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Dentin Adhesion: Why Does It Fail and Methods to Prevent Bond Degradation: An Overview

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Abstract

Adhesive interfaces are susceptible to degradation. The reduction of bond strength values on ageing and progressive loss of resin dentin bond integrity has been reported extensively in the literature. An understanding of the mechanism of hybrid layer degradation has led the researchers towards development of strategies to preserve the hybrid layer integrity and bond durability.

The present review emphasizes the clinical approaches that can improve resin impregnation and the strength of polymer formed by the adhesives as well as reduce the activation of host-derived proteases further improving the longevity of the resin-dentin bonds.

Keywords: Dentin Bonding, hybrid layer, self etch, total etch, host derived proteases, Oxalate Desensitisers, resin impregnation, Biomimetic Remineralisation.

Introduction

The continuing advances in adhesive dentistry , since its evolution in 1955 by Buonocore have revolutionized the practice of contemporary restorative dentistry.[1] The demand for esthetic , tooth coloured restorative materials , along with the adhesive techniques has become a routine in today's dental practice.[2] The ultimate goal of adhesive procedures is to achieve an effective long lasting seal between the restoration and tooth structure, through surface modification and micromechanical retention.[3]

The two adhesive strategies namely the Etch and Rinse approach (E&R) and the Self Etch (SE) approach can be presently employed in resin bonding procedures.[4] Regardless of the adhesive strategy , dentin bonding relies on the formation of " Hybrid layer " or the " Resin Dentin interdiffusion zone ", a structure composed of demineralized collagen fibres reinforced by the resin matrix.[5]

However, several in-vitro and in-vivo studies have demonstrated that the hybrid layer created on the variable and dynamic dentin substrate is not perfect and is prone to hydrolytic degradation , thus inducing marginal discolourations , marginal leakage eventually leading to the subsequent loss of retention of the composite restoration.[6,7]

The present review elaborates on the mechanism of degradation of the resin-dentin bonds and focusses on the different strategies employed to promote stability and preservation of the adhesive interface over longer time.

Discussion

Understanding Adhesive Strategy: Etch and Rinse Vs Self Etch Approach

Based on the underlying adhesive strategy, contemporary adhesives can be broadly classified as “Etch & Rinse” and “ Self- Etch Adhesives”.[8] With the Etch and Rinse strategy , there is an initial etching step with 37 % phosphoric acid that completely removes the smear layer and demineralizes the superficial dentin to a depth of 5-8 µm creating microporosities into which the resin monomer penetrates and interlocks creating the “ Hybrid zone “. The etch and Rinse adhesives are further classified as “Three - step” and “two –step”. The Two step ER adhesives combines the primer and adhesive resin in a single bottle.[9]

With the self etch adhesive strategy , the etching and rinsing steps are omitted. They are composed of aqueous mixtures of acidic monomers (such as phosphoric acid or carboxylic acid esters) that simultaneously etch and infiltrate enamel and dentin and partially dissolve the smear layer and hydroxyapatite creating a hybrid zone that incorporates minerals and smear layer. The self etch adhesives can be further classified as “Two step” and “One step “.[10,11]

Importance of Creating “Hybrid Layer”

Hybrid layer , Is the resin infiltrated demineralized dentin having an ultimate tensile strength of about 120 Mpa , thus suggesting how strong the hybrid layer can be , once it is completely infiltrated with the adhesive resin . These strengths are far in excess of the forces of polymerization shrinkage. The creation of this high quality hybridized dentin is resistant to both acidic and proteolytic challenges, thus preventing microleakage and hence secondary caries.[12] Studies have reported that the two etch-and-rinse self-priming adhesives exhibited thicker hybrid layers than those found in self-etching adhesive systems. The all-in-one adhesives showed droplet formation between the adhesive and the resin composite.[13]

Failure of Adhesive Interface: Why And How …?

The exact mechanism for the degradation of the hybrid layer is not completely understood. However , the first phase involves the degradation of the resin polymer network followed by the collagen fibres .[14] The factors responsible for the degradation of the polymer network could be due to the inherent hydrophilicity of the adhesive resins seen particularly with One step or All in one adhesives. These self etch adhesives act as “ Semipermeable permeable “ thus allowing the passage of water in and out of the adhesive interface. Also , Studies have reported retention of water varying from 24.6 % to 41.6 % .[15]The entrapment of this excess water prevents adequate cross linking and hence inadequate polymerization of the adhesive layer. During the bonding of composite restorations , the surface and subsurface mineral component of dentin is removed either completely using acid etching with ER adhesives or partially with acidic primers and adhesives in self etch adhesives . This etched collagen fibers is then infiltrated with resin monomers . However , in reality they are not able to completely encapsulate the collagen fibers leaving partially or totally exposed collagen fibres at the bottom of hybrid layer which are lacking the protection of polymerized resin .This lack of resin protection & presence of water leaves the demineralized collagen fibers highly vulnerable to time dependant hydrolytic degradation.[16]

How To Optimize Resin Dentin Bonds…??

