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ADHESIVE DENTISTRY : FUTURE FROM THE PAST

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Summary

Today the goal of adhesive dentistry is to accomplish the development of a truly adhesive bond between a restorative material and the natural tooth structures. Contemporary dentin bonding agents and composite systems are offering possibility to adhere, seal, provide durable bond, long lasting surface in very harsh environment. Adhesive approach to the reconstructive dentistry is enhancing conservation of tooth structure during preparation. The aim of this paper is to present the development of dentin bonding agents and their present status, interface between tooth and composite resin with all relevant clinician procedures regarding this matter. The new classification of dentin bonding agents will be presented as recommendation to the practitioners. Results of some studies will be used in discussion to clear the influence of composite resin on dental tissue, bond strength and nature with some compatible materials such are metal and ceramics.

Key words: dentin bonding agents, dental materials, adhesion, enamel and dentin tissue

Introduction

Rapid changes occurring in the field of restorative dentistry during the last few decades have transformed the practice of dentistry. Not only do we see restorative changes occurring because of technologic advances in materials and devices but also because of patients' demand for aesthetic, safe and durable dental care. The main breakthrough in aesthetic dentistry was opening the era of acid etching of enamel and latter dentin bonding procedures. Dentists must keep up with this rapid pace of change to stay in tune with latest developments. Therefore, it seems reasonable to gather some of scientific data and clinical experience in a state of the art aesthetic dentistry at the start of this century. This paper will present development of dentin bonding agents from the early beginnings with methacrylate-bonding to now days tissue sealing and resin infiltration. The efforts to distinguish the nature of the bond between composite systems, enamel and dentin tissue (mechanical vs. chemical bonding) will be presented. One could say that development of dentin bonding agents should lead to new generations of chemicals that provide intimate contact between cavity walls and restorations without microleakage.

The nature of a bond between two different materials might be mechanical, chemical, or a combination of these two. Typical example of mechanical bond is penetration of composite resin into etched enamel. After

setting of the resin micromechanical interlocking is achieved. This is a base for good seal, adaptation and it prevents gap formation and microleakage around composite filling.

The benefits of the reliable and durable adhesion between tooth structures and composite resin are twofold: conservation of sound tooth tissues and elimination of bacteria penetration around cavity walls. The development of dentin bonding agents in the beginning was based on efforts to achieve chemical bonds, where one part of adhesive molecule bonds with Ca^{++} ions and another part copolymerizes with successively applied composite resin. For this purpose a methacrylate was used¹. The other possibility at that time was to establish covalent bond to dentin proteins, preferably collagen.



Fig.1: SEM micrograph of etched enamel with 37% orthophosphoric acid after 30 seconds.

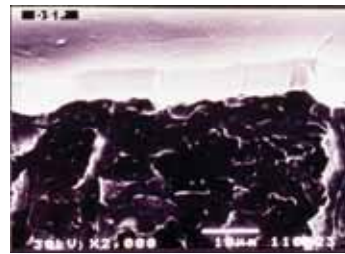


Fig.2: SEM micrograph of DBA-dentin interface with Dentsply bonding agent. Samples were demineralized and deproteinized.

Resin enamel bonding is the most reliable and most predictable of all bonding procedures. The basis of this type of bond is etching enamel with phosphoric acid. This started with research of Buonacore in 1955 when he described the use of 85% phosphoric acid on enamel surface². This acid was firstly applied on enamel surface for one minute. Even with such a strong concentration, the effect on the pulp was no more severe than that of distilled water according to research of Gwinnett^{3,4}. That opened the safe approach for this handy and elegant method in future conservative dentistry. Now days the use of 35 to 37% phosphoric acid is advocated for 15 to 30 second on enamel tissue⁵. During this time micro gaps can be find within the depth of 25 to 50 microns into subsurface enamel. Acid etching causes enamel prisms and interprismatic enamel to dissolve differently so that a microretentive pattern is formed^{6,7}(Figure 1.). This gives a reliable basis for composite resin bonding. When the low viscosity bonding agents are placed on etched enamel surface, the resin enters the enamel gaps and forms resin tags deep into the structure of enamel. The use of the composite materials with acid etch technique can provide a durable and intimate marginal relationship with enamel.

