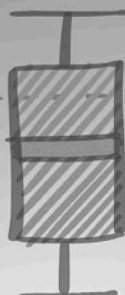


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## iBOND® Universal

Dental Science: Scientific Compendium

Giving a hand to oral health.



**KULZER**  
MITSUI CHEMICALS GROUP

## Preface

Advances in the development of adhesive technology greatly influence treatment concepts in the field of conservative dentistry. Adhesive filling therapy for the first time ever enables a direct, stable, aesthetically pleasing and minimally invasive restoration. Various concepts for bonding to the hard tooth tissue were pursued. There are presently two main clinically relevant approaches to the adhesive bonding of composites to the hard tooth tissue: etch & rinse (total-etch) and self-etching techniques (Cardoso *et al.*, 2011; Frankenberger, 2013; Pashley, *et al.*, 2011; Van Meerbeek *et al.*, 2011).

The primary aim was to make the bonding process simpler and more reliable, which was achieved mainly by reducing the number of steps involved. Etch & rinse bondings were reduced from three or more steps to the two steps of etching and bonding by introducing one-bottle adhesives (Frankenberger, 2013; Frankenberger, 2001). The self-etching products were developed into all-in-one adhesives in which all the components are contained in a single bottle. These one-bottle adhesives gained popularity thanks to their ease of use, and they also confirmed themselves in various clinical studies (Kugel & Ferrari, 2000). The etch & rinse technique offers clear benefits in terms of adhesion to the enamel. The strengths of the self-etching technique are seen especially when used on dentine (Hannig *et al.*, 1999). For several years, selective enamel etching has been promoted as a technique combining the benefits of etch & rinse with those of the self-etching technique (Suh, 2014).

Many dentists decide which adhesive to use according to the particular indication. They therefore have to keep several adhesives with different usage protocols ready, increasing the risk of incorrect usage.

The recently developed group of universal adhesives helps to minimise this risk (Suh, 2014; Miyazaki, 2014). The term “universal adhesive” is, however, defined differently by the

individual manufacturers: common to all of them is that they can be used together with the etch & rinse technique, selective enamel etching and the self-etching technique.

There are also universal adhesives that additionally adhere “universally” to various surfaces (e.g. ceramics, metal alloys, composites). Not all universal adhesives are suitable for all surfaces. Several of the universal adhesives require an additional “dual cure” activator that ensures compatibility with self curing and dual-curing composites and resin-based cements. The term “universal” therefore does not mean actual universal applicability for all products.

With iBOND Universal, Kulzer has drawn on its many years of scientific and clinical experience in the development of adhesives to develop a universal adhesive which can be used not only in the various bonding techniques but also adheres to a wide variety of dental materials.

It does not require an additional activator in combination with dual-curing and self-curing composites. iBOND Ceramic Primer is additionally required for adhesion to silicate ceramics. With iBOND Universal, an innovation developed in a German-Japanese collaboration, Kulzer is now continuing the tradition of developing easy-to-use and reliable adhesives for a successful daily dental routine that it began in 2007 with the first all-in-one adhesive.



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# Introduction to adhesive technology

Adhesives in dentistry are generally used to bond a resin-based restorative material to the hard tooth tissue.

Adhesives must connect different materials with one another. First, they have to ensure permanent anchoring to the enamel and dentine (Silva e Souza, 2010; Van Meerbeek, 2001; Toledano, 2001) while also achieving good adhesion on composite restorations or, sometimes, on restorations made of metal and ceramic (Chen, 2013; Chen, 2012).

The great advantage of the adhesive technique is that macromechanical retentions in the cavity design are unnecessary. Compared with an amalgam filling, this eliminates the preparation of undercuts and enables a cavity geometry that preserves hard tooth tissue (Kugel & Ferrari, 2000; Frankenberger, 2013).

The adhesive bond to tooth surface is based on a micro-mechanical and a chemical connection of specific functional monomers of the adhesive to the calcium of the hydroxyapatite. This is made possible by the etching procedure, in which the hard tooth tissue is demineralised. This demineralised zone is then refilled by the adhesive's monomers (hybridisation) (Van Meerbeek, 2001).

## Classification of adhesives

Various generations of adhesives have been developed in past decades. Only the third to eighth generations are still relevant today. The following diagram provides an overview of the classification of adhesives currently in use.

Adhesives can be classified according to their generation, the etching technique, the number of steps and the number of bottles. Some of them must additionally be mixed from two components prior to application.

