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Current Advances In Adhesive Dentistry: A Mini Review

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Abstract:
In the present review, we contribute towards the better understanding of adhesion and the current trends. We cover the types of classification and how it was bettered with subsequent newer generations. The current trends in dentin bonding and the research that's contributed to a stronger dentin enamel and dentin restoration bonding is also explained in depth. We also discuss the various ways in which additives or certain modifications with the bonding protocol can enhance the bonding strength and lead to a long lasting restoration. Along with these use and advantages of lasers is also touched upon. Lastly we elaborate about the future of dental adhesives where the bonding material is derived from aquatic fauna.

Key-words: *Dental adhesives, restorative dentistry, adhesive dentistry*

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I. Background

Ever since Michael Buonocore introduced the acid etch technique, adhesive dentistry has been growing by leaps and bounds and has been experiencing a paradigm shift not only in restorative but cosmetic, prosthetic and the orthodontic fields as well (1). The current trends focus more towards reducing the bonding steps and making the whole procedure more clinician friendly (2). This shouldn't be achieved by reducing the bond strength and compromising the overall restoration.

Composite resins are widely used as a restorative material so much so that conventional amalgam is barely used now. But the longevity of resinous filling is questionable and failure rates are high mainly due to secondary caries, fracture, marginal deficiencies, wear and post- operative sensitivity. Also resin-dentin bonds are less strong than resin-enamel due to the heterogeneity of the structure and composition of dentin. Hence it is important to modify these adhesives to improve its dentin bonding ability (3).

The following review article will cover the advances, pioneering work and the advantages and disadvantages of the major bonding techniques.

CLASSIFICATION

Dental adhesives are currently classified by generation or by the way they interact with the smear layer (preparing dental cavities form a layer of cutting debris on the final prepared surface of the tooth, its known as the smear layer). The generational classification is based on the marketing chronology and doesn't necessarily mean that the newest/latest introduced adhesive is the superior one. As the generations have evolved it has aimed at reducing the number of steps/bottles used so as to make it easier for the clinician.

Generations of bonding agent	Bonding mechanism	Technique of bonding	shear bond strength MPa
First generation	Molecule interaction	No longer in use	2
Second generation	Surface wetting phenomenon	No longer in use	5
Third generation	Bonding to smear layered covered dentin	Multiple steps selective etch	12
Fourth generation	Forming hybrid layer	Three steps total etch	24
Fifth generation	Forming hybrid layer	Two step total etch	25

Sixth generation	Forming hybrid layer	Two steps self etch	20
Seventh generation	Forming hybrid layer	No mix, one step Self etching	25
Eighth generation	Forming hybrid layer	Total etch, selective enamel etch or self etch	30-38

And the second classification is split into two parts.

1. Etch and rinse (total etch): which dissolves the smear layer. Available in three or two step system
2. Self etch: incorporates the smear layer in certain portions (dentin). Available in single or two bottle systems

The first researchers to use Glycerophosphoric acid dimethacrylate (GPDM) were Kramer and McLean (4). Later, Buonocore used 7% hydrochloric acid and applied GPDM bonding and this laid the foundation for adhesive dentistry which has applications in almost all branches of dentistry (5). Later the second generation bonding agents were composed of halophosphorous esters of unfilled resins such as bisphenol-glycidylmethacrylate (BisGMA) and hydroxyethyl methacrylate (HEMA). However instead of bonding to the dentin these bonded to the smear layer. Hence the bond formed by these agents belonging to the first 2 generations was weak to withstand polymerization shrinkage and hydrolysis of composite resin, hence aren't used anymore. Next generation of agents aimed at modifying or removing the smear layer. The third generation bonding agents mainly used a hydrophilic dentin resin primer that penetrates and softens the smear layer and promotes the adhesion to dentin. Even though these agents did not completely eliminate marginal leakage they were still an improvement from the earlier bonding agents. Following these approaches a lot of studies and research was going on about how to increase the dentin bonding capacity and total etch technique was born where the enamel and dentin are etched with phosphoric acid which fully dissolves the smear layer (6). The next generation of primer has two functional groups, a hydrophilic component that binds to the dentin matrix and the hydrophobic one bonds to the resin. This resin-collagen layer is commonly called as the hybrid layer and Nakabayashi et al. were the first to report this in 1992 (7). This multi-step adhesive is considered to be the gold standard of adhesive dentistry. In the subsequent generation to improve the clinicians ease and reduce working time the primer and bond were combined in one application and thus 5th generation bonding agents were formed. But this still was a two bottle system. Later, self-etch adhesives were introduced which are single bottle systems that etch and bond simultaneously. They contain specific monomers such as 10MDP, 4-MET, and phenyl-P with carboxylic and phosphate groups. The latest generation the 8th founded by Voco contains nano sized fillers which increases the penetration is the resin and increases the depth of the hybrid layer and subsequently increases bonding strength. However if the thickness of the fillers is more the viscosity increases resulting in cracks in the restoration.

Despite this extensive research there are still instances in which failure of bonding is seen in clinical scenario and it called for the need of further research. Currently 6 strategies are available for overcoming this resin-bond degradation.

1.Use of collagen cross linking agents (8) (9) (10)- Agents like glutaraldehyde, carbodiimide, proanthocyanins, chlorhexidine, riboflavin 5- phosphate, bromelain, enzyme, methacrylate-modified chitosan, polyphenols aim to reinforce collagen fibrils through intermolecular crossing by increasing the strength of the hybrid layer.

