

Deproteinization of tooth enamel surfaces to prevent white spot lesions and bracket bond failure: A revolution in orthodontic bonding

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Abstract

Orthodontic treatment success is jeopardized by the risk of development of white spot lesions (WSLs) around orthodontic brackets. Unfortunately, the formation of WSLs still remains a common complication during treatment in patients with poor oral hygiene. Nearly 75% of orthodontic patients are reported to develop enamel decalcification because of prolonged plaque retention around brackets. It is the orthodontist's responsibility to minimize the risk of patients having enamel decalcifications as a consequence of orthodontic treatment. This can be achieved by using hybrid, fluoride-releasing, glass ionomer cement to bond brackets, with deproteinization of the enamel surface before phosphoric acid etching.

Key words: Acquired pellicle, conditioning, deproteinization, enamel, etching patterns, Hippocratic Oath, moistening, resin-modified glass ionomer cements, white spot lesions

INTERVIEW QUESTIONS AND ANSWERS

1. What is the prevalence of white spot lesions (WSLs) in the scientific literature?

A review of the scientific literature indicates that there is a high prevalence of WSLs that develop during comprehensive orthodontic treatment. Richter *et al.*,^[1] using the photographic method to detect WSLs, found that 72.9% of 350 orthodontic patients treated with comprehensive orthodontics between 1997 and 2004 in the Department of Orthodontics at the University of Michigan had developed new WSLs. These 350 patients were selected at random from the photographic records of 2300 patients

treated at that institution. Boersma *et al.*,^[2] using the quantitative light-induced fluorescence method to detect WSLs, found that 97% of 62 patients who were evaluated immediately following comprehensive orthodontic treatment were affected with WSLs. Ogaard,^[3] using the clinical inspection method to detect WSLs, in a study of 51 patients treated with comprehensive orthodontics, found that the prevalence of WSLs on vestibular surfaces 5 years posttreatment was significantly higher than in a matched control sample of untreated individuals. Van der Veen *et al.*^[4] used the quantitative light-induced fluorescence method in 58 patients to determine whether WSLs diminish after orthodontic treatment (through the natural remineralization process). These researchers found that 6 months after bracket debonding, while 33% of WSLs did remineralize somewhat (lesion regression), the majority of WSLs remained unchanged, and 10% worsened (lesion

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DOI:
10.4103/2321-1407.186431

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How to cite this article: Justus R. Deproteinization of tooth enamel surfaces to prevent white spot lesions and bracket bond failure: A revolution in orthodontic bonding. APOS Trends Orthod 2016;6:179-84.

progression). They concluded that in spite of some WSL natural remineralization occurring postorthodontic bracket removal, these lesions generally do not disappear.

The results from all the above-mentioned studies indicate that methods of prevention for WSLs must be strongly considered.

2. What is the scientifically proven effect of fluoride-releasing resin-modified glass ionomer cements (RMGICs) on WSLs?

RMGICs have been proposed as bracket bonding materials due to their continuous fluoride-releasing properties throughout the orthodontic treatment. RMGICs act as fluoride pumps because they continuously absorb fluoride from the environment (e.g., fluoride in dentifrice, in oral rinse, and in potable fluoridated water) and subsequently re-release it precisely in the areas most susceptible to WSLs. These are the gingival third of the teeth, the bracket perimeter and voids beneath the bracket base. *In vivo*,^[5,6] *ex vivo*,^[7,8] and *in vitro*^[9] studies plus systematic reviews^[10,11] have documented that RMGICs do protect the enamel from the development of WSLs. These studies confirm that less demineralization occurs during fixed orthodontic appliance treatment with RMGICs than with traditional resin-based adhesives.

3. What kind of etch-pattern types are currently known?

There are three enamel etch-pattern types. They are known as types 1, 2, and 3.^[12] Examples of these three can be observed in Figures 1-3, respectively.

