three evaluated parameters, that is time, pressure, and amount of powder used. In Table 1 we sum up the different applications the two samples received.

The samples were then designated by the value of these three parameters, time, pressure and powder. Thus, sample 1 is called “2-4-4.” The samples were
Figure 11
(a) Measurement of the height of the profile Ry. (b) Measurement of irregularities at ten points Rz.

Table 1
Variables “time, pressure and quantity of powder” of the two samples.

<table>
<thead>
<tr>
<th>Sample</th>
<th>Time (in seconds)</th>
<th>Pressure (in bars)</th>
<th>Powder</th>
</tr>
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<td>2</td>
<td>4</td>
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</tr>
<tr>
<td>2</td>
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<td>9</td>
<td>10</td>
<td>2</td>
<td>2</td>
</tr>
</tbody>
</table>

then rinsed to remove any remaining grains of aluminum oxide.

Next we used the Mitutoyo® profilometer to assess the surfaces of group 1 that we had fixed with Lactona wax. This gave analysis of the indentations obtained. The following step was to examine the surfaces with a scanning electronic microscope (SEM) in order to assure that a concordance existed between the images obtained for the first group and those made from the second.

The objective of this step was, first, to determine the depth of the indentations created by the varying treatments and, second, to study the profile view and, in so doing, to measure:

- the average arithmetic changes in profile (roughness) Ra, that represents the arithmetic average of the absolute values of the deviations of each peak from the baseline;
- the maximum height of the profile Ry representing, in μm, the distance between the highest peak and the lowest peak of the tracing (Fig. 11a);
- the height of the irregularities over ten points Rz representing, in μm, the average height of the five highest points and the five lowest points of the tracing (Fig. 11b).

The samples taken from group 2 were examined under the scanning electronic microscope in order to observe the surface conditions created by each of the treatments.

4.3.2. Results

– Results obtained with the profilometer (Tab. 2)

These data show that surface conditions in fact depended on the three parameters that we varied, that are time, pressure and quantity of powder and that this variation occurred in relation to each of the variables (Fig. 12a to 12c).
We observed that the values Rz (height of the irregularities at 10 points) and Ra (average arithmetic profile deviation) increased with the time factor up to 6 s of exposure, then the curve was reversed and values decreased with time. This study also shows that an increase in pressure causes a considerable augmentation of the depths of the valleys as demonstrated by the finding that a pressure of 4 bars evoked the highest values irrespective of the duration of the air abrasion. Finally, the quantity of powder used did not seem to have much effect on the depth of the indentations although it did appear to play a role in determining the frequency of the peaks.

This data tends to show that an optimal arrangement of peaks and valleys is obtained from use of a precise value for time and pressure.

– Results obtained with the SEM

The pictures taken after examination under the scanning electronic microscope of the different samples in group 2 (Fig. 13a to 13d) show that for the samples treated with weak pressure for a short time impacts were fewer than they were for samples treated for a longer time with higher pressure. The enamel zones that were lightly or totally unaffected were, therefore, less and less visible when the variables time and pressure increased in value. After 6 s, moreover, no matter what the pressure was, observed indentations scarcely differed from those of other samples and it became quite difficult to distinguish between the samples.

We took other pictures at an angle of 180° (Fig. 14) that gave us an idea of the surface conditions but provided no information on the depth of the indentations created. It should also be noted that in every case, the enamel architecture was completely re-arranged; there were no profile characteristics that could be identified with the initial condition of the enamel.

