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Effect of aging in bond strength - A Review

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Abstract: Dental adhesives are used to bond composite resins to tooth structure. The earliest bonding systems required an acid-etch technique and were only compatible with enamel. The challenge has always been to predictably bond to enamel and dentin simultaneously. The material should have such a property that it should have better retention to the dentin and it should be able to withstand forces of occlusion and mastication. The ideal requirements of an effective dentin adhesive system include the ability to thoroughly infiltrate the collagen pathways and partially demineralized zone, to encapsulate the collagen and hydroxyapatite crystallites, to produce a well polymerized durable hybrid layer with high bond strengths. As a hybrid layer is created by a mixture of the dentin organic matrix, residual hydroxyapatite crystallites, resin monomers and solvents, aging may affect each of the individual components differently or may result in synergistic combinations of degradation phenomena within the hybrid layer.

Keywords: Bond strength, Hybridisation, Etching, Adhesives, Matrix metalloproteinases

1. INTRODUCTION

Dental adhesives are used to bond composite resins to tooth structure. The earliest bonding systems required an acid-etch technique and were only compatible with enamel and the

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challenge has always been to predictably bond to enamel and dentin simultaneously[1]. Current adhesive systems interact using two different strategies. They are removing the smear layer (the etch-and-rinse technique) and maintaining it as the substrate for the bonding[2] (the self-etch technique).

DENTAL ADHESIVES BONDING SYSTEM

- Etch-and-Rinse Adhesives (Total etch)
  - Three-step multiple-bottle etch-and-rinse adhesives
  - Two-step single-bottle etch-and-rinse adhesives
- Self-Etch Adhesives

Two-step multiple-bottle self-etch adhesives
  - One-step multiple-bottle mix self-etch adhesives
  - One-step no-mix self-etch adhesives

IDEAL REQUISITE FOR DENTIN - BONDING MATERIAL

The material should have such a property that it should have better retention to the dentin and it should be able to withstand forces of occlusion and mastication. The ideal requirements of an effective dentin adhesive system include the ability to thoroughly infiltrate the collagen pathways and partially demineralized zone, to encapsulate the collagen and hydroxyapatite crystallites and to produce a well polymerized durable hybrid layer with high bond strengths. Microleakage and marginal percolation are the most detrimental factors disturbing the success of any restoration. However, even in the absence of microleakage, the presence of leakage pathways called nanoleakage has been observed in the hybrid layer [3]. The ideal requisites are :

- The bond should be instantaneous once the material has set.
- The material and technique must be biocompatible.
- The material should resist the forces of polymerization shrinkage of composite resins and the coefficient of thermal expansion and contraction to eliminate microleakage.
- The bonding between the material and the dentine should be long lasting.
- Postoperative sensitivity must be minimized or eliminated[1].

HYBRID LAYER

Hybridisation is the perfect replacement of the hydroxyapatite and the surface dentin by the resins. This resin, in combination with the collagen fibres forms the hybrid layer[4].

AGING OF HYBRID LAYER

The impregnation of the dentin substrate by blends of resin monomers results in bonding. Hence the stability of the bonded interface relies on the creation of a compact and homogenous hybrid layer. In the etch-and-rinse technique, after the preliminary etching to demineralize the substrate, bonding monomers impregnate the porous etched substrate[2-5]. Thus stable bonds can be achieved if the etched substrate is fully infiltrated by the adhesive to avoid different degrees of incomplete impregnation[6,7]. Since the self-etch approach utilizes acidic adhesive co-monomers that simultaneously demineralize and infiltrate dentin, the adhesive stability is related to the effective coupling of the co-monomers with the infiltrated substrate[8].

FACTORS INFLUENCING AGING OF HYBRID LAYER

Both physical and chemical factors play an important role in clinical longevity of the hybrid layer.

Physical factors

The occlusal masticatory forces, repetitive expansion and contraction stresses due to temperature changes within the oral cavity[9] might affect the interface stability[10].