Classification by generation	3	4	5	6 I	6 II	7	8
Classification by bonding system/ steps	Etch & rinse 4-Step	Etch & rinse 3-Step	Etch & rinse 2-Step	Self-etch 2-Step	Self-etch 1-Step	Self-etch 1-Step	Self-etch 1-Step Total-etch 2-Step Selective Enamel Etch 2-Step
Philosophy	selective enamel etching	Total-etch	Total-etch	Self-etch	Self-etch	Self-etch	Universal
No. of bottles/ primary packaging (without etchant)	≥ 3	≥ 2	1	2	1 or 2	1	1
No. of steps	3 – 4	3 – 4	2	2	1 + 1 mixing step	1	According to selected technique
Step 1	etch enamel	etch enamel & dentine	etch enamel & dentine	etch & prime	mix 2 liquids or components	etch & prime & bond	etch & prime & bond
Step 2	prime (sometimes mixing of two primers required)	prime (sometimes mixing of two primers required)	prime & bond	bond	etch & prime & bond		
Step 3	prime	bond					
Step 4	bond						
Kulzer Adhesives	–	GLUMA Solid Bond	iBOND Total Etch	–	–	iBOND Self Etch	iBOND Universal

Caption: Classification of adhesives currently in use

Despite their differences, a common feature of all adhesives is that they involve the steps of etching, priming and bonding. In earlier adhesive generations, these steps were performed successively by applying etching gel, primer and bonding. As part of the trend toward greater simplification, some or even all of the steps are performed simultaneously in recent adhesive generations. All-in one system (1 step, 1 bottle) have even combined the functions of etching, priming and bonding into a single liquid.

Etching serves to demineralise the hard tooth tissue, while priming conditions the hydrophilic tooth surface and ensures that the hydrophobic monomers from the bonding can penetrate deep. The bonding step seals the tooth surface and makes it possible to bind to the hydrophobic composite.

### Principles of adhesives

Adhesives generally consist of functional monomers, initiators, solvents, stabilisers and possibly inorganic fillers. The type of monomers is critical to the formation of a stable network with a high degree of polymerisation, good mechanical strength, durability and hydrolytic stability of the adhesive and hybrid layer (Frankenberger, 2013; Van Landuyt *et al.*, 2007). Because the tooth surface is hydrophilic and the composite is hydrophobic, mixtures of various monomers are often employed. Hydrophobic monomers include, for example, Bis-GMA or UDMA and are used to bind to the composite. They are responsible for the formation of a polymerisation network. Hydrophilic monomers such as HEMA or 4-META are required to ensure complete penetration into the hydrophilic collagen fibre network of the demineralised dentine. Functional monomers such as 4-META and MDP bind to the calcium of the hydroxyapatite. This results either in chemical bonding to the hard tooth tissue or in demineralisation due to dissolution of the calcium (Yoshida *et al.*, 2001; Yoshida *et al.*, 2012). Water, ethanol and acetone are the most common solvents and promote penetration of the adhesives into the hard tooth tissue (Hannig *et al.*, 1999; Perdigao & Lopes, 1999; Perdigao *et al.*, 1997). Solvents like acetone and ethanol possess as well the function of the water removal out of the hybrid layer during air-drying. With self-conditioning adhesives, water is required to activate the acidity. Acetone or ethanol acts as a solvent for the monomers while also removing the water from the tooth tissue and from the adhesive during evaporation (Silva e Souza *et al.*, 2010; Van Meerbeek *et al.*, 2001). Initiators are required to start polymerisation of the adhesive. Light-activated initiators are used primarily. The interaction between initiators and stabilisers determines the storage characteristics, the polymerisation time and the polymerisation reaction. Fillers are sometimes added to provide additional stability in the adhesive layer and a pleasant consistency.

### Adhesion to enamel

The enamel surface is modified by phosphoric acid etching, which was introduced to dentistry by Buonocore. An etching time of approx. 30 seconds results in an irreversible loss of material in a 8–10 µm layer and creates a rough surface enlarged ten- to twenty-fold. This expands the retention of the methacrylate on the enamel by a factor of one hundred (Cardoso *et al.*, 2011; Frankenberger *et al.*, 2001; Van Meerbeek *et al.*, 2001).

The etching creates a 20–30 µm deep microporous etching pattern (as shown in Figure 1), which can be easily penetrated by unfilled or slightly filled adhesives due to the capillary effect.

The enamel adhesion is primarily a mechanical anchoring, and it is viewed as a safe and successful procedure (Van Meerbeek *et al.*, 2001). Self-etch adhesives are used as alternatives to phosphoric acid etching. These do not require separate acid conditioning of the enamel surface; since the acidic monomers simultaneously condition (etch) and hybridise the enamel surface.

Depending on the composition and acidity of the self-etch adhesive used, the etching effect on the enamel is less than when using phosphoric acid etching (Hannig *et al.*, 1999; Kugel & Ferrari, 2000). If secure bonding to an unground enamel surface is to be achieved, the enamel surface must be etched with phosphoric acid even when using self-etch adhesives.

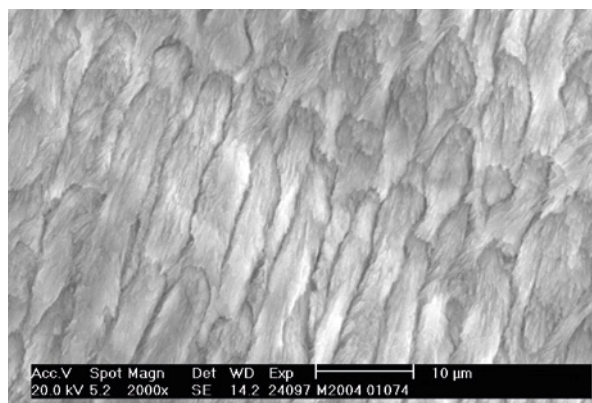


Fig. 1: Scanning electron microscopy (SEM) image of enamel etched with phosphoric acid.