4.3.3. Discussion

The objective of this study was to determine the ultrastructure of air abraded enamel. In addition, thanks to the use of the profilometer, it allowed us

<table>
<thead>
<tr>
<th>Sample</th>
<th>Direction of movement</th>
<th>Ra (μm)</th>
<th>Ry (μm)</th>
<th>Rz (μm)</th>
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<td>2-4-4</td>
<td>Vertical</td>
<td>2.72</td>
<td>15.20</td>
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<td></td>
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<td>1.46</td>
<td>14.35</td>
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<td>4-2-2</td>
<td>Vertical</td>
<td>0.86</td>
<td>7.81</td>
<td>4.27</td>
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</tr>
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<td>4-2-4</td>
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<td>0.86</td>
<td>7.94</td>
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<td></td>
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<td>23.08</td>
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<td></td>
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<tr>
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</table>
to determine the depth of the indentations obtained. However, this study, because of its very nature, had to be conducted in a manner that did not precisely reproduce clinical conditions. For instance, we had to flatten the buccal surfaces of the extracted teeth because in their natural curved state they could not have been measured with the profilometer. So the results we derived from its use probably differ slightly from those that would be found in every day clinical practice, if such measurements were possible.

After many analyses, we could find no treatment that led to loss of more than 100 μm of enamel, an amount that is not considered to be particularly damaging to the integrity of this outer tooth layer [13]. In effect, all the values we recorded in this study are considerably below this limiting value so we can conclude, with the commentaries of Resiner, et al. [15] in 1997 and Canay [4] in 2000 that air abrasion techniques do not inflict any important distress on enamel structure. Still, our study clearly shows that variations of the parameters time and pressure exert a substantial effect on the depth of the indentations obtained. Accordingly, we have shown that the practitioner can regulate the depth of the indentations created on enamel surface by maintaining precise control in adjustment of the variables that are indicated for manipulation of the air abrasion device.

Our study shows, in addition, that adding more powder to the abrasive stream has little effect on the cratering effect on the enamel; but, on the other hand, the time of exposure is a paramount parameter because the depth of the indentations steadily increases up to an exposure of 6 s at a pressure of 2 bars, after which it begins to decline. It would seem, then, that in increasing the time, the prepared flattened surface becomes less favorable for bonding and that a new layer of enamel begins to be altered. Pressure, too, is a highly important parameter to consider, because it is the factor that provokes the greatest amount of variation in the indentations obtained. That is precisely what Van Waveren
Hogervorst and co-workers asserted in a paper published in 2000 [23].

An inspection of the images taken with the scanning electronic microscope clearly shows that air abrasion causes a loss of organic and inorganic material that will prevent any future re-mineralization. So the loss of tooth structure is permanent. But at the same time this loss of enamel has the advantage of protecting against the prolonged retention of bonding material on the tooth surface after attachments have been removed.

Summing up, prolonging the time of air abrasion planes the tooth surface and makes it less receptive to bonding. Augmentation of sand blasting time removes successive layers of enamel and causes practically no accentuation of the micro-hills and micro-
valleys desired for retention of bonded brackets. On the other hand, pressure and amount of powder have a substantial effect.

We recommend, therefore, to:
- decrease in air abrasion time;
- use a sufficiently high pressure;
- project a sufficiently high quantity of powder.

From the data developed in our research we can estimate the ideal parameters for air abrasion procedures carried out with Aquacut®. They are:
- time: 2 to 6 s on an unprepared tooth;
- pressure: 3 to 4 bars;
- powder: scale 3 to 4.

4.3.4. Conclusion

After having studied the data furnished by two methods of analyzing the ultrastructure produced by air abrasion of enamel, we can conclude that the operator can adjust the depth of indentations achieved by this process by varying the pressure applied and the time of application. Employed in this way under good conditions, air abrasion does not cause serious damage to enamel surface. More profound studies of each appliance now commercially available are needed so that a determination can be made for each of the best risk/benefit relationship, that is, how to obtain satisfactory bond strength while causing as little harm to enamel as possible.

According to the majority of studies already carried out, bond strength provided by composite resins is clearly lower than those required for orthodontic treatment. However, with the development of resin modified glass ionomer cements, accumulated data have given a different picture and, as we shall see, it can be stated that air abrasion cleans enamel surfaces and creates irregularities on them that are retentive enough to provide good bond strength.