Chemical factors

- Acidic chemical agents in saliva, dentinal fluid, bacterial products, food and beverages further interferes the tooth biomaterials interface resulting in various patterns of degradation of unprotected collagen fibrils[11].
- Elution of resin monomers.
- Degradation of resin components[12].

DEGRADATION OF RESIN COMPONENTS

Degradation patterns observed within the hybrid layer after storage of a three-step etch and rinse adhesive system (Scotchbond Multi Purpose, 3M/ESPE, St. Paul, MN, USA) in water for 1 year were due to disorganization of collagen fibrils and hydrolysis of resin from interfibrillar spaces.

Studies reported high water sorption by hydrophilic acidic resin systems and low water sorption by hydrophobic resin. Water sorption causes a significant amount of decrease in the modulus of elasticity of the resins which causes the reductions in bond strength[13]. One study concluded that simplified etch-and-rinse adhesives have higher quantity of hydrophilic monomers compared to three-step adhesives and hence they exhibit high degrees of permeability after polymerization and increased nanoleakage expression[14].

DEGRADATION OF EXPOSED COLLAGEN FIBRILS

Deterioration of collagen fibrils within the hybrid layer, detectable both in vitro and in vivo tests reveals many exposed collagen fibrils within the hybrid layer. Complete infiltration and encapsulation of the collagen fibrils by the bonding resin are the final goals of bonding procedures. This is recommended in order to protect them against degradation[13].

For total- etch adhesives, a decreasing gradient of resin monomer diffusion within the acid-etched dentin results in incompletely infiltrated zones along the bottom of the hybrid Layer created by the discrepancy between the depth of acid etching and resin infiltration[15]. There is also insolubility of BisGMA in water-saturated dentin. By substituting ethanol for water, BisGMA / TEGDMA mixtures have shown to infiltrate dentin and produce high bond strength.

For self - etch adhesives, the acidic monomers simultaneously primes and infiltrates the dentin matrix resulting in fewer exposed collagen fibrils[16].

Matrix Metalloproteinases

MMPs are a class of zinc and calcium-dependent endopeptidases that are trapped within the mineralized dentin matrix during tooth development. Matrix metalloproteinase was first published in 1962 by Jerome Gross and Charles Lap. MMPs are classified into 5 main classes: collagenases, gelatinases, stromelysins, membrane-type and matrilysin. Activation of endogenous enzymes during dentin bonding procedures are responsible for the disappearance of collagen fibrils from incompletely infiltrated hybrid layers in aged, bonded dentin . Phosphoric acid demineralization activates the MMPs, trapped within the mineralized dentin, resulting in the collagenolytic and gelatinolytic activities identified within the hybridized dentin. Presence of MMP-2 and MMP-9 in demineralized mature dentin are identified by gelatin zymography and Western blotting. Cell secreted inhibitors called Tissue Inhibitors of Metalloproteinases (TIMPs) is balanced in time and spatially by the protein cleavage activity of MMPs. Connective tissue cells (fibroblasts, osteoblasts, and odontoblasts) as zymogens, a pro or inactive enzyme form plays an important role by secreting MMPs. They are released from the dentin by lowering the pH to 4.5 or below[17]. During acid etching of the dentinal surface there occurs release and increased activation of MMPs. Activating proteins are part of the Small Integrin Binding Ligand N-linked Glycoproteins (SIBLING) gene family . Bone Sialoprotein (BSP), Osteopontin (OPN) and Dentin Matrix Protein1 (DMP1) are the three binding proteins and these binding proteins pair specifically together with MMPs in the following groups for activation: MMP-2 with BSP, MMP-3 with OPN and MMP-9 with DMP1.

ROLE OF BACTERIA

Adhesion promoting monomers such as N-methacryloyl 5-aminosalicylic acid (5-NMSA) and Phenyl-P particularly methylene diphosphonate (MDP) slightly inhibit bacterial growth because of its specific antibacterial components (such as glutaraldehyde) which are found in some adhesives[18]. However, the antibacterial properties are significantly reduced by photocuring self-etching adhesives . Many studies have reported on the inability of adhesives to inhibit bacterial growth or secondary caries[19-21].