Bearing in mind the composition and structure of dentin tissue, one could easily recognize that obtaining adhesion to dentin in such a simple manner is not

almost completely denuded of hydroxyapatite, so possibility for additional chemical interaction is excluded. The adhesion mechanism to enamel and dentin is therefore based on diffusion and very similar to etch and rinse systems. Hybrid layers formed by these adhesives are 2-3 μm wide, with morphological characteristics that closely resemble ones observed in etch and rinse systems⁴⁶.

Glass-Ionomer Based Adhesives

Glass-ionomer based adhesives (Fuji Bond LC – GC, Reactmer – Shofu) are usually used through two clinical application steps. In step one, polyalkenoic acid conditioner is applied, rinsed off and gently dried without dehydrating the surface, resulting in 0.5-1 μm demineralization. Step two is the application of the bonding agent. Adhesion mechanism is twofold, and similar to mild self-etch adhesives: micro-mechanical, through hybridization, and chemical, through ionic bonding of carboxyl groups of the polyalkenoic acid with hydroxyapatite⁴⁷.

Laboratory Bond Strength Testing

One of possible ways to investigate and compare adhesive systems is laboratory bond strength testing. In the beginning, shear and tensile bond strength tests had been used. Along with the development of adhesive systems,



Fig.13: A sample prepared for microtensile bond strength test. The upper half of the beam is made of composite resin and the lower half is dentin. Cross sectional area is 0,9mm².

some drawbacks of these tests were recognized, like lack of standardization⁴⁸.

Another disadvantage of conventional tests is non-uniform stress distribution which, in contemporary adhesive systems, tends to produce mostly cohesive fractures of dentin, therefore precluding measurement of interfacial bond strength. In 1994, Sano et al. introduced microtensile bond strength test, using so-called hourglass designed specimens⁴⁹. Although this method is more time consuming, the highest stress during testing is built-up right at the interface and fractures are mostly adhesive. It also makes

possible. Dentin tissue is surrounding pulp chamber and root canals. In coronal part it is covered with enamel and in root area with cementum. Dentin is composed of about 50% vol mineral, 30 % vol organic matter and 20 % vol fluid. By weight, 20% is organic material, primarily collagen and collagen-type compounds, and the inorganic percentage is about 70% presented as apatite or amorphous calcium phosphate. Structure of the dentin tissue can be described as a complex hydrated composite of four elements: oriented tubules surrounded by a highly mineralized peritubular zone, embedded in an intertubular matrix consisting largely of type I collagen with embedded apatite crystals, and dentinal fluid⁸. The dentinal tubules are not smooth tubes, but have irregular walls with many lateral branches and micro channels that communicate with surrounding tubules. They are filled with odontoblastic processes close to the pulp chamber and they permit the fluid movement which is related to pain and sensitivity⁹. The normal mineral content of dentin can be found in two areas between tubules: in the intertubular dentin and concentrated in peritubular dentin. The apatite crystals are much smaller than in enamel tissue and therefore much more difficult to study. Crystallite orientation has some relationship with tubule direction. Dentin liquor is an extracellular tissue liquid with high protein content formed in the pulp. Due to the pulpal tissue pressure of 20 to 30 mm Hg, the dentin fluid flows outward. After tooth preparation with rotating instruments a specific structure is formed on the surface of dentin. It is a 1 to 5µm thick smear layer, that consists of hydroxyapatite crystals and denatured collagen, and it can not be removed with cotton or water. This biological liner reduces sensitivity and lowers the rate of flow of the dentin liquor. However, smear layer in this form is not a reliable bonding surface¹⁰.