## Adhesion to dentine

Dentine adhesion is more difficult due to the consistency of the dentine (Ekambaram *et al.*, 2015). Dentine contains a significantly higher portion of organic components than enamel does. These are primarily collagen fibres. Further, the pulp pressure causes dentine liquor to permanently exude from opened dentine tubules. This poses a challenge for the adhesive technology where a hydrophobic composite needs to be anchored to the tooth.

Similar to adhesion to enamel, the dentine surface is also demineralised during bonding procedure. The demineralisation is performed using a phosphoric acid gel or the acidic components of self-etch adhesives.

If dentine is processed using rotating instruments, this leaves behind on the surface a smear layer consisting mostly of remnants of the inorganic and organic components of the dentine (Frankenberger, 2013; Hannig *et al.*, 1999; Kugel & Ferrari, 2000; Perdigao & Lopes, 1999). Depending on the adhesive technique used, there are two different approaches to handle the smear layer: the etch & rinse strategy and the self-etch strategy. This is followed by the application of the adhesive system, which then penetrates into the depth of the dentine and chemically binds to the hydroxyapatite.

Regardless of the adhesive technique used (etch & rinse or self-etch), it is important to evaporate solvents contained in a primer (three-step adhesive and two-step self-etch adhesives) or directly in the adhesive (all-in-one-bottle adhesives). Due to its low vapour pressure, water hardly evaporates and can cause various problems. Water remaining in the adhesive film causes defects in the adhesive layer and incomplete polymerisation. Careful evaporation of the primer in case of a multi-bottle adhesive or the adhesive in case of a one-bottle system is thus one of the most important, and unfortunately often underestimated steps in successful bonding (Frankenberger, 2013; Luque-Martinez *et al.*, 2014; Silva e Souza *et al.*, 2010; Van Meerbeek *et al.*, 2001). Correct evaporation takes some time especially in the presence of a complex cavity geometry.

## Adhesive strategies

Three adhesive strategies have proven themselves to date: the etch & rinse (total-etch) technique, the self-etch technique and the selective enamel etching technique.

### The etch & rinse (total-etch) technique



Total-etch

In etch & rinse systems, also referred to as total-etch systems, the enamel and dentine are conditioned using phosphoric acid in a separate step prior to the application of primer followed by the adhesive or the adhesive in a one-bottle system.

The etching pattern already described above is created on the enamel. With the etch & rinse technique, the smear layer on the dentine is dissolved completely by the preceding phosphoric acid etching and the adhesive system can penetrate into the exposed collagen fibre network of the dentine. The following scheme (Fig. 2) depicts the process of the etch & rinse approach.

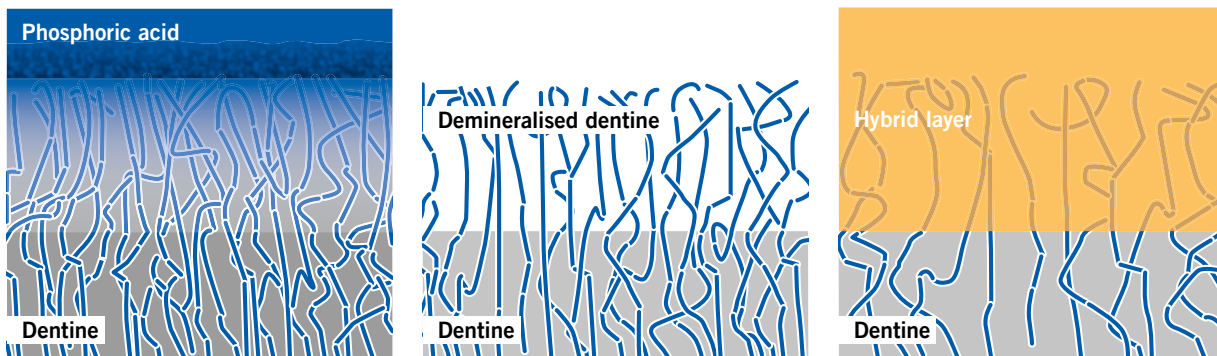


Fig. 2: Etch & rinse technique: Dissolution of the smear layer and demineralisation of the dentine by phosphoric acid (left), exposed collagen fibre network of the dentine after rinsing the etching gel (centre), hybridisation of the dentine by the primer and adhesive (right).

The etching gel and the dissolved components of the hard tooth tissue must be thoroughly rinsed with water after etching in order to achieve good and stable adhesion.

The hydrophilic, conditioned dentine surface reacts more sensitively than the enamel and should not be overetched or overdried. In the etch & rinse procedure, the dentine is therefore etched for a significantly shorter time than the enamel. Specifically when using a one-bottle system, merely the excess water is removed from the dentine cleaned of obvious excess water to avoid post-operative complications (Van Meerbeek *et al.*, 2001).