Ferrari and Tay conducteda study which demonstrated that nanoleakage can occur even in the absence of gaps along in vivo resin dentin interfaces suggesting degradation of incompletely infiltrated zones by host-derived proteinases. This process proceeds even in the absence of bacterial enzymes[22].

METHODS TO INCREASE BOND STRENGTH

Bond strength and durability rely on proper impregnation of the dentin substrate rather than on the thickness or morphology of hybrid layer and resin tags. Different clinical approaches have been proposed to improve monomers infiltration to reduce the rate of water sorption and also to reduce collagen degradation. The hydrophobic coating on one-step adhesive system results in thicker and uniform adhesive layer with lower concentrations of retained water and solvent. Thus this improves the quality of the adhesive layer. Bond strengths increases with each adhesive coating up to four coats, while at the same time nanoleakage decreases with each coat, being almost absent after four or more coats. Enhanced solvent evaporation aids in avoiding phase separation within the adhesive agent. The possibility of air-blowing the adhesive with full power might be a clinical technique for removing substantial interfacial water, thereby improving bonding effectiveness[23]. Extending the curing time beyond 20s the time period recommended by manufacturers results in improved polymerization and reduced permeability[12]. Use of electric current to enhance monomer infiltration in dentin. The device generates an electric current (ElectroBond; Seti, Rome, Italy) with which the handpiece of the device applies an adhesive-filled disposable sponge to dentin. This resulted in increased micro-tensile bond strength. FE-SEM and TEM findings revealed reduced nanoleakage in bonded interfaces.

1. CONCLUSION

As a hybrid layer is created by a mixture of the dentinorganic matrix, residual hydroxyapatite crystallites, resin monomers, and solvents, aging may affect each of the individual components differently or may result in synergistic combinations of degradation phenomena within the hybrid layer.