Figures 1 and 2 show $\times 2000$ scanning electron microscope (SEM) photographs of enamel surfaces moistened with 5.25% sodium hypochlorite (NaOCl) for 1 min (to deproteinize the enamel surface) and etched with 35% phosphoric acid, applied for 15 s. The high number of microporosities created in these good-quality etching patterns are characteristic of type 1 etching (in which the enamel rod, or prism, heads are dissolved [Figure 1]), and type 2 etching (in which the enamel interprismatic substance is dissolved [Figure 2]). These microporosities allow the adhesive to penetrate the enamel surface increasing the bond strength due to the many adhesive tags created.

Figure 3 shows a $\times 500$ SEM image of an enamel surface etched with 35% phosphoric acid applied for 15 s without prior deproteinization. This low-quality etching pattern type, called type 3 (also known as superficial etching), is characterized by some areas which are well etched, while many are etched poorly, or not etched at all.

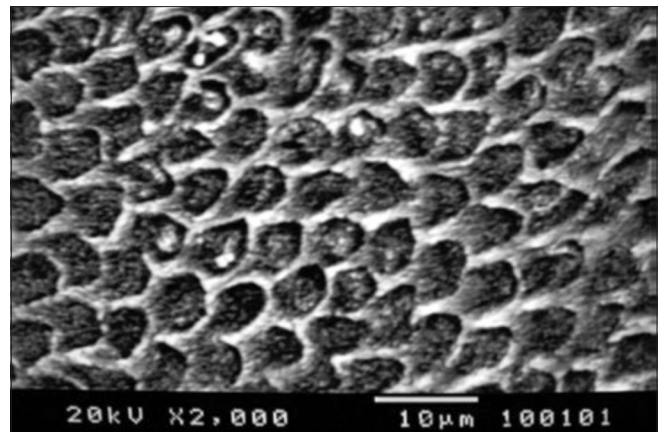


Figure 1: Enamel moistened with 5.25 sodium hypochlorite for 1 min and etched with 35% phosphoric acid for 15 s. Observe type 1 etching pattern (scanning electron microscope, $\times 2000$) (courtesy: Dr. R. Espinosa, Universidad de Guadalajara, Mexico)

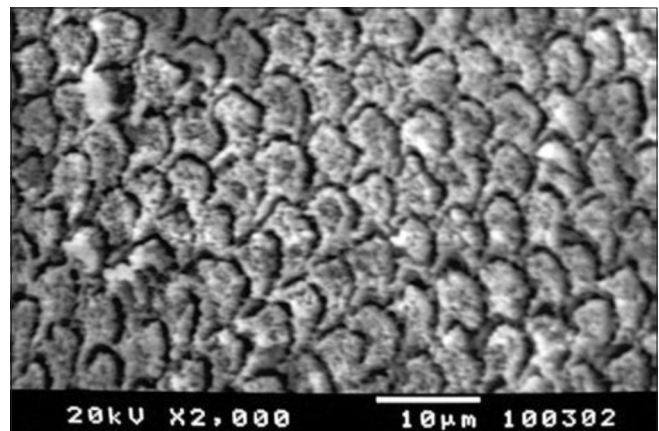


Figure 2: Enamel moistened with 5.25 sodium hypochlorite for 1 min and etched with 35% phosphoric acid for 15 s. Observe type 2 etching pattern (scanning electron microscope, $\times 2000$) (courtesy: Dr. R. Espinosa, Universidad de Guadalajara, Mexico)

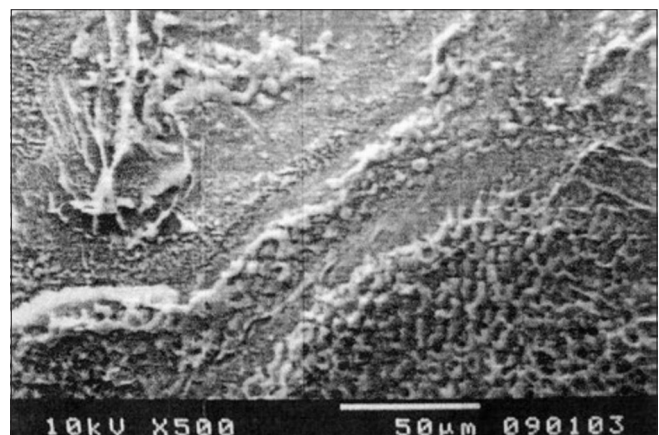


Figure 3: Enamel etched with 35% phosphoric acid for 15 s (no sodium hypochlorite was used). Observe type 3 etching pattern (scanning electron microscope, $\times 500$) (courtesy: Dr. R. Espinosa, Universidad de Guadalajara, Mexico)