Adhesive systems have most commonly been classified into generations, mostly according to the time of the release into dental market. The first dentin bonding generation was actually unfilled resin, based on a Bowen resin bis GMA which just improved wetting of enamel. Bond strength values with etched enamel were satisfactory - 15 to 20 Mpa, but bond to dentin was negligible. Second generation of DBA was based on organic phosphate esters and methacrylate which were bonded to calcium ions of hydroxyapatite in dentin (Figure 2.). Bond strength values with dentin ranged from 2 to 5 MPa. Unfortunately, the bond did not last as it was quickly broken due to hydrolysis of its ester bonds. The era of priming and conditioning the exposed dentin tissue started with the third generation of dentin bonding agents¹¹. For the very first time bond strength values reached 7 to 15 MPa. The idea was to increase the wettability of dentin, and today it is a state of the art. There have been two major groups of dentin bonding agents: one where the smear layer was removed with chelating agents such is EDTA, or the other group with priming agents which modified the structure of the smear layer. A representative of the first group was Gluma bonding system where for the first time the resin tags were reported (Figure 3.), as a basis for micromechanical

retention. With second group (Superlux Prep, Prisma Universal bond 2) crystal like formations were reported as an interface between dentin tissue and composite resin^{12,13}(Figure 4.).



Fig.3: SEM micrograph of Gluma bonding resin tags that penetrated dentin after EDTA pretreatment. Samples were demineralized and deproteinized.



Fig.4: SEM micrograph of modified smear layer with Prisma Universal Bond 2. Samples were demineralized and deproteinized.

Classification of Contemporary Adhesive Systems

In the past few years, the so called "generation" classification has been criticized, as being mainly chronologically based, thus lacking scientific background and fairly describing adhesion mechanisms.

Contemporary adhesive systems are now classified in a different manner. The new classification evolved from the description of fundamental principle of adhesion. Basic adhesion mechanism is an exchange process comprising of removing inorganic tooth structure and replacing it with resin monomers¹⁴. Upon polymerization, resin monomers become micro-mechanically interlocked into created porosities, due to diffusion mechanisms, and it is believed that relationship achieved this way contributes the most to the final quality and longevity of the tooth-restoration interface (Figure 5.). Possibility for chemical interaction of resin monomers with tooth tissue was considered to be of secondary or no importance at all, depending on the adhesive system itself. Recently, the idea of possible advantages of chemical interaction between functional monomers and tooth tissue has drawn new attention, mostly in terms of potential benefits against hydrolytic degradation to which adhesive systems are exposed over a long period of clinical service^{15,16}.

Depending on adhesion strategy and the intensity of exchange process, modern adhesive systems can be categorized into three major groups¹⁴: etch and rinse (formerly referred to as "total-etch systems"), self-etch and glass-ionomer based adhesives. Between each group, adhesives can be further classified according to the number of clinical steps required for application.

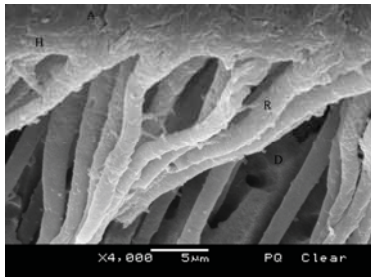


Fig.5: SEM micrograph of a two-step etch and rinse adhesive system PQ Clear (*Ultradent*) interface with dentin. Samples were demineralized (6N HCl, 30 seconds) and deproteinized (2.5% NaOCl, 10 minutes)* to enable the examination. A: adhesive layer. H: hybrid layer. R: resin tag. D: dentin.

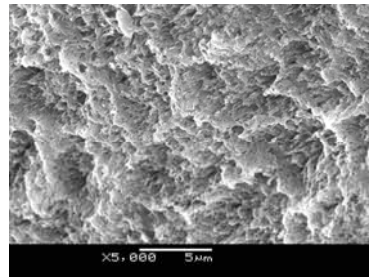


Fig.6: SEM micrograph of enamel ground with 600 grit Silicon carbide paper and etched with 37.5% orthophosphoric acid (Gel Etchant - Kerr) for 15 seconds. A well defined etching pattern is visible.

Etch and Rinse Adhesives

Etch and rinse adhesive systems are used either through two or three clinical application steps. First step always involves application of the conditioner or acid etchant (30-40% phosphoric acid) on both enamel and dentin. In three-step etch and rinse systems (also categorized into 4th generation), first step is followed by application of the primer, or adhesion promoter, and in the third step bonding agent or adhesive resin. Two-step etch and rinse systems were next to be introduced (also known as 5th generation dentin bonding agents), offering primer and adhesive combined into one bottle. Bonding to phosphoric acid-etched enamel remains the most predictable and effective procedure in adhesive dentistry (Figure 6.).