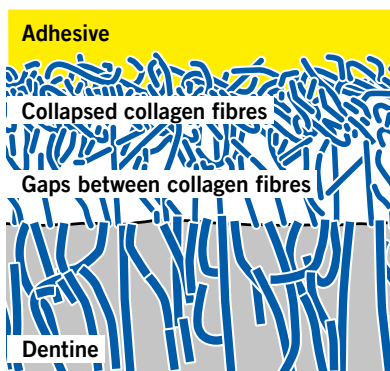


Fig. 3: Collapsed collagen due to overdrying renders the adhesive unable to penetrate deep into the demineralised area.

An overdried dentine surface would cause the exposed collagen fibre network to collapse and it would no longer be fully penetrable by the adhesive, resulting in cavities as shown in Fig. 3.

Such cavities at the base of the collagen fibre network are subject to enzymatic degradation and are a cause of secondary caries or complete failure of the restoration (Miyazaki *et al.*, 2014; Silva e Souza *et al.*, 2010; Tay, 2014). Multi-bottle systems react less sensitively to excessively dry dentine because the dentine is rewetted by the intermediary primer step (Frankenberger, 2013; Kugel & Ferrari, 2000; Pashley *et al.*, 2011; Suh, 2014).

Here it is imperative that the primer of a 3-step etch & rinse adhesive or the liquid (primer and adhesive in one bottle) of a 2-step etch & rinse adhesive is applied for a sufficient time to penetrate fully into the depth of the demineralised area because in the etch & rinse technique, the demineralisation and hybridisation are performed in succession. After proper air-drying and removal of the solvent, in case of 3-step etch & rinse adhesives the bonding (sealer) of the second bottle need to be applied and light cured. In case of a 2-step etch & rinse adhesive system the prime and bonding liquid need only to be evaporated and light cured.

### The self-etch technique



Self-etch

In the self-etch technique, the etch is performed by acidic monomer components in the bonding agent. The self-etch adhesives can be applied directly to the prepared hard tooth tissue. The phosphoric acid etching step required with the etch & rinse products is eliminated. The smear layer is, depending on the pH value of the self-etching adhesive, only partially dissolved and the underlying dentine is demineralised hardly to moderately deeply. The smear layer is incorporated into the adhesive layer (Hannig *et al.*, 1999; Tay, 2014; Pashley *et al.*, 2011; Van Meerbeek *et al.*, 2011).

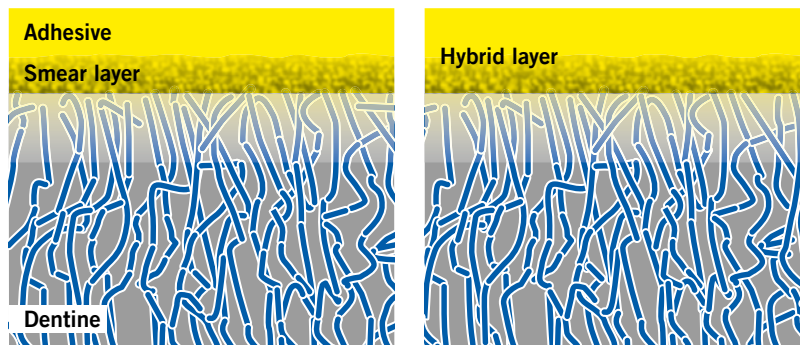


Fig. 4: Self-etch technique: Demineralisation (left) and hybridisation of the dentine (right) in one step. The smear layer is incorporated into the hybrid layer.

Self-etch adhesives etch, prime and bond in one or two steps, depending on the product (Hannig *et al.*, 1999; Kugel & Ferrari, 2000; Van Meerbeek *et al.*, 2011).

This reduces the steps and the possibility of error. Conditioning and monomer infiltration occur simultaneously so that the risk of overetching or overdrying of the dentine is nearly eliminated. The principle of self-etch adhesives is shown in fig. 4. The etching depth and the hybrid layer thickness correspond. There is therefore hardly any risk of cavities remaining with later development of post-operational hypersensitivities. However, despite the many benefits of self-conditioning adhesives, there are some points that require special attention. For example, many all-in-one products are incompatible or have limited compatibility with self-curing materials.

Further, studies show that, depending on the acidity of the product, the etching effect on enamel is less pronounced than with phosphoric acid etching.

A permanent bond can therefore be established only on prepared or bevelled enamel. For all self-etch adhesives it is mandatory that the primer or the liquid of an all-in-one-adhesive has plenty of time to react with the tooth surface. Furthermore, the liquid needs to be agitated in the cavity to make sure that consumed monomers are removed and fresh monomer come in contact with the tooth surface. Because of the needed water activation of the acidic groups of self-etch adhesives, these products contain, in addition to alcohol or ethanol, plenty of water that must be removed from the adhesive layer by sufficient air-drying prior to polymerisation. As described, this is the only way to form a completely polymerised, long-lasting adhesive layer (Frankenberger, 2013; Suh, 2014; Tay, 2014; Van Meerbeek *et al.*, 2001).

