A comparison of the resin tag penetration of the total etch and the self-etch dentin bonding systems in the primary teeth: An in vitro study

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Abstract

Background and Objective: Restoration of carious lesions with a strong permanent bond would be a highly desirable requisite. Ultra morphological characterization shows that observing and understanding the interfacial phenomenon and its quality would be of great importance in the selection of a dental adhesive for its use in pediatric restorative dentistry. Study design: Human primary molars, indicated for extraction, for reasons like caries, normal exfoliation, pathological root resorption, over-retained and serial extraction, were collected. Teeth were then equally distributed into 2 subgroups each namely B1 - Prime and Bond NT & B2 - Xeno III. Results: The resin tags seen in the samples of group B2 were both qualitatively and quantitatively advanced as compared to group B1. This reveals that the quality of the penetration of the resin was better in group B2. Conclusion: Reduction in the technique sensitivity of any bonding system would always be a preferred factor in pediatric restorative dentistry. Thus the inclination towards the selection of adhesive system may lean towards the self-etching bonding system at this juncture.

Keywords: Axial wall, hybrid layer, interfacial morphology, pulpal wall, resin penetration, resin tags, self-etch system

Introduction

Early childhood is marked by tremendous growth and development of the face and dentition, both of which require the attention of a dental professional. Overall, nearly one in five (18.7%) U.S. children aged 2-4 have experienced visually evident tooth decay.¹

National surveys conducted during the past three decades have demonstrated a decline in the overall mean levels of clinically detectable dental caries in U.S. children and adolescents.² In a study conducted by Balwant Rai et al (2007), the mean DMFT was found to be 2.82, 2.87, 3.40, and 3.15 in 9-, 10-, 11-, and 12-year-old children while the mean DMFS was found to be 3.82, 3.87, 3.76, and 4.26.³

Hybridization of dentin is identified as a basic bonding mechanism between resin and dentin, hence studying the micro-morphology of hybrid layer and resin tags in primary dentition formed the mainstay of our project. Despite the basic differences in some micro-mechanical and histological characteristics of dentin in primary teeth along with its hardness and mineral content as compared to permanent dentin, manufacturers do not provide specific instructions for the use of their adhesives in primary dentition.⁴⁻⁹

Longevity of restorations is very low in the primary dentition.¹⁰ Generally, the earlier the age at restoration, the lower the longevity.¹¹⁻¹² The predicted life span of re-restorations is even shorter.¹¹ Qvist et al. found that the major reasons for replacement of restorations in the primary dentition were restoration fracture or total loss of the same.¹³

Marginal leakage cannot be eliminated even when higher shear bond strength is obtained for some adhesive systems. Thus, it can be assumed that the magnitude of bond strengths is not the only predictor of the sealing ability. So the development of bonding systems, which will provide a true and stable adhesive bond to tooth structure in the rigors of the oral environment, is a high priority.

The widespread demand for and the use of dental adhesives have thus fueled an intense development of better and easier dental adhesives in rapid succession. Though bonding to the enamel could be effectively achieved, bonding to dentin was a real challenge due to its heterogeneous nature and presence of water, presence of smear layer, and smear plugs, etc.

Until recently, all adhesive systems used in the past had three steps before restoration. These involved etching, priming, and
bonding. This was quite cumbersome. Hence, the thought process continued in the direction of reducing the number of steps involved in bonding before the restoration with better clinical results. Currently, there are two philosophies on simplification of the adhesive systems, namely
• The Total-Etch Systems, with a separate etchant and a primer/adhesive and
• The Self-Etching Systems, which combines etching and priming in one bottle and have a separate adhesive agent or which combine all three steps in a single solution.

Studies comparing the total-etch systems and self-etching systems showed results varying from no significant difference to higher or lower bond strength and sealing ability in primary dentition than in permanent dentition.[14,15] Results of recent in vitro studies have revealed the lower efficacy of self-etch system than the total etch system in primary dentition. Chemical, physiological, and micro-morphological differences such as decreased mineralization, small size and lower concentration of dentinal tubules, decreased permeability, and more reactivity of primary dentin to acidic conditioner were thought to be responsible for lower bond strength and sealing ability in primary dentition.[16] Despite simplification of bonding systems, technique sensitivity, and substrate variability, concerns about enamel and dentin bonds have increased.

In the light of these developments, this study was undertaken to compare the behavior of both the fifth-generation bonding system (PRIME and Bond NT) and the sixth-generation bonding system (XENO III) by examining their penetrability, i.e., measuring the depth of their resin tag formation in the dentinal tubules in primary teeth.