Enhancing resin-dentin bonding effectiveness and durability is a goal that needs to be achieved for improving the longevity of resin-based composite restorations.[17]

The clinical approaches to optimize resin dentin bonds fall under three major categories:

1. Improving resin impregnation into mineralized and demineralized dentin substrates(Table-1)

Method	Adhesive System	Mechanism	Concern
A) Use of vigorous rubbing motion[18]	Simplified ER adhesives , Self etch adhesives	▪ Allows Enhanced diffusion into wet demineralized dentin	▪ Technique operator sensitive ▪ Increased pressure on acid etched enamel prisms may have detrimental effects on enamel
B) Application of multiple adhesive coats[19]	Simplified ER and self etch adhesives	The first layers , as they begin to etch the dentin , may get buffered by the hydroxyapatite such that subsequent layers would improve the etching capability and hence resin impregnation	Time consuming
C) Delayed light curing [17]	Simplified ER and self etch adhesives	Enhanced solvent evaporation, thus leading to better resin impregnation.	Lack of clinical data

Table: 1

2) Improving the strength of the polymer formed by the adhesive systems (Table-2)

Method	Adhesive System	Mechanism	Concern
A) Application of additional hydrophobic coating [20]	Simplified self etch adhesives	The additional hydrophobic coating would act as a primer , reducing the inherent hydrophilicity of simplified adhesives	Time consuming
B) Extending the light curing time[17,21]	Simplified ER and self etch adhesives	Enhances formation of free radicals and hence the degree of conversion and polymerization	Requires clinical studies Time consuming

C) Use of warm air stream (60°C)[17]	Simplified SE adhesives	Enhanced solvent evaporation	Requires special devices Lack of clinical studies
D) Preheating of adhesive systems[17]	Simplified ER and self etch adhesives	Enhances monomer conversion leading to higher polymer cross linking	Potential effects on pulp and dentin Time consuming
E) Ethanol wet bonding technique[23]	Simplified ER and self etch adhesives	Ethanol replaces water from acid etched matrix, allowing the infiltration of the hydrophobic resins , creating hydrophobic hybrid layers	Requires careful clinical investigations

Table: 2

3) Improving the resistance of collagen fibrils to enzymatic degradation (Table-3)

Method	Mechanism	Concern	Evidence
A) Use of MMP Inhibitors (Protease inhibitors) [25] ▪ Chlorhexidine ▪ Chelating agents (EDTA) ▪ Tetracyclines & its derivatives ▪ Galardin	Acts by cation chelation , thus sequestrating the Zinc and calcium ions required for activation of MMP, responsible for collagen fibre degradation	Time consuming Mild cytotoxic effects reported	A systematic review and metanalysis published in 2014 reported Both 2% and 0.2% CHX had a beneficial effect for the stability of dentin adhesion after aging.[26]
B) Enzyme Cross linkers[22,27] ▪ Glutaraldehyde ▪ Carbodiimides ▪ Proanthocyanidins ▪ UVA activated riboflavin	Induces cross linking in collagen and hence prevents matrix degradation	▪ Longer application time(> 1 hour) ▪ Clinically not feasible ▪ Not applicable with self etch adhesive system	Requires clinical studies

Table: 3

Other Clinical Approaches (Table - 4) :

Method	Adhesive System	Mechanism	Concern
A) Use of Oxalate Desensitisers[17,21]	Simplified ER adhesives	Oxalate , used as an additional step before primer application occludes the dentinal tubules , thus reducing the transudation of water through dentin into the adhesive layer	▪ Concerns over Incompatibilities of the oxalate and the adhesive layer ▪ Requires prior dental demineralization , hence not applicable to self etch adhesive systems
B) Selective enamel etching [22,24]	Universal and self etch adhesives	▪ Improves the surface area for bonding ▪ Improves marginal adaptation and decreases microleakage	
C) Use of electrically assisted devices[17]	Simplified ER adhesives , Self etch adhesives	Enhances resin monomer infiltration into demineralized dentin by iantrophoresis	Lack of clinical studies

Table-4

Recent Trends and Future Prospects In Adhesive Bonding

The recent efforts are directed towards modification of resin monomer chemistry . Ether based and metharyalte based monomers are currently being explored for optimization of the physical characteristics and polymerization mechanism . Also , Thiolene based chemistry shows resistant to esterase degradation.[28]

A new approach to resin dentin bonding is to perfect the resin dentin bonds formed using Simplified ER and self etch adhesives . The process involves using remineralizing agents to backfill the water filled voids with nano meter sized apatite crystallites, also called as BIOMIMETIC REMINERALIZATON [29]. Polyanions like PAA , polyaspartic acid are used which bind to collagen and serve as template for calcium binding and promote apatite nucleation.The addition of bioactive glasses to the adhesive formulation has shown promising results, but it still requires further evaluations.[29]

Conclusion

The degradation of resin tooth adhesive interface is a common problem that reduces the longevity of adhesive

restorations. Hence , It is fundamental that professionals are aware of the strategies to counteract degradation as much as possible. Although ,none of the mentioned strategies are efficient to completely solve the problem, but they certainly represent reasonable alternatives to increase the lifetime of adhesive restorations. The clinician must therefore be aware of the various optimization strategies based on the particular adhesive technique to improve the life of their dental restorations .

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