Deproteinization of Tooth Enamel Surfaces to Prevent White Spot Lesions and Bracket Bond Failure: A Revolution in Orthodontic Bonding

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 demineralization because of prolonged plaque retention around brackets. It is the orthodontist’s responsibility to minimize the risk of patients having enamel deminerlization 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 prior to phosphoric acid etching.

Key words: Enamel: acquired pellicle, conditioning, deproteinization, etching patterns, moistening, white spot lesions. Hippocratic Oath. RMGICs.

Running title: Deproteinization of tooth enamel surfaces.

Interview questions and answers

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

A review of the scientific literature indicates that there is a high prevalence of white spot lesions (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 2,300 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 progression). They concluded that in spite of some WSL natural remineralization occurring post-orthodontic bracket removal, these lesions generally do not disappear.

The results from all the abovementioned 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 (sustained fluoride release). RMGICs act as fluoride pumps due to the fact that they continuously absorb/recharge 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 and the bracket perimeters.

The main mechanisms by which fluoride protects the enamel surface against demineralization is by maintaining the plaque supersaturated with respect to fluorapatite, hence tipping the balance of the caries process against demineralization and in favor of remineralization [5], and by an inhibitory effect of fluoride on bacterial activity [6].

In vivo [7, 8], ex vivo [9, 10], and in vitro [11] studies plus systematic reviews [12, 13] 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.

When brackets are initially bonded with RMGICs, a burst of fluoride is released. This has been documented in many studies [11, 14-19]. However, this initial burst is followed by a dramatic drop in fluoride levels. Chin et al determined that fluoride release drops from an initial burst of 0.8 ppm to levels below 0.1 ppm after 5 days [11]. They found however that if RMGICs are in daily contact with fluoride they recharge and subsequently re-release fluoride at levels of between 0.1 and 0.2 ppm. Even though these levels appear to be quite low, Jacobson et al [20] found that levels as low as 0.02 to .0.06 ppm promote enamel remineralization. This fact highlights the importance of using RMGICs to bond brackets, particularly since daily fluoride uptake by RMGICs probably occurs routinely because most dentifrices contain fluoride.

In conclusion, continuous contact with fluorides is critical to protect the enamel surface against the development of WSLs during treatment with fixed orthodontic appliances.
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 [21]. Examples of these three can be observed in Figs. 1, 2 and 3, respectively.

Figures 1 and 2 show 2,000× 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, Fig. 1), and type 2 etching (in which the enamel inter-prismatic substance is dissolved, Fig. 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 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. Type 3 etching pattern provides diminished micromechanical retention.

A 500x SEM image of type 3 etch-pattern, instead of a 2,000x SEM image, is presented (Fig. 3) so one may observe that enamel which was pumiced, but not deproteinized, has areas that do not etch well due to the remaining organic layer (pellicle). Had a 2,000x image been presented, one would not be able observe the difference between the type 1 and type 2 etch patterns (Figs. 1 and 2) versus the type 3 etch pattern, since a 2,000x image would only exhibit either a well etched or a non-etched area.
Figs. 1, 2 and 3 serve to illustrate the importance of removing the acquired pellicle from the enamel surface prior to acid-etching. The pellicle is firmly attached to the tooth surface and is 1 to 3 microns deep. Although it can be removed by abrasion, this normally involves fairly extensive polishing. Professional tooth cleaning by the use of a rubber cup or rotary brush with pumice reduces matured pellicle to a great extent, but does not completely remove the pellicle from the enamel surface [22]. In order to completely remove the pellicle, a deproteinizing agent, such as 5.25 % sodium hypochlorite, needs to be applied to the enamel surface. Incomplete removal of the pellicle impedes adequate etching of the enamel surface [22-24], which can lead to *bracket bond failure*.

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 [23]. The pellicle is permeable to fluoride ions and thus does not hinder fluoride uptake at the enamel surface [24].

Hobson et al. [25] reported that the majority of phosphoric acid enamel etchings carried out by dentists result in type 3 etching patterns, even though pumice-prophy is performed prior to acid-etching. 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.