Mechanism of adhesion to dentin is similar for three- and two-step etch and rinse systems. The first, etch and rinse phase, completely removes smear layer, opens dentinal tubules and demineralizes dentin surface to a depth of 3-5 μm¹⁷. By this step, collagen fibrils become almost completely exposed, denuded of hydroxyapatite and form a micro-retentive network. Monomers that are successively applied should completely infiltrate the spaces between collagen fibers in order to achieve micro-mechanical interlocking, described and referred to as a hybrid layer¹⁸⁻²². Besides the process of hybridization, resin penetrates into opened dentin tubules and forms resin tags (Figure 7.). However, the length of resin tags itself does not influence bond strength and is considered to be of secondary importance. The adhesion mechanism in etch and rinse systems is purely based on micro-mechanical interlocking, since no chemical interaction is possible between collagen fibers depleted from hydroxyapatite and functional groups of monomers²³.

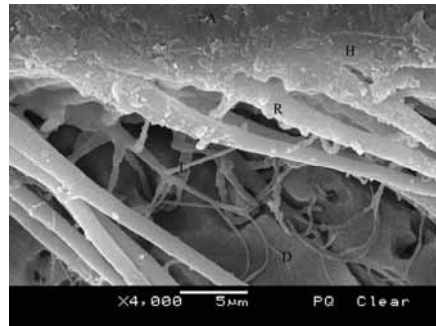


Fig.7: SEM micrograph of a two-step etch and rinse adhesive system PQ Clear (*Ultradent*) interface with dentin. Samples were demineralized and deproteinized. An extensive resin penetration into dentin tubules is visible, along with forming of numerous lateral tags. A: adhesive layer. H: hybrid layer. R: resin tag. L: lateral tag. D: dentin.

Features of three-step etch and rinse systems

In three-step etch and rinse systems, primer and adhesive resin are applied in separate clinical steps. On dentin, priming step should assure transforming hydrophilic into hydrophobic state. Primer wets exposed collagen fibers, carries monomers into porosities between fibers and at the same time displaces residual moisture from the surface through evaporation of the solvent included in its formulation. Following priming step, adhesive resin is applied, aiming to fill remaining porosities between fibers, form resin tags that seal dentinal tubules and stabilize hybrid layer. Adhesive resin should also provide methacrylate double bonds for co-polymerization with the restorative resin. Unlike dentin, enamel tissue does not require a separate priming step, since being hydrophobic in nature. On the other hand, application of primer onto acid-etched dentin doesn't negatively influence adhesion with enamel. When a wet bonding approach is followed (described later), and cavity is left moist after rinsing of the acid, it is important to apply primer on enamel to ensure that residual surface moisture is displaced through evaporation of the primer solvent.

Features of two-step etch and rinse systems

Two-step etch and rinse systems were introduced in attempt to reduce the number of application steps and simplify the bonding procedure. Since priming and bonding step were joined, these systems needed to be formulated as more hydrophilic, compared to conventional three-step etch and rinse systems. The solvent to monomer ratio in these systems is also higher, which can result in applying the adhesive in a layer too thin. Bearing in mind that the layer too thin won't polymerize, due to oxygen inhibition, some manufacturers recommend applying adhesive resin in multiple layers. This way, actual clinical

application time is not reduced, and in general, these systems have been described as being more technique sensitive than three-step systems²⁴.