### Selective enamel etch



Selective Enamel Etch

Selective enamel etching was originally used with earlier generations of adhesives. The enamel margins were selectively conditioned using phosphoric acid gel as in the etch & rinse method of later generations. The dentine was not etched using phosphoric acid but rather conditioned with slightly acidic primers that modify the smear layer. This yields a hybrid layer resembling that of current self-etch adhesives. But due to the complex technique involving 3 bottles and 4 steps, etch & rinse or self-etch adhesives were preferred by the general dental practitioners. Only recently selective enamel etching has begun to be used again more frequently in combination with self-etching adhesives. Only the enamel is etched with phosphoric acid and rinsed, then a self-etch adhesive is applied to the entire cavity. This procedure combines optimum enamel etch with preservation of the dentine and a reduction in post-operative complications (Cardoso *et al.*, 2011; Miyazaki *et al.*, 2014; Suh, 2014).



## Universal adhesives

Universal adhesives are the latest development in the field of adhesives. They bridge the different bonding philosophies and indications. While dentists previously had to choose one bonding technique when using self-etch or etch & rinse products, universal adhesives allow them to make indication-based decisions. These adhesives can be used in the etch & rinse, the self-etch or the selective enamel etching technique (Luque-Martinez *et al.*, 2014; Miyazaki *et al.*, 2014; Suh, 2014).

Not just the adhesive technique aspect makes the universal adhesives interesting. The term “universal” can indeed also mean that the range of indications is very large and the adhesive can be bonded to a wide range of dental materials. This does not, however, apply to all universal adhesives. Some universal adhesives require a primer for adhesion to some materials such as silicate ceramics or metal (Chen *et al.*, 2013; Chen *et al.*, 2012; Tay, 2014). Some other universal adhesives are not compatible with self-curing or dual-curing composites for core build-up or for cementing indirect restorations or they are only compatible in combination with special activators. Only very few universal adhesives can do this without such an activator.

Since there is no official consistent definition of the range of applications for a universal adhesive, the practitioner must determine precisely which indications are possible and which ones may require the use of additional components when choosing a specific universal adhesive. The major benefit of universal adhesives remains, however, that only one adhesive is required for indication-related bonding strategies and, depending on the adhesive, no further materials is needed. The fewer different application protocols and components are required, the lower the risk of incorrect usage of the adhesives.

## The iBOND® product family

The new iBOND Universal expands and supplements Kulzer's existing bonding portfolio in terms of application possibilities, comfort and safety. With its innovative adhesives, Kulzer covers the entire range of bonding applications across indications. In addition to the fourth-generation adhesive GLUMA Solid Bond, the fifth-generation adhesive iBOND Total Etch, the seventh-generation adhesive iBOND Self Etch, there is now a representative of the eighth generation: the new iBOND Universal.

### GLUMA® Solid Bond



GLUMA Solid Bond is a fourth-generation two-bottle, three-steps adhesive made up of GLUMA Solid Bond P (Primer) and GLUMA Solid Bond S (Sealer). It conditions the surface in the etch & rinse technique with phosphoric acid etching. The hydrophilic dentine is rendered hydrophobic by the primer, and an excessively dry dentine surface is rewetted and prepared for the sealer. After polymerisation, a stable hybrid layer is created that ensures bonding to the restoration material. GLUMA Solid Bond is indicated for all direct and indirect restorations with composite-based restoration or luting materials.

### iBOND® Total Etch



iBOND Total Etch is a fifth-generation one-bottle adhesive and provides everything one could expect from a modern etch & rinse system. The fact it is supplied as a single component reduces the workload and the risk of mixing up different bottles. Following separate phosphoric acid etching (using e.g. iBOND Etch) of the entire cavity, iBOND Total Etch is applied in only a single layer. It wettens the collagen fibre network, forms a homogeneous hybrid layer and prevents post-operative sensitivities. The solvent ethanol can be evaporated quickly and safely, and the entire application of adhesive can be checked easily based on the sheen of the adhesive layer. Thanks to its optimum monomer mixture, iBOND Total Etch achieves high bond strength and excellent margin quality both on the enamel and on the dentine. iBOND Total Etch is indicated for direct and indirect restorations as well as the treatment of hypersensitive tooth areas. Years of clinical experience and substantial independent university studies confirm the outstanding characteristics of iBOND Total Etch.

### iBOND® Self Etch



iBOND Self Etch is a seventh-generation all-in-one adhesive. More than ten years ago, Kulzer brought to market the world's first all-in-one adhesive, originally called iBOND. The current iBOND Self Etch was adapted to the needs of modern dentistry on the basis of continuous clinical research and market analyses, and it now stands for simple handling, high performance and reliability in the field of self-conditioning adhesives. Its functional monomer is 4-META and it uses an acetone-water mixture as a solvent. iBOND Self Etch does not require a separate etching step for enamel and dentine, and like iBOND Total Etch it is applied in only one layer. Etching, priming, bonding and desensitisation desensitizing are performed in one step. iBOND Self Etch is ideally applied to simplify the work processes in pure self-etch technique, but it can also be used in combination with selective enamel etching. iBOND Self Etch is indicated in combination with all light-curing direct and indirect composite materials. Both handling and quality are confirmed continuously by practising dentists and tested scientifically and clinically by numerous universities.