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

![Fig. 1 2,000x SEM photograph of enamel moistened with 5.25 NaOCl for 1 min and etched with 35 % phosphoric acid for 15 s. Observe type 1 etching pattern (Courtesy: Dr. R. Espinosa, Universidad de Guadalajara, Mexico)](image-url)

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

In orthodontics, the average force of mastication on anterior brackets is approximately 5 MPa and approximately 20 MPa on posterior teeth [26]. With the generation of biting forces in the
posterior region of the mouth approaching 20 MPa there may be an indication for the need to attain SBSs of bonded brackets of at least 20 MPa on posterior teeth. However, because masticatory forces are dynamic and complex this is not the case [27]. It has been recorded that materials such as glass ionomers remain satisfactorily bonded intraorally, even though when tested in the laboratory recorded SBSs may be as low as 2.2 MPa [28, 29].

Enamel fractures have been observed with bond strengths as low as 9.7 MPa [30] at the adhesive-etched enamel interface. Thus, SBS should be around 9 MPa to help prevent damage to the enamel surface at the time of debonding. Reynolds [31] proposed that “clinically acceptable” tensile bond strengths should be in the 6-8 MPa range (the Reynolds number).

Bond strengths that are too high may do nothing more than create iatrogenic damage during bracket debonding (gross enamel facture, enamel tearing, crazing and microfractures). The “ideal bond strength” is difficult to define, as every patient is unique with respect to the ability of their enamel to be etched and their individualized masticatory and intraoral factors that may affect bonding and bond strength. Indeed, the differences in the composition of enamel within the teeth of each patient, and the complex masticatory forces at work on bonded brackets, while chewing a range of different foods, differing muscular patterns, bruxism and clenching habits, and the different forces present in the mouth as the teeth are being moved during treatment, make predicting bond strengths a formidable task. It seems reasonable to assume that for minimal reliable clinical bond strengths to occur, in vitro SBS testing should yield values of at least 3-4 MPa for the lowest values in the range, generated in a bond strength test series. Preferably SBSs should be consistent along the test range with low coefficients of variation (<20%) [27].

Bracket failure most frequently occurs either at the enamel-adhesive interface or at 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 [32].


5. Can shear bond strength 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 % sodium hypochlorite, as demonstrated by Justus et al. [32]. By removing this organic material the 37 % 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 prior to 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 prior to 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 [33].


6. Is there a difference in bracket placement time with resin-modified glass ionomer cements 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* [34]. 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 non-important compared with the time having to spend with post-treatment 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 to 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 % sodium hypochlorite prior to 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 first 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. [32] suggested deproteinizing with NaOCl, etching with H₃PO₄ and wetting the enamel surface with a water-moistened cotton roll, all these steps prior to 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 [34]:

- 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 (Figs. 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 (.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 [34].

Hegarty 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 design was used to analyze bracket retention. Both adhesives had 4 times more bracket failures when opposing occlusion was present [35]. 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 Hegarty and Macfarlane study [35] 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 [36], so many additional micromechanical retentions must be created on the enamel surface in order 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 % sodium hypochlorite, etching the enamel surface with 37 % phosphoric acid, and moistening the enamel surface, preferably with water since saliva contains proteins.

Fig. 4 Photograph on the left shows a glass container with a 5.25% sodium hypochlorite (NaOCl) solution. This dark container helps prevent the deactivation of this solution by light. Photograph on the right shows a Dappen Dish containing the NaOCl solution and a microbrush used to transport it to the labial/buccal surfaces of the teeth (reprinted with permission from Justus et al. [32]).

Fig. 5 Clinical example of enamel deproteinization by applying 5.25% NaOCl 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 SBS (reprinted with permission from Justus et al. [32]).
10. Are there disadvantages of RMGICs in clinical orthodontics?

RMGICs have three disadvantages:

a- Fuji Ortho LC requires a longer time to fully harden than composite resin (even though Vivanco [37] determined that the SBS was adequate 30 min after bonding).

b- Deproteinization of the enamel surfaces with NaOCl for 1 min, to increase bracket SBS, is imperative.

c- 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 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.