Wet and dry bonding approach

The main reason for widely discussed technique sensitivity of etch and rinse systems is the questionable degree of surface wetness needed after rinsing the acid. While enamel should preferably be dry to allow penetration of adhesive monomers, proper treating of dentin is more complex. As mentioned before, etching and rinsing step leaves dentin surface demineralized to a depth of 3-5 μ m. More importantly, collagen fibers are exposed and left without inorganic support of hydroxyapatite. In order to achieve penetration of resin monomers into such a structure and assure interlocking, collapse of collagen fibers needs to be prevented. It has been described that overdrying of dentin surface induces collapse of collagen fibers which form a coagulate, thereby impeding proper resin penetration²⁵. Depending on the kind of solvent of the primer (or primer/adhesive in two-step systems), two different clinical approaches have been described. One method is referred to as wet bonding, and it was introduced in the early '90s by Kanca²⁶ and Gwinett²⁷. This technique should be used with acetone based adhesive systems. The cavity is left visibly wet after rinsing the phosphoric acid, and wet bonding concept relies on the ability of acetone to displace residual water, at the same time carrying resin monomers into porosities of the collagen web. Acetone solvent is then gently dried to evaporate, while monomers stay left behind. The critical step in this approach is the precise amount of surface wetness. If a cavity is left too wet, solvent will not be able to displace all the water, and consequently, polymerization will be affected. The other, so-called "dry bonding" approach is less technique sensitive. This approach is advised to be used with water/ethanol based adhesives. In general, cavity should be slightly dried, since these primers can re-hydrate and re-expand the collapsed collagen fibers.

Regardless of the bonding technique used, the possibility for discrepancy between depth of dentin demineralization and monomer infiltration²⁸⁻³⁰ was recognized as a main drawback of etch and rinse adhesives. It was shown that leakage can exist within the porosities of the hybrid layer even in the absence of gap. This specific form of leakage is referred to as nanoleakage, and in its initial description it was explained by incomplete infiltration of resins into acid etched dentin³¹.

Self-Etch Adhesives

The self-etching adhesive concept is generally based on the use of non-rinsing acidic monomers that simultaneously condition (etch) and prime enamel and dentin. This concept was first introduced in the early '90s with

Scotchbond 2 (3M), but this adhesive was applied on dentin alone, requiring a selective acid etching of enamel. Contemporary self-etching adhesives are applied on both enamel and dentin. According to the number of clinical application steps, further classification can be made to two-step and one-step systems.

In two-step systems (also referred to as 6th generation), application of a self-etching primer is followed by adhesive resin (AdheSE – Ivoclar Vivadent, Contax – DMG Hamburg, Clearfil SE – Kuraray, OptiBond Solo plus self-etch system – Kerr, Unifil Bond – GC).

One-step systems combine conditioning, priming and bonding into a single clinical step (following “generations” approach, classified into 7th generation). These systems can be further divided into two sub-groups. One group represents one-step two-components adhesive systems in which two components are mixed shortly before applying (Adper Prompt L-Pop – 3M ESPE, Prompt L-Pop 2 – 3M ESPE, Futurabond NR – Voco). The other group represents so called “all in one adhesives”, the newest achievement in adhesion to tooth structure. These are one-step one-component self-etching adhesives, that require no mixing (i-Bond – Kulzer, G-Bond – GC).

Self-etching systems are often referred to as utilizing the most promising adhesive approach. Since rinsing phase is excluded, so is the need for establishing the debatable optimal level of moisture on cavity surfaces, which significantly reduces technique sensitivity. These systems are user-friendly due to reduced number of application steps and reduced application time. Another important characteristic of self-etching systems is simultaneous demineralization and infiltration of resin monomers. This feature was believed to ensure that no discrepancies are possible between two processes, unlike etch and rinse systems.

However, recently published studies demonstrated the phenomenon of nanoleakage in some self-etching systems³² and concluded that the general concept that self-etch adhesives etch and infiltrate to the same extension in dentine doesn't apply to all adhesives in this category. It was also pointed that the original description of nanoleakage should be redefined, since tracer identified spaces within the adhesive and hybrid layer are believed to form as a result of incomplete water removal from the adhesive itself, rather than incomplete resin infiltration^{33,34}. Water is a common part of all self-etching systems. It ionizes acidic monomers, therefore enabling demineralization of tooth tissues. Lately, a lot of research has been focused on simplified, more hydrophilic one-step systems. Studies reported that these adhesives do not seal dentin very well, since being permeable to dentinal fluid, resulting in formation of water droplets along the adhesive-composite interface³⁵.

Concern is often raised regarding the quality of adhesion of self-etching systems with enamel since the pH value of self-etching primers is a few times higher compared to phosphoric acid (Figure 8. and 9.). Numerous studies

showed that bond strength of self-etch systems to enamel was either in the range of etch and rinse systems, or lower³⁶⁻³⁹.