Hobson *et al.*^[13] reported that the majority of phosphoric acid enamel etchings carried out by dentists result in type 3 etching patterns. These researchers demonstrated that the typical enamel surface etch pattern was as follows: 22% of the surface not etched at all, 7% with a tenuous etch, 69% with type 3 etch, and only 2% with type 1 and 2 etch.

The low-quality type 3 etching pattern has two important associated issues: It provides diminished micromechanical retention, and it allows the creation of voids between the bracket base and the enamel.

Even though orthodontists pumice the teeth before etching, organic material (the acquired dental pellicle) still remains attached to the enamel surface. The dental pellicle layer plays an important role in maintaining tooth integrity by controlling mineral dissolution dynamics at the enamel surface and confers resistance and stability against chemical dissolution and attack by acidic agents.^[14] Thus, the pellicle does not allow adequate etching of the enamel surface,^[14-16] which can lead to both bracket bond failure and WSL development on the periphery of the bracket base. Voids in the areas close to the bracket base perimeter create a particular risk for WSLs because biofilm can be trapped in them. Normal brushing cannot adequately clean these areas leading to WSL development.

Enamel deproteinization, to remove the surface organic layer, is, therefore, an important step, before etching the enamel, to allow the creation of types 1 and/or 2 etch patterns. Either of these two etch patterns should be obtained to increase the success rate of brackets bonded with composite resins and with RMGICs; the latter providing the added benefit of minimizing WSL development.

4. What is the preferred shear bond strength (SBS) in orthodontics?

Reynolds^[17] determined that for a bracket adhesive to be clinically acceptable it should have tensile bond strength (TBS) of a minimum of 5.9 MPa. This figure is called the Reynolds number. Orthodontists are more interested in the SBS than in the TBS. The reason is that bracket failure mostly occurs due to shear rather than tensile forces. Still, the Reynolds number is used. Ideal SBS should be around 9 MPa because higher SBSs could damage the enamel surface at the time of debonding. Bracket failure most frequently occurs either at the enamel-adhesive interface or the bracket-adhesive interface. Bracket failure at each of the two interfaces has its own advantages and disadvantages. Bracket failure at the bracket-adhesive interface is advantageous as it indicates good adhesion to the enamel. However, considerable chair time is needed to

remove the residual adhesive, with the added possibility of damaging the enamel surface during the cleaning process. In contrast, when brackets fail at the enamel-adhesive interface, less residual adhesive remains on the enamel, but then accidental bracket failure probably occurs more often during treatment, disrupting chair time, and prolonging the duration of orthodontic treatment.^[18]

5. Can SBS of fluoride-releasing RMGICs be increased?

Yes, it can, provided additional microporosities are created on the enamel surface. This goal can be achieved by removing all the organic material on the enamel surface (dental acquired pellicle and organic material from the enamel cuticle and subcuticle) with 5.25% NaOCl, as demonstrated by Justus *et al.*^[18] By removing this organic material, the 37% of phosphoric acid etching agent (not the 10% polyacrylic acid conditioning agent) can attack the enamel surface creating type 1 and 2 etch patterns, thereby increasing bracket SBS. This study demonstrated that by deproteinizing the human enamel surface before 37% phosphoric acid etching for 30 s and moistening the enamel surface after acid etching, the mean SBS of an RMGIC (Fuji Ortho LC) increased almost 70% (from 5.7 to 9.6 MPa), and the mean SBS of a composite resin (Transbond XT) increased from 8.1 to 9.4 MPa. This clinically important, and statistically significant increase in SBS, in the case of the RMGIC, finally allows orthodontists to reliably use RMGICs to bond brackets, thereby minimizing the risk of WSL development and also bracket bond failure. Clinicians still using the traditional resin-based composites as bracket adhesives may reduce their bracket failure rates by deproteinizing the enamel surface for 1 min before etching. This simple step can reduce accidental bracket failures because bracket SBS is increased.