## iBOND® Universal

iBOND Universal is a light-curing, self conditioning all-in-one adhesive for use in adhesive restorative dentistry. A wide range of applications with minimised technique sensitivity was optimally combined: both with regard to the range of indications as well as the handling.

## Bonding mechanism

Adhesion is primarily obtained via the functional monomers 4-META and MDP, tried and tested over many years in a variety of adhesives.

iBOND Universal monomers contain a combination of hydrophilic and hydrophobic groups, so both the conditioning and infiltration of hydrophobic enamel as well as hydrophilic dentine can be reached. The following figure 5 indicates the functional monomers of iBOND Universal:

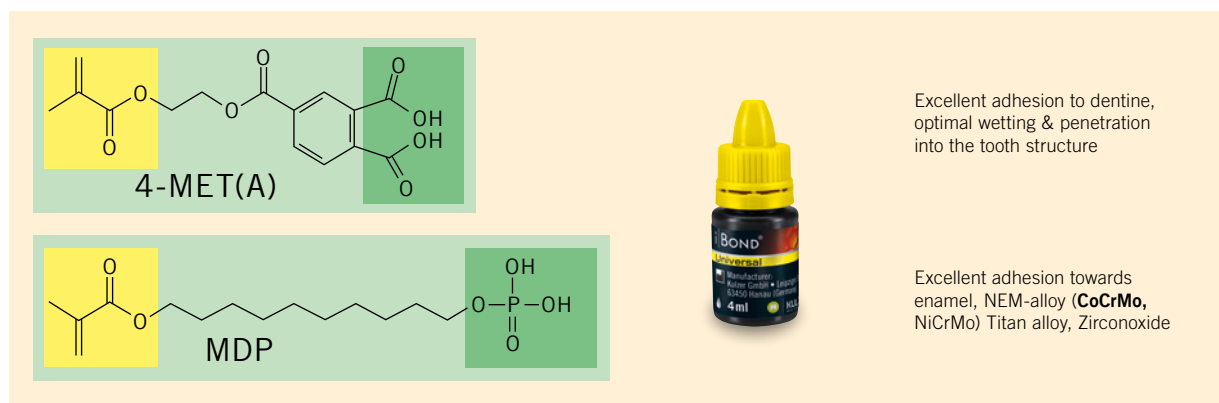


Fig. 5: Functional monomers of iBOND Universal and their benefits (yellow: methacrylic ester to crosslink with other monomers, dark green: acidic functional groups to bind to the calcium of the hydroxyapatite of the tooth or to metal and zirconia)

These monomers enable reliable demineralisation of enamel and dentine as a result of their acidic groups and provide direct chemical adhesion to the calcium of the hydroxyapatite of enamel and dentine. With its phosphoric acid groups, MDP enables chemical adhesion to the calcium of the hydroxyapatite as well as to metal and oxide ceramics. 4-META binds to the calcium of the hydroxyapatite by carboxylic acid groups and has proven itself in iBOND Self Etch particularly due to its very good adhesion to dentine.

The monomers of iBOND Universal ensure optimum cross-linking and connection to the composite using their methacrylate function, forming a stable hybrid layer that also provides a mechanical connection to the tooth. The adhesive layer is homogeneous and approx. 5–10µm thick. iBOND Universal does not flow off the vertical cavity as it can be seen in fig. 6.

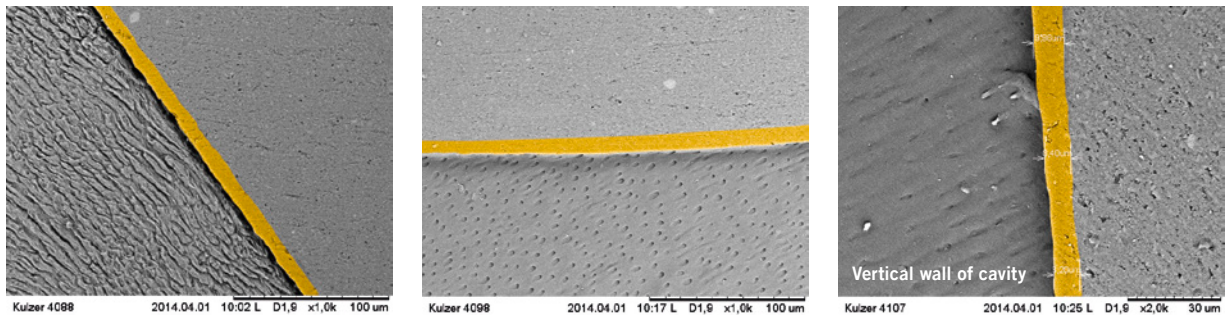


Fig. 6: Homogeneous 5–10µm thick iBOND Universal adhesive layer (self-etching) on enamel (left) and dentine (centre), vertical cavity wall (right).