In addition to classification according to number of clinical steps, self-etching systems can be divided depending on etching aggressiveness, into mild, moderate and strong^{40,23}. This particular classification may be meaningful as it is based on morphologic findings at the tooth-adhesive interface.

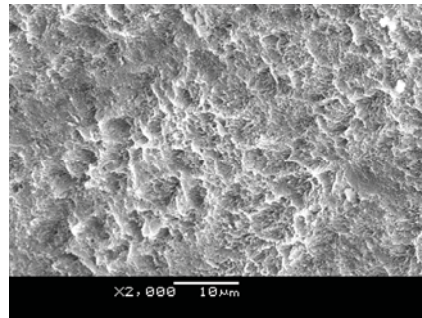


Fig.8: SEM micrograph of enamel ground with 600 grit Silicon carbide paper and etched with 37,5% orthophosphoric acid (Gel Etchant – Kerr) for 15 seconds.

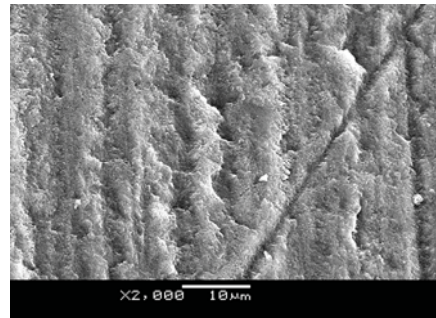


Fig.9: SEM micrograph of enamel ground with 600 grit Silicon carbide paper and conditioned and primed with a self-etching primer (AdheSE – Ivoclar Vivadent).

Mild Self-Etch Adhesives

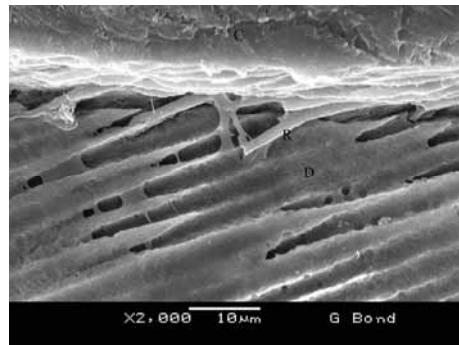


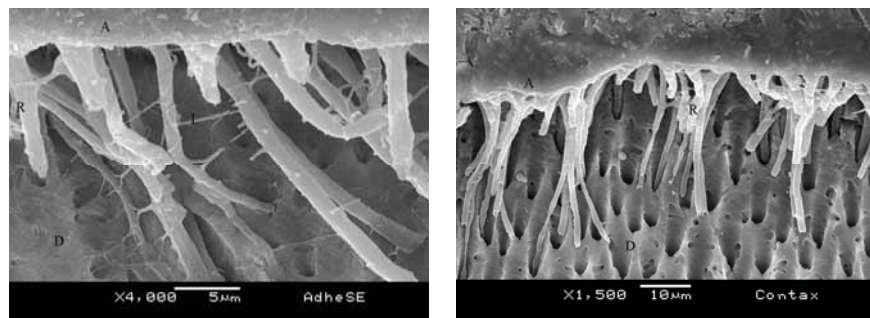
Fig.10: SEM micrograph of a mild one-step one-component adhesive G-BOND (GC Corp.) interface with dentin. Samples were demineralized and deproteinized. Hybrid layer is not visible. Resin tags formation is minimal, with non-uniform tags and no lateral tags. C: composite resin. R: resin tag. D: dentin.

Mild self-etch adhesives have a pH of around 2, and demineralize dentin to a depth of 1μm, in a way that collagen fibers are not completely deprived of hydroxyapatite. Smear layer is dissolved and becomes an integral part of a hybrid layer which is less than 1μm thick (Figure 10.). Although hybrid layer is noticeably thinner compared with etch and rinse systems, it has been shown that this feature doesn't negatively affect bond strength of self-etch systems^{41,42}. An important characteristic of mild self-etch

systems is possibility for additional chemical interaction between functional groups of monomers and calcium of hydroxyapatite that is surrounding collagen fibers. Using X-ray Photoelectron Spectroscopy (XPS)⁴³ it is possible to investigate both the existence of a chemical interaction and its intensity, through quantification of the degree of ionic bond formation between acidic groups of functional monomers with calcium of hydroxyapatite. In a recently published study it was shown that investigated functional monomers (4-MET, phenyl-P and 10 MDP) of different mild self-etching systems do interact chemically with hydroxyapatite within a clinically reasonable time⁴⁴. It has also been shown that the chemical bonding potential of the acid/acidic monomer will be higher if the calcium salt that it forms is less soluble⁴⁵.