2. REFERENCES

1. Strassler HE, Mann M. Dental adhesives for direct placement composite restorations: an update. Dental Economics. 2011 Sep;15 (2): 1-16.
2. Tay FR, Lai CN, Chersoni S, Pashley DH, Mak YF, Suppa P, Prati C, King NM. Osmotic blistering in enamel bonded with one-step self-etch adhesives. Journal of Dental Research. 2004 Apr;83(4):290-5.
3. Neelakantan P, Sanjeev K, Rao CS. Ultramorphological Characterization of the Resin Dentin Interface–An in vitro Analysis of Nanoleakage Patterns of Dentin Adhesives. Journal of Clinical Pediatric Dentistry. 2009 Apr 1;33(3):223-30.
4. Nakabayashi N, Kojima K, Masuhara E. The promotion of adhesion by the infiltration of monomers into tooth substrates. Journal of biomedical materials research. 1982 May;16(3):265-73.
5. Van Meerbeek B, Dhem A, Goret-Nicaise M, Braem M, Lambrechts P, Vanherle G. Comparative SEM and TEM examination of the ultrastructure of the resin-dentin interdiffusion zone. Journal of Dental Research. 1993 Feb;72(2):495-501.
6. Sano H, Shono T, Takatsu T, Hosoda H. Microporous dentin zone beneath resin-impregnated layer. Operative dentistry. 1994;19(2):59.
7. Eliades G, Vougiouklakis G, Palaghias G. Heterogeneous distribution of single-bottle adhesive monomers in the resin–dentin interdiffusion zone. Dental Materials. 2001 Jul 1;17(4):277-83.
8. Yoshida Y, Meerbeek BV, Snauwaert J, Hellemans L, Lambrechts P, Vanherle G, Wakasa K, Pashley DH. A novel approach to AFM characterization of adhesive tooth–biomaterial interfaces. Journal of Biomedical Materials Research: An Official Journal of The Society for Biomaterials, The Japanese Society for Biomaterials, and The Australian Society for Biomaterials and the Korean Society for Biomaterials. 1999 Oct;47(1):85-90.
9. Gale MS, Darvell BW. Thermal cycling procedures for laboratory testing of dental restorations. Journal of dentistry. 1999 Feb 1;27(2):89-99.
10. De Munck J. Influence of a shock absorbing layer on the fatigue resistance of a dentin-biomaterial interface. Eur J Oral Sci. 2005;113:1-6.
11. Hashimoto M, Ohno H, Kaga M, Endo K, Sano H, Oguchi H. In vivo degradation of resin-dentin bonds in humans over 1 to 3 years. Journal of Dental Research. 2000 Jun;79(6):1385-91.
12. Cadenaro M, Antoniolli F, Sauro S, Tay FR, Di Lenarda R, Prati C, Biasotto M, Contardo L, Breschi L. Degree of conversion and permeability of dental adhesives. European journal of oral sciences. 2005 Dec;113(6):525-30.
13. Hashimoto M, Ohno H, Sano H, Kaga M, Oguchi H. In vitro degradation of resin–dentin bonds analyzed by microtensile bond test, scanning and transmission electron microscopy. Biomaterials. 2003 Sep 1;24(21):3795-803.
14. Hashimoto M, Tay FR, Ohno H, Sano H, Kaga M, Yiu C, Kumagai H, Kudou Y, Kubota M, Oguchi H. SEM and TEM analysis of water degradation of human dentinal collagen. Journal of Biomedical Materials Research Part B: Applied Biomaterials: An Official Journal of The Society for Biomaterials, The Japanese Society for Biomaterials, and The Australian Society for Biomaterials and the Korean Society for Biomaterials. 2003 Jul 15;66(1):287-98.
15. Pashley DH, Tay FR, Carvalho RM, Rueggeberg FA, Agee KA, Carrilho M, Donnelly A, García-Godoy F. From dry bonding to water-wet bonding to ethanol-wet bonding. A review

ISSN 2515-8260 Volume 07, Issue 03, 2020

of the interactions between dentin matrix and solvated resins using a macromodel of the hybrid layer. American journal of dentistry. 2007 Feb 1;20(1):7.

16. Nishitani Y, Yoshiyama M, Donnelly AM, Agee KA, Sword J, Tay FR, Pashley DH. Effects of resin hydrophilicity on dentin bond strength. Journal of dental research. 2006 Nov;85(11):1016-21.

17. Moon PC, Weaver J, Brooks CN. Review of matrix metalloproteinases' effect on the hybrid dentin bond layer stability and chlorhexidine clinical use to prevent bond failure. The open dentistry journal. 2010;4:147.

18. Imazato S. Antibacterial properties of resin composites and dentin bonding systems. Dental materials. 2003 Sep 1;19(6):449-57.

19. Emilson CG, Bergenholtz G. Antibacterial activity of dentinal bonding agents. Quintessence International. 1993 Jul 1;24(7):511-5.

20. Prati C, Fava F, Di Gioia D, Selighini M, Pashley DH. Antibacterial effectiveness of dentin bonding systems. Dental Materials. 1993 Nov 1;9(6):338-43.

21. Gondim JO, Duque C, Hebling J, Giro EM. Influence of human dentine on the antibacterial activity of self-etching adhesive systems against cariogenic bacteria. Journal of dentistry. 2008 Apr 1;36(4):241-8.

22. Ferrari M, Tay FR. Technique sensitivity in bonding to vital, acid-etched dentin. Operative dentistry. 2003 Jan 1;28(1):3-8.

23. De Munck JD, Van Landuyt K, Peumans M, Poitevin A, Lambrechts P, Braem M, Van Meerbeek B. A critical review of the durability of adhesion to tooth tissue: methods and results. Journal of dental research. 2005 Feb;84(2):118-32.