Materials used in the study
• Bonding agents: Prime and Bond NT (LOT – 051123 2007-11) and Xeno III (LOT—060500856-857 2008-04) bonding adhesives
• HILUX dental curing light—Kulzer, Benlioglu Dental Inc., Turkey. Order no. 950-200-230, Class II equipment
• Gold Palladium Sputtering Unit: JEOL JFC 1600 auto fine coater, Tokyo, Japan
• Analytical scanning electron microscope—JSM 6360-A, JSM 6360-LA
• Double-sided diamond discs procured from Dental World, Pune
• 0.5% Chloramine T powder
• Novelty Diamond Paste for final polishing of the samples
• Small straight fissure diamond abrasive point (Ex 41—Mani)

Materials and Methods

 Twenty-four human primary molars, which were indicated for extraction, for a variety of reasons like caries, normal exfoliation, pathological root resorption, overretained, and serial extraction, were collected for the study purpose. They were stored in 0.5% Chloramine T solution at 37°C until further procedures.[17] Total number of teeth was then equally distributed into two subgroups each, namely B1—Prime and Bond NT and B2—Xeno III.

Selection criteria for cavity preparation

Selection of the area for cavity preparation was done in such a way that the cavity would house in sound dentin structure.

Selection of bur

Small straight fissure diamond abrasive point (Ex 41—Mani) with a height and diameter measuring 2 mm and 1 mm, respectively, was selected because primary enamel is 1 mm in thickness and primary dentin is 2–3 mm in thickness.[18] Despite simplification of bonding systems, technique sensitivity, and substrate variability, concerns about enamel and dentin bonds have increased.

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Results and Conclusion

Only a few representative photomicrographs have been included as the total number of photomicrographs was quite large. Figure 2 show the measurement of the resin tag length by computerized scale in micrometers. Thus, near-accurate measurements can thus be obtained by this method. Also, the length can be measured in micrometers manually by the scale given at the bottom of each photomicrograph.

Photomicrographs showing the resin tag penetration in primary dentin in Group B1 (Prime and bond NT)
The emergence of funnel-shaped resin tags from the dentinal tubules and the hybrid layer. Figure 3 shows a very sparse distribution of resin tags on the pulpal wall in a sample of group B1 (Prime and Bond NT).

Photomicrographs showing the resin tag penetration in primary dentin in Group B2 (Xeno III)
The profound penetration of resin and the emergence of the cylindrical resin tags through the dentinal tubules in abundance in a specimen of group B2 (Xeno III). Figure 4 shows the abundance of resin tags on the pulpal floor with deeper penetration.

Tables show the 10 representative resin tag length readings measured in micrometers from the photomicrographs of the individual samples from each group B1 (Prime and Bond NT) and B2 (Xeno III). They also highlight the mean length of all the 10 readings and their standard deviations for each sample in each group. At the end of the table, the value in the left column expresses the mean penetrability of the resin tag length in micrometers and the value in the right column represents the mean standard deviation of all the samples in each group B1 (Prime and Bond NT) and B2 (Xeno III), respectively.

Penetrability [resin tag length in micrometers (µm)] in Group B1 (Prime and bond NT)
From Table 1 it is seen that the mean of the resin tag length measured in micrometers of all the 12 samples came to 11.434 µm with a mean standard deviation of 4.03.
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Penetrability [resin tag length in micrometers (µm)] in Group B2 (Xeno III)

From Table 2 it is seen that the mean of the resin tag length measured in micrometers of all the 12 samples came to 18.75 µm with a mean standard deviation of 5.12.

**Statistical analysis**

A statistical analysis and computation procedure were performed. Data collected was entered into MS-Excel worksheet and use of “Statistical Package for Social Sciences” (SPSS) software was done. Results were represented in the form of tables and graphs.

The results were expressed in the form of mean for the following objective:

To evaluate and compare the penetrability of different bonding agents by measuring the depth of their resin tag formation in the dentinal tubules—unpaired t-test was applied to determine the depth of penetration of resin tags. “P” value was determined at 95% confidence limits for all the tests mentioned above.

**Statistical results**

Since the samples in both the groups are independent of each other, Student’s unpaired “t” test was applied. Table 3 illustrates the data analyzed by unpaired “t” test to actual value. Table 3 shows that the “t” test value is 3.311.