Moderate self-etch adhesives

Moderate self-etch adhesives have a pH of around 1.5, which is why micro-mechanical interlocking at dentin and enamel induced by systems from this group is more intense compared to mild self-etch adhesives (Figure 11. and 12). Also, residual hydroxyapatite is present at the hybrid layer base, and might serve as a receptor for additional chemical reaction.



Figures 11 and 12: SEM micrographs of moderate two-step two-component adhesives AdheSE - Ivoclar Vivadent (figure 7) and Contax - DMG Hamburg (figure 8) interface with dentin. Samples were demineralized and deproteinized. Resin tag formation with corresponding lateral tags is visible. Hybrid layer is not clearly visible. A: adhesive. R: resin tag. L: lateral tag. D: dentin.

Strong self-etch systems

Strong self-etch systems have a pH of 1 or less, and degree of demineralization induced on enamel and dentin is the highest among self-etching systems. Dentin is demineralized in a way that hydroxyapatite is

possible to measure bond strength on any area of the tooth, on sclerotic or on caries affected dentin, and even calculate means and variances for single tooth. In the last decade this method has been widely excepted and at the same time criticized and modified. Shono et al⁵⁰ introduced the so-called non trimming version of microtensile test, which uses sticks (beams) made half of dentin/enamel and half of composite resin, with a cross-sectional area of bellow 1mm²(Figure 13.). In a recently published study⁵¹ these two methods were compared and hourglass specimens were found to show more defects near the bonding interface, probably because trimming is usually done free-hand. In attempt to standardize the microtensile test as much as possible, some researchers use MicroSpecimen Former, which enables producing specimens in the form of sticks that are trimmed at the interface to a cylindrical shape⁵².

Although there is a correlation between laboratory and clinical effectiveness²³, long term, controlled clinical trials remain the most relevant way to completely evaluate new material or treatment method.

Biocompatibility Testing

Most of the testing regarding biocompatibility of dental materials point out on their possible citototoxicity. Today, during the standard procedure of pre-clinical investigation, application of different tests recommended by ISO 10993 is supposed to present possible citotoxicity of tested materials, all with intention to introduce standards in this kind of testing⁵³.

During the citotoxicity testing of some hybrid materials samples (ISO10993-5: Test for citotoxicity), Marković (2001)



Fig.14; Appearance of cell cultures 48h following setting of test samples (Luxat). Reduction in number and loss of fibroblast cell morphology. Remaining cells are of filamentous appearance with no signs of mitotic activity.

noticed while working on human diploid line WI 38 change in acidity of MEM-Eagle medium and reduction of cell culture ranging from moderate to full cell destruction (Figure 14.). Change in acidity undoubtedly disturb stability and cause variability of cell culture. Further investigation on degree of diffusion of potentially toxic substances through dentin would be of great importance⁵⁴⁻⁵⁶.

Tests of tissue response on implanted materials (ISO10993-6) in the same investigation showed moderate response on surrounding tissues. Mild aseptic inflammatory reaction was registered in tissue surrounding implanted sample, together with appearance of cystic formation. In the

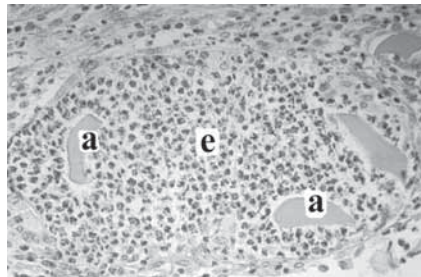


Fig.15: Particles of tested materials (a) inside the muscle tissues in strong eosinophilic (e) aseptic reaction.

center of allergic reaction around particles of tested material, eosinophilic cells in various stages of differentiation may be noticed (Figure 15.). Pre-clinical testing of dental materials where a direct contact of material with cell culture or living tissues of experimental animals is accomplished show that it provokes significant reaction that has to be declared as an undesirable one⁵⁷⁻⁵⁹.