The composition and functions of the individual components are shown in the table below.

Composition and function	
<b>4-META</b>	Dissolution of the mineral components of the hard tooth tissue (demineralisation); effective dentine connection to the calcium of the hydroxyapatite
<b>MDP</b>	Bonding of the hard tooth tissue to the calcium of the hydroxyapatite by chemical bonding; effective enamel connection; bonding of metal and ceramic surfaces
<b>Methacrylates</b>	Film formation, wetting, formation of the 3D network, stability of the adhesive layer, connection to composite/resin-based cement
<b>Acetone</b>	Solvent and carrier for hydrophilic and hydrophobic monomers; facilitates the removal of water from the adhesive layer during evaporation.
<b>Water</b>	Hydrolysis of 4-META; triggering of the etching process

The pH of iBOND Universal is between 1.6 and 1.8.

## Variable bonding technique

iBOND Universal gives the dentist the ability to decide whether to work with the etch & rinse, self-etch or selective enamel etching technique (fig. 7).



Fig. 7: Different bonding strategies: Etch & rinse (total-etch), selective enamel etching, self-etch

Therefore, the dentist does not need to switch his usual etching strategy. But iBOND Universal can also be used according to indication: for example, the etch & rinse technique has benefits for aesthetic and indirect restorations, while the self-etching technique is recommended for paediatric dentistry and the selective enamel etch technique has particular strengths in the restoration of cervical lesions.

## Range of indications

iBOND Universal was developed for a wide range of indications, from the bonding of direct restorations and indirect restorations in combination with an adhesive cement or composite material to the sealing or intraoral repair of restorations. Compared with other Kulzer adhesives, iBOND Universal covers the widest range of indications.

The following table lists the various indications in detail.

### iBOND Universal is indicated for the following applications:

- Adhesive bonding of direct light-curing, self-curing or dual-curing methacrylate-based composite or compomer restorations in all cavity classes
- Bonding of light-curing, self-curing or dual-curing methacrylate-based core build-up materials
- Treatment of hypersensitive tooth regions
- Sealing of cavities before applying amalgam
- Bonding of fissure sealings
- Sealing of cavities and preparations prior to insertion of temporary indirect restorations according to the Immediate Dentine Sealing Technique.
- Bonding of indirect restorations with light-curing, self-curing or dual-curing composite cements
- Intraoral repair of composite and compomer restorations as well as metal and metal ceramic restorations

## Adhesion to different surfaces

iBOND Universal shows its “universal” character by bonding to all dental materials made of composite, compomer, ceramics and metal.

The monomer MDP which is contained in iBOND Universal enables to bond chemically to metal and oxide ceramic surfaces without any additional components.

For the adhesive bonding and repair of silicate/glass ceramic a pre-conditioning of the restoration surface using iBOND Ceramic Primer is needed. iBOND Ceramic Primer is an isopropanol-based solution of silane monomers (MEMO) as shown in fig. 8.