4.4. Air abrasion and bond strength

As we have already made clear, according to Osario, et al. [14], a minimal force of 6 to 8 MPa is necessary and sufficient for executing the needed tooth movements in orthodontic treatment. Air abrasion cannot be considered a weak technique for resin bonding preparation (Tab. 3). Furthermore, air abrasion before etching increases the reliability of resin bond strength; however, all the disadvantages of acid use necessarily accompany this dual procedure (Tab. 4).

Bond strength of composite resin is not adequate when enamel has been prepared only with micro-air abrasion because this material requires a more fractured enamel surface than this procedure alone can
create. However if the combination resin/abrasion is not satisfactory, must we reject air abrasion altogether? No, if we change the bonding agent. The resin-modified glass ionomer cements offer the advantage, because of their make up, of adhering chemically to dental structure. The combination of this type of agent with a mechanical preparation of enamel surfaces can, therefore, constitute an alternative to traditional bonding techniques.

The study Sorel [22] carried out compared the bond strengths obtained with three types of enamel preparation followed by identical bonding protocols, that is, bonding Discovery® attachments using RMGIC (Fuji Ortho LC®). The results of in vivo force application, ranked in decreasing order of force attained are:

Group 2: Protocol without etching (simple cleaning with a brush): 8.47 MPa ± 1.57.

From this data we can see that bond adhesion is clearly affected by the type of enamel preparation. Results of statistical tests show that all the groups differ significantly from each other, underlining the contention that the mode of enamel preparation is important for bond strength. The bond strength average for each group was in the neighborhood of 10 MPa, which is considered to be the ideal value for bonding. Only the average bond strength of group 2 (protocol without etching and elimination of the acquired exogenous pellicle with a brush) was slightly below this mark.

All the protocols, according to this in vitro study, would seem to be utilizable in vivo. In fact, all the protocols tested produced generous anti-rupture capacities that would, in our view, make them appropriate for clinical use. It was the chemical adhesion of RMGIC (Fuji Ortho LC) that made it possible to achieve these results; the excellent mechanical retention of brackets being the counterpart.

Acid-etching does not, in our opinion, contribute sufficient additional bond strength benefits to justify the damage it does to enamel, which is a consistent loss of at least 30 μm of tooth substance.

5. General conclusion

Following George Newman’s mid-century introduction of the technique of bonding orthodontic brackets directly to teeth, a number of different approaches for conditioning enamel surface to receive them have been proposed. The usual widely accepted and well recognized technique for doing this is the application of orthophosphoric acid to change the outer enamel layer chemically and mechanically so that it will become a retentive surface for the bonding agent. This technique has been evaluated over the years in an effort to determine what the ideal time and concentration of this application should be to produce the best bonding attachment with the least loss of enamel.

Other approaches have been suggested, notably air abrasion of the enamel, which, instead of etching the surface, creates macro-porosity thanks to the differential loss of enamel substance. This air blasting preparation produces a suitable surface so long as an appropriate bonding agent, the resin modified glass ionomer cement (RMGIC), is employed. The studies assessed in this paper show that by properly adjusting for the ideal values of time, pressure, and amount of powder it is possible for the practitioner to condition the enamel surface into a proper field for the bonding the attachments needed in orthodontic treatment. The best results were obtained with the use of RMGIC because the natural chemical bonding and the increased retentivity of the mechanically air abraded enamel surface combined to produce a satisfactory bracket to tooth attachment without significantly harming enamel structure.

Air abrasion coupled with RMGIC bonding has a considerably lesser deleterious effect on enamel, as shown by the relatively minor loss of 10 μm in substance and the decrease in residual resin left in enamel crevices, than acid-etching does; in addition it removes the exogenously acquired enamel pellicle and prepares the surface to receive the adhesive in a single step. At the rate of 4 s per tooth, an orthodontist can prepare 10 teeth in 40 s and then ask the patient to rinse rapidly to complete the pre-bonding preparation. In less than 1 min, the teeth are ready to be bonded.
Bibliography