The glutaraldehyde containing agents even though studies have shown that they can reduce the amount of collagen solubilized from dentinal scaffold into the hybrid layer and enhance the cohesive strength of the collagen fibrils, has been observed that it is highly toxic and its use in clinical practice is limited (11).

Carbodiimide on the other hand has shown promising results with clinically acceptable application time. It also has low cytotoxicity which makes it highly biocompatible.

Proanthocyanins improve the quality of the hybrid layer by improving the mechanical properties of dentin. They are highly capable of stabilizing demineralised dentin collagen against enzymatic activities clinically due to collagens cross linking effect.

Chlohexidine which is essentially an antimicrobial agent was also found to possess cross linking abilities. There are two distinct compounds cholrhexidine- methacrylate and chlorhexidine digluconate. chlorhexidine methacrylate was found to co polymerise with other monomers thus improving the stability of the hybrid layer. Chlorhexidine digluconate also resulted in a strong hybrid layer thus improving the resin dentin bonds.

2.Use of anti-oxidants (12)- Agents like proanthocyanidins, noni fruit juice, accel, vitamin c, vitamin e and quercetin.

Of these proanthocyanidins, noni fruit juice and accel restores the redox potential of NaOCl treated dentin and allows for proper bonding.

Also agents like vitamin c, vitamin E and quercetin improve the strength of the hybrid layer and it does it over a period of time.

3.Use of protease inhibitors (13) (14)- demineralised dentin collage matrix acts as a scaffold for resin infiltration during the resin dentin bonding procedure, forming the hybrid layer which is extremely important for dentinal bonding strength. Hence, degradation of dentin collagen matrices by matrix metalloproteinases and cysteine cathepsins are believed to be an important factor that causes restorations to fail.
Agents like carbodiimide, chlorhexidine, doxycycline, minocycline, polyphenols, benzalkonium chloride, and quaternary ammonium methacrylate polymer help in prolonging the dental bond durability.
Carbodiimide which is a collagen cross linking agent also works by inhibiting MMPs(matrixmetalloproteianse) which are calcium dependant endopepdisases that are associated with the degradation of of most extracellular matrix compounds and are found in the dentin matrix. Carbodiimide use thus helps to prolong the bond durability.
Tetracycline, minocycline and doxycycline have studies that have shown that when they are used after the acid etching step the bond strength and durability is immediately increased by inhibiting MMPs.
Polyphenols, quaternary ammonium methacrylate polymer and benzalkonium have all shown MMP inhibition activity which improves the quality of the hybrid layer.

4 Modification of bonding procedure- there are various methods by which bond strength is improved by changing the bonding protocol.
In the first technique hydrophobic resin is used after the bonding step and air dried so that it spreads as a thin uniform layer. This causes the hybrid layer to become densely packed and highly resistant to tensile forces and less prone to long term degradation.
Another method involves applying two layers of adhesive resin that produces longer resin tags thus enhancing the resin dentin bond.
Another approach is the ethanol wet bonding(EWB) method where the dentin is dehydrated by application of 50% ethanol for 10 seconds followed by 100% absolute ethanol for 10 seconds. This allowed for the resin to be infiltrated better due to early evaporation of water from the dentin matrix scaffold. Another method involves treating the enamel with 100% ethanol before bonding. These studies concluded that this method reduces water at the matrix as well as the hybrid layer level thus improving the bond strength. However further studies are important prior to safely incorporating these practices in clinical settings (15).

5. Laser treatment of the substrate prior to bonding (16)- non thermal argon plasma, non thermal atmospheric pressure plasma.
It has been suggested that ER:YAG laser may result in bond strength enhancement. It causes very specific physical changes on the dentinal surface like removal of the smear layer, evaporation of the water and organic component and creates 'crater- like ' irregularities that increase the surface area available for micromechanical retention.

6. Reinforcement of the resin matrix with inorganic fillers or remineralizing agents or nano fillers (17) (18) (19)- agents like carboxylic acid functionalized titanium dioxide nanoparticles, halloysite aluminosilicate clay nanotubes, copper, silver or zinc oxide nanoparticles, calcium silicate, fluoride, bioactive particles, apatite crystals increases the dentin bond strength, bond durability and reduces the bond degradation over time.
So even though protease inhibitors improve bond strength and prolong durability they cannot restore the demineralised hybrid layer. Also cariogenic bacteria can cause demineralization of the tooth at the tooth restoration margins leading to secondary decay. This is where these agents help by remineralising the hybrid layer. Bioactive glass, calcium phosphate, and hydroxyapatite can be utilized as a source of calcium phosphate which fossilizes the MMPs thus protecting the matrix collagen from future demineralization. Also adding alpha-tricalcium phosphate nanofiller to adhesive resins has been hypothesized to increase bond strength.Morever, another study was conducted where universal adhesive was reinforced by ribose crosslinker and it was concluded that using 1% or 2% ribose helped maintain the dentin collagen scaffold and was successful in improving wettability, protease inhibition and stability of demineralized dentin substrates.

Future directions:

Another interesting study stated that with the advances in biomimetic sciences in the future these new bonding agents might have components derived from protein-based, underwater bio adhesives secreted by aquatic animals like mussels and barnacles, making them less susceptible to hydrolytic degradation as well as the surface energy of the bonding substrates. They may also have fluorescent markers to indicate marginal leakage. They may also have self-repair and healing ability by inducing reparative dentin formation and promote mineralization of the sound dentin.

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