However, investigations carried out by the authors Bergenholz (1989)⁶⁰, Brannstrom (1982)⁶¹, and Cox (1987)⁶² point to significance of bacteria presence below the filling and their influence on pulp tissue. Therefore, the aim of adhesive dentistry is to provide proper marginal adaptation of cavity filling in order to prevent possible changes on pulp tissue.

Investigation of the authors Kanca (1992)⁶³, Pashley (1993)⁴ White⁶⁴ and Cox (1994)⁶⁵ conducted on Rhesus monkeys and the influence of total etch technique on their pulp tissue, where the teeth were extracted and analyzed after 3, 25 and 80 days, showed that with routine dentine etching, irritability factor was not confirmed.

The influence of composite materials and components that might be obtained from them, have to be observed in the light of buffer capacity of remaining dentine, smear layer, dentin permeability and length and extending direction of dental tubules, since a simple interpretation of results of biocompatibility tests may lead to a wrong conclusion on influence of many dental materials⁶⁶.

Synergism Of Adhesive Systems With Other Materials

Bonding to metal surfaces has always proven to be difficult. The metal structure can be precious or nonprecious alloy, depending on the thickness and the amount that will be exposed. For adequate bonding it is necessary to obtain the clean surface and adhesion promoting primer. In laboratory conditions, adhesion can be improved by the use of silica coatings. These coatings are connected with heating which is not possible in oral surrounding. Up to now the simplest way intraorally to clean the surface seems to be sand blasting. Metal surface must be sand blasted with clean at least 110 microne grain size Aluminum oxide and 2 bar of air pressure. Various compounds have been used as priming agents (Figure 16.). One recently developed and introduced interface lining is Kevloc System. It uses the principle of direct

acrylizing of metal surface. Kevloc primer and layer is fused to the metal surface. With this procedure surface penetration and water resistant coating is achieved. Kevloc replaces complicated handling with easy and simple application, achieving a strong bond between metal and resin⁶⁷(Figure 17.).



Fig.16: Pretreatment of metal surfaces prior luting with composite resin



Fig.17: Reinforced interface with Kevlock System provides reliable basis for long lasting prosthodontic constructions made from composite resin, such is ArtGlass, on metal alloy.

To bond composite resin with organic base to a porcelain surface with inorganic base there is a need for modification of the porcelain surface to enhance the compatibility of resin and to achieve high bond strength. Silane primer is the best coupling agent to achieve reliable bond strength. To explain proper porcelain bonding there is a need to clear the chemistry of both silane compound and the porcelain surface itself. Porcelain contains silica in addition with other alkaline oxides. As the water is absorbed on the surface of porcelain this layer could become strongly alkaline. Therefore there is a need to place hydrofluoric acid based porcelain etchant, which will wash away alkaline layer. After this etching procedure a single component silane in alcohol or acetone solution is used. An organosilane compound is hydrolyzed in the presence of water and this silanol is reactive and it reacts with the porcelain surface. With a layer of unfilled resin durable and long lasting adhesion can be obtained with composite resin⁶⁸.

Conclusion

At the end one could ask: What will be the future in adhesive dentistry? Where is the bonding agent that will be capable of preventing both displacement of the restoration and the formation of gaps? The future of dentin bonding agents is to become simple for use, one-step, multi purpose, biocompatible, containing fillers with -OH ions with high pH values, more elastic, with real Fluoride adsorption and release, strong and reliable.

Composite resins are to be based on epoxy resins and resins which will not shrink but expand slightly during setting, mechanically improved, stable, with glass particles and strips or fibers. Also, curing time is to be shorter and setting improved. The benefits for clinicians will be in simple bulk placement, elimination of postoperative sensitivity and secondary caries, with extensive durability and longevity achieved. If our predictions are wrong, than Edmund Burke, an 18th century statesman was right when he said: "You can never plan the future by the past".

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