### Table 1: Penetrability [resin tag length] in group B1 (prime and bond NT)

| Sample No. | R1   | R2   | R3   | R4   | R5   | R6   | R7   | R8   | R9   | R10 (Left column) mean | R10 (Right column) mean |
|------------|------|------|------|------|------|------|------|------|------|------------------------|------------------------|
| 1          | 13.3 | 11.6 | 11.2 | 15.8 | 15.8 | 20   | 10.8 | 14.1 | 15.4 | 7.5                     | 13.5                   |
| 2          | 12.5 | 17.9 | 10   | 12.5 | 9.1  | 14.1 | 10   | 10   | 11.6 | 10                     | 11.77                  |
| 3          | 8.3  | 9.1  | 11.6 | 7.5  | 9.1  | 8.75 | 9.1  | 9.5  | 10.4 | 11.6                    | 9.4                    |
| 4          | 7.5  | 8.3  | 10   | 12.08| 8.3  | 6.6  | 9.1  | 13.3 | 10   | 7.9                     | 9.308                  |
| 5          | 25.4 | 23.3 | 8.3  | 13.75| 14.5 | 15.8 | 20   | 29.5 | 19.11| 30.8                    | 20.04                  |
| 6          | 7.5  | 10.8 | 15.4 | 9.1  | 13.75| 8.7  | 5.8  | 11.6 | 8.3  | 15                     | 10.59                  |
| 7          | 10.8 | 14.1 | 18.3 | 13.3 | 16.6 | 14.1 | 17.08| 19.5 | 18.3 | 15                     | 15.71                  |
| 8          | 10   | 8.3  | 7.9  | 9.1  | 8.3  | 5.8  | 8.3  | 11.25| 11.6 | 10                     | 9.04                   |
| 9          | 10.8 | 12.5 | 10.8 | 12.5 | 8.3  | 13.75| 15.4 | 15   | 14.1 | 14.1                    | 12.72                  |
| 10         | 8    | 10.6 | 11.3 | 10   | 10.3 | 7.3  | 8    | 4.6  | 8    | 2.6                     | 8.07                   |
| 11         | 10   | 11.6 | 12.5 | 15.8 | 12.9 | 15   | 14.1 | 10.8 | 11.6 | 14.1                    | 12.84                  |
| 12         | 2.9  | 7.5  | 3.3  | 2.5  | 9.1  | 2.5  | 1.6  | 7.9  | 2.08| 2.9                    | 4.228                  |
| Mean       | 11.434 |      |      |      |      |      |      |      |      |                        | 4.03                   |

### Table 2: Penetrability [resin tag length] in group B2 (Xeno III)

| Sample No. | R1   | R2   | R3   | R4   | R5   | R6   | R7   | R8   | R9   | R10 Mean | R10 SD |
|------------|------|------|------|------|------|------|------|------|------|-----------|--------|
| 1          | 27.5 | 25.8 | 20.8 | 20.8 | 23.3 | 22.5 | 22.5 | 27.5 | 24.1 | 18.33     | 23.31  |
| 2          | 20   | 25   | 18.3 | 20.8 | 21.6 | 20.8 | 21.6 | 23.3 | 22.5 | 15.8      | 20.97  |
| 3          | 21.6 | 24.1 | 27.5 | 23.3 | 20.8 | 22.5 | 22.5 | 30.8 | 25   | 15        | 23.06  |
| 4          | 15.8 | 14.1 | 18.3 | 26.6 | 29.1 | 26.6 | 15.8 | 23.3 | 20.8 | 23.3      | 21.37  |
| 5          | 13.3 | 11.2 | 14.1 | 12.5 | 14.1 | 11.6 | 10.8 | 13.7 | 10.8 | 13.7      | 12.58  |
| 6          | 10.8 | 10   | 8.75 | 11.25| 10.8 | 9.5  | 10.8 | 11.6 | 11.8 | 12.9      | 10.28  |
| 7          | 15   | 19.1 | 13.3 | 19.1 | 28.3 | 15.8 | 14.1 | 12.5 | 13.3 | 16.6      | 16.71  |
| 8          | 17.5 | 35.8 | 56.6 | 13.3 | 50   | 20   | 20   | 14.1 | 19.1 | -         | 27.37  |
| 9          | 17.5 | 16.6 | 20   | 15   | 12.5 | 14.1 | 15   | 10.8 | 16.6 | 15.8      | 15.39  |
| 10         | 21.6 | 19.1 | 20   | 23.3 | 20.4 | 20.8 | 25.8 | 21.6 | 20.8 | 28.3      | 22.17  |
| 11         | 14.7 | 12.7 | 11.6 | 14.4 | 15.2 | 15   | 12.2 | 11.6 | 11.9 | 17.2      | 13.65  |
| 12         | 15.2 | 20.4 | 16.6 | 25.4 | 19.58| 18.1 | 16.4 | 15.6 | 16.2 | 18.1      | 18.158 |
| Mean       | 18.75|      |      |      |      |      |      |      |      | 5.12       |        |

### Table 3: Statistical analysis and the calculated “t” test and “P” value

| t test | Degrees of freedom | P value |
|--------|-------------------|---------|
| 3.311  | 22                | 0.003*  |

*P < 0.01 highly significant
The $P$ value is 0.003 ($P < 0.05$), which means that the difference in the mean penetrability (resin tag length in microns) of both the groups B1 and B2 is statistically highly significant.