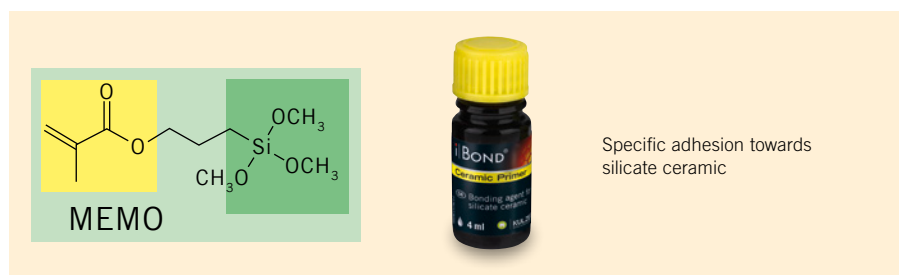


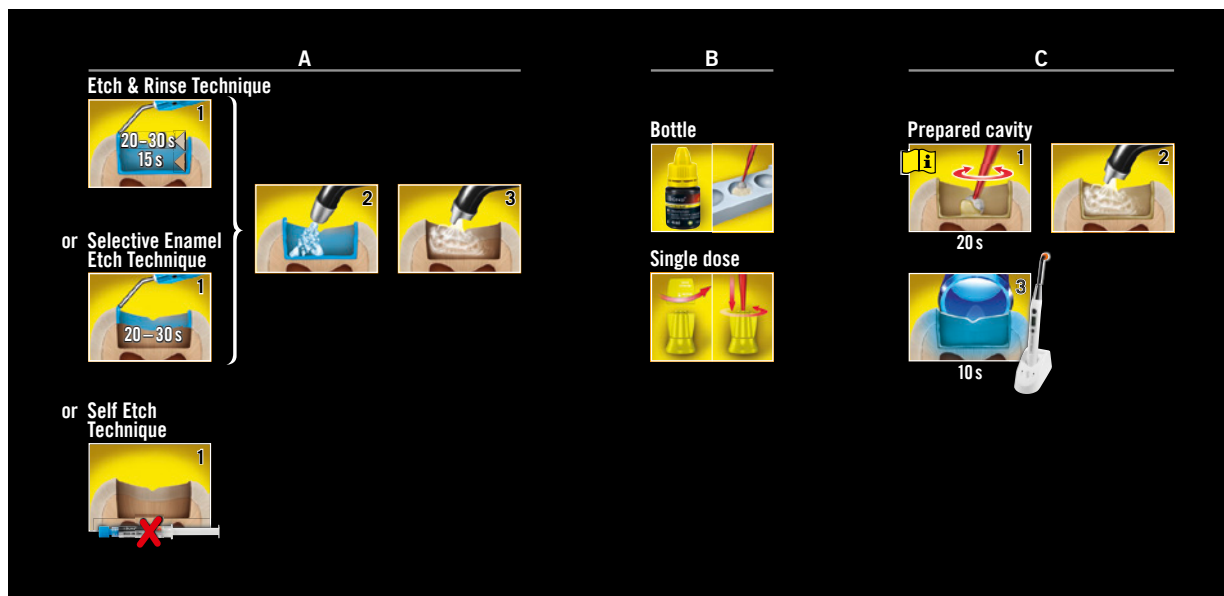
Fig. 8: Silane in iBOND Ceramic Primer

Unlike some other universal adhesive systems, iBOND Universal is also compatible with all conventional composite materials regardless of their curing mechanism (light-curing, self-curing or dual-curing). An additional activator for dual-curing that has to be mixed into the adhesive, as with other systems, is not required (see the Studies chapter). Compatibility with all light-curing, dual-curing or self-curing composite materials is achieved thanks to the photoinitiator system optimally adapted to this purpose.

The “universal” bonding of iBOND Universal to all relevant dental surfaces is recommended particularly for intraoral repair of direct and indirect restorations. Especially for small localised defects such as marginal caries, fractures and chippings or small marginal defects and discolourations, the international scientific consensus is now to prefer minimally invasive repair to total filling replacement (Gordan *et al.*, 2015) in order to preserve sound hard tooth tissue.

## Application

The instruction card below illustrates the simple application of iBOND Universal for direct restorations:



The formulation of iBOND Universal offers unique control of moisture, meaning that acetone and water contained in iBOND Universal as solvents can be removed from the adhesive layer very effectively and easily during evaporation. Water remaining in the adhesive layer would result in worse polymerisation and reduced long-term stability of the adhesive layer. Water coming from the adhesive and the moist dentine is transported to the surface of the adhesive, where it can be easily evaporated. It is very beneficial to use acetone because the vapour pressure of acetone, which enhances the evaporation of water, is four times higher than that of ethanol (Ekambaram *et al.*, 2015).

The following images (fig. 9) illustrate the ease with which water can be removed from the adhesive layer.

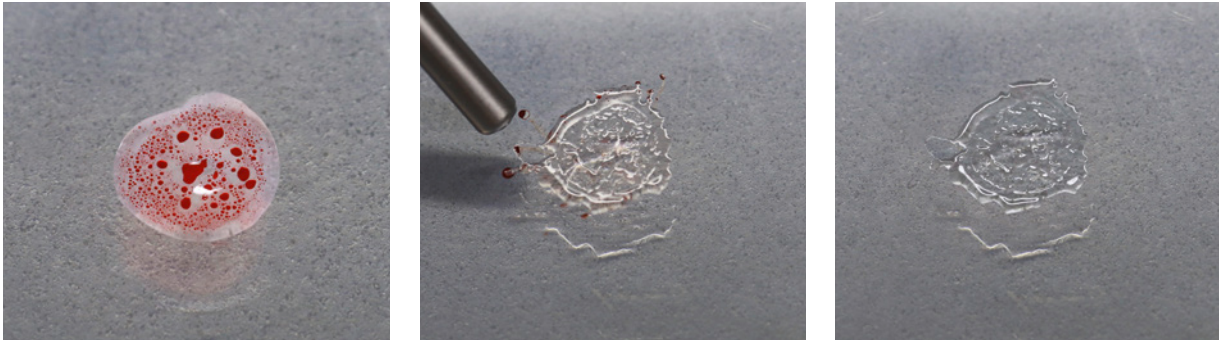


Fig. 9: Left: The aqueous phase was marked with a selectively soluble red dye, while the monomer phase is colourless. Phase separation (separation of the oily monomer portions and the aqueous portions) is visible. Centre: The volatile components such as acetone and water are removed from the film by evaporation. Right: A colourless film remains. This illustrates the effective expulsion of water from the adhesive layer.

This makes iBOND Universal very simple and effective to use, as various tests with laypeople have shown (see Studies chapter), as well as impressive with its immediate high bonding strength.

But the application is simplified by more than just the special formulation of iBOND Universal. The new dropper on the bottle (fig. 10) and the various sizes of microbrushes (fig. 11) do their part too.



Fig. 10: Drop control of the iBOND Universal bottle



Fig. 11: iBOND Universal kit with iBOND Ceramic Primer