Moistening the enamel surface when using RMGICs, as per the manufacturer's instructions (GC Corp., Tokyo, Japan) of Fuji Ortho LC, is also an important step to increase bracket SBS; this was validated by Larmour and Stirrups.^[19]

6. Is there a difference in bracket placement time with RMGICs when compared with a composite resin?

In the litigious environment in which we live today, it is very important to prevent iatrogenic problems from developing, particularly WSLs. That is why I recently published a book titled *Iatrogenic Effects of Orthodontic Treatment: Decision-making in Prevention, Diagnosis, and Treatment*.^[20] The first chapter of this book, published by Springer-Verlag, is dedicated to the prevention of WSLs, with the main goals of protecting the health of the patient's teeth (Hippocratic Oath) and also protecting the clinician from malpractice lawsuits.

The small extra time it takes to bond brackets with RMGICs is nonimportant compared with the time having to spend with posttreatment patient complaints due to WSLs. The auxiliary help in my office are the ones who bond the brackets using the direct bonding method. However, it is me who does the final positioning of the brackets before photocuring the adhesive. In my office, the total time it takes my auxiliaries to bond a single full arch is 20–25 min, deproteinizing, etching, moistening, bonding, and photocuring two teeth at a time. However, it takes only 7 min of my own time because I solely adjust the final bracket positions. It should be noted that more than two teeth can be bonded at a time, as is discussed in the answer to question number 9.

7. How many years clinical experience have you had with RMGICs in your office?

Sixteen years, the last 6 years using deproteinization of the enamel surface with 5.25% NaOCl before phosphoric acid etching. In all these years, the only WSLs I observed in my practice occurred in patients who were transferred to me with their brackets already bonded, probably with the traditional resin-based composites.

8. What is your bracket failure rate in your office?

Anecdotally, in my office the bracket failure rate is approximately 5%. To my knowledge, no clinical research has yet been published on bracket failure rates when brackets are bonded with RMGICs, having the enamel surface been deproteinized/etched/moistened. However, it has been my experience that if a bracket fails it usually happens during the 1st month after bracket bonding, particularly in the lower arch due to chewing on hard foods. The patient pretty quickly learns what not to chew on. Investigators have evaluated various methods to increase bracket SBS of brackets cemented with RMGICs, such as using different enamel conditioners and concentrations, for different time periods, and increasing the light-curing time. Still, the resulting bracket SBS was inadequate until Justus *et al.*^[18] suggested deproteinizing with NaOCl, etching with H₃PO₄ and wetting the enamel surface with a water-moistened cotton roll, all these steps before photocuring.

9. What would you recommend as a routine protocol for bracket placement?

To reduce the risk of WSL development during orthodontic treatment, I recommend bonding orthodontic brackets with Fuji Ortho LC, which has been the most frequently used RMGIC in published studies and is thus the industry standard. Taking into account the fact that the acid-base

reaction in Fuji Ortho LC takes 24 h to set, I recommend the following protocol for bracket placement:^[20]