The bar diagram [Figure 5] elucidates the occurrence of penetrability (resin tag length) in both the groups. The group B1 (Prime and Bond NT) shows the mean value of penetrability, which is 11.434 µm, whereas the group B2 (Xeno III) shows the mean value of penetrability as 18.75 µm.

From the results of the study of penetrability (resin tag length in micrometers), we concluded that the resin tags seen in the samples of group B2 (Xeno III) were both qualitatively and quantitatively advanced as compared to group B1 (Prime and Bond NT) which revealed that the quality of the penetration of the resin was better in group B2 (Xeno III).

Therefore, in consonance with the results obtained in the study it appears that in primary dentin, which demineralizes more easily than permanent dentin when exposed to acid etching, the reduction in etching time or the use of milder acids for etching may produce more functional hybrid layers. Therefore, it is concluded that a differentiated protocol for bonding to primary dentin with shorter time for dentin conditioning could be used as a mean to reproduce the hybrid layer thickness seen in permanent teeth.

Despite the micro-morphological and histological difference in primary teeth, manufacturers do not provide separate specific instructions for the use of dental adhesives in primary dentition. So the pediatric dentist has to be selective while choosing the appropriate bonding system for its use in pediatric dentistry.

Discussion

There is a plethora of information available on the mechanism of adhesion for bonding systems on permanent teeth. Primary teeth are smaller in size, has thinner enamel dentin, and show a rapid spread of dental caries. Hence, with less tooth structure available for bonding of composite resin material, proper dentin bonding steps should be followed for success of the composite restoration in primary teeth. Achievement of a consistently reliable, gap-free, and complete attachment of resin composite to dentin is of profound importance in restorative dentistry. Formation of an acid-resistant, resin-impregnated hybrid layer seems to depend on the penetrating ability of resin into etched dentin surface and also on conditioning and permeability of dentinal surface.$^{[24,25]}$ However, the similar type of information on primary teeth appears to be scanty. Few studies in the past stated the presence of formation of thicker hybrid layers$^{[26]}$ in primary teeth with shorter resin tags. Dentin conditioning is a fundamental step for effective bonding and so the composition, concentrations of acidic solution, and time of application should be carefully controlled.

From our observations of the penetrability study, it could be stated that the length of the resin tags in group B1 (Prime and Bond NT) were shorter indicating lower penetration of the resin into the dentinal tubules compared to group B2 (Xeno III).

The shorter length of resin tags observed in group B1 (Prime and Bond NT) in our study could probably be the result of etching with a strong etchant (34% phosphoric acid) for 30 seconds following the manufacturer’s guidelines. Acids, which are too aggressive, expose collagen so deeply that current dentin adhesive resins may not penetrate completely, leaving behind an uninfiltrated weak collagenous layer of dentin that is susceptible to long-term degradation. Owing to the high reactivity of primary dentin, the etchants should therefore be applied for shorter time period compared to permanent dentine for better performance of composite restorations in primary teeth.$^{[27-31]}$

Refractory to the results of group B1, the results of group B2 (Xeno III) were very promising. Both the density and the length of the resin tags were found to be quiet adequate. This could be because of the milder acid etching that is seen with the self-etching systems.$^{[30]}$ A lesser dentinal demineralization, simultaneous to resin monomer penetration with self-etching system, is therefore recommended and this may be a solution for the problems of excessive dentin demineralization seen with total etch systems.

The increased thickness of the hybrid layer in primary teeth by 25–30% and the subsequent lack of complete penetration of adhesive resin into previously demineralized dentin contributed to the lower bond strengths to primary dentin.

Since the reduction in the technique sensitivity of any bonding system would always be a preferred factor in pediatric restorative dentistry, further studies should be carried out keeping in mind the above variables toward the development of a universal bonding system. Therefore, after having gone through the review of literature and the study conducted with its limitations, it appears that the inclination toward the selection of the bonding system may lean toward the self-etching bonding system. The candid recommendation for the use of any specific bonding system in pediatric dentistry seemed to be difficult at this juncture due to the availability of the limited resources at the time of conducting the study.

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