- Pumice prophylaxis with a rubber cup for 5 s per tooth
- Rinse and dry
- Apply 5.25% NaOCl with a microbrush to two (or more) teeth at a time [Figures 4 and 5], rubbing the solution for 1 min on the enamel surface where the brackets will be placed (the saliva suction tip should be positioned in such a fashion as to suction away any NaOCl excess. Patients do not perceive the odor of the bleach because a very minute amount is used to deproteinize the enamel surfaces of the teeth)
- Rinse and dry
- Etch with 37% phosphoric acid for 15–30 s
- Rinse and dry
- Wet the etched enamel surface with a water-moistened cotton roll
- Mix powder and liquid as per manufacturer recommendations, taking note that the operator has less than a minute or two (depending on room temperature and the ambient light) to position the brackets before the resinous fraction of this adhesive begins to harden/polymerize. It is therefore recommended to prepare adhesive for only two teeth at a time. However, if the clinician wishes to bond more than two brackets per mix, a cold slab can be used to mix the powder and liquid. GC Corp., now offers a no-mix Fuji Ortho LC for the clinician who wishes to avoid the mixing procedure. This 2-paste adhesive can be refrigerated so more than 2 teeth may be bonded at a time
- Load the adhesive onto the bracket bases and press them against the enamel surface making sure that the brackets do not contact the opposing teeth while in occlusion
- Remove excess adhesive with a sharp scaler
- Light cure and remove excess adhesive.

Once all brackets have been bonded, tie in a very light wire (0.010" SS or a NiTi) avoiding full bracket engagement in severely malaligned teeth to prevent bracket failure, since the glass ionomer fraction of RMGICs takes 24 h to set. Keeping brackets away from occlusion is also critical to help avoid bracket failure.^[20] Hegarthy and Macfarlane, in a clinical trial comprising 61 patients, compared the clinical performance of a RMGIC adhesive with a resin-based adhesive over a 12-month period. The split-mouth technique was used to analyze bracket retention. Both adhesives had 4 times more bracket failures when opposing occlusion was present.^[21] Thus, keeping brackets away from occlusion is critical to minimize bracket failure. The use of occlusal stops, when indicated, should be considered to avoid bracket failure. The brackets with the RMGIC adhesive, in the Hegarthy and Macfarlane study,^[21]



Figure 4: A glass container with a 5.25% sodium hypochlorite solution. This dark container helps prevent the deactivation of this solution by light (left). Dappen Dish containing the sodium hypochlorite solution and a microbrush used to transport it to the labial/buccal surfaces of the teeth (right) (reprinted with permission from Justus *et al.*)^[18]

were bonded using the traditional method, specifically without deproteinizing or phosphoric acid etching the enamel surface. Brackets bonded with RMGICs using the traditional method have a much lower initial SBS than composite resins,^[22] so many additional micromechanical retentions must be created on the enamel surface to increase the initial bracket SBS and thus be able to successfully use these adhesives. To increase this inadequate initial SBS of the RMGICs, three steps have been recommended: Deproteinizing the enamel surface with 5.25% NaOCl, etching the enamel surface with 37% phosphoric acid, and moistening the enamel surface, preferably with water since saliva contains proteins.

10. Are there disadvantages of RMGICs in clinical orthodontics?

RMGICs have three disadvantages:

1. Fuji Ortho LC requires a longer time to fully harden than composite resin (even though Vivanco^[23] determined that the SBS was adequate 30 min after bonding)
2. Deproteinization of the enamel surfaces with NaOCl for 1 min, to increase bracket SBS, is imperative
3. Mixing Fuji Ortho LC powder and liquid takes additional chair time. Although the manufacturer is now selling a no mix Fuji Ortho LC, which this author has not yet tried, it would be advisable to carry out laboratory studies before using it on patients.

CONCLUSION

Clinicians need to consider the properties of RMGICs to be able to use them successfully. Because of the recent



Figure 5: Clinical example of enamel deproteinization by applying 5.25% sodium hypochlorite solution to the enamel surface for 1 min with a microbrush. The objective is to eliminate the acquired pellicle so the 37% acid etch can create improved etching patterns on the enamel surface to increase bracket shear bond strength (reprinted with permission from Justus *et al.*)^[18]

improvements in the bracket SBS with deproteinization, and the fluoride-releasing and uptake properties of RMGICs, it is suggested that these adhesives should see greater use in bonding orthodontic brackets in the future. The advantages of using RMGICs far outweigh the disadvantages.

Financial support and sponsorship

Nil.

Conflicts of interest

There are no conflicts of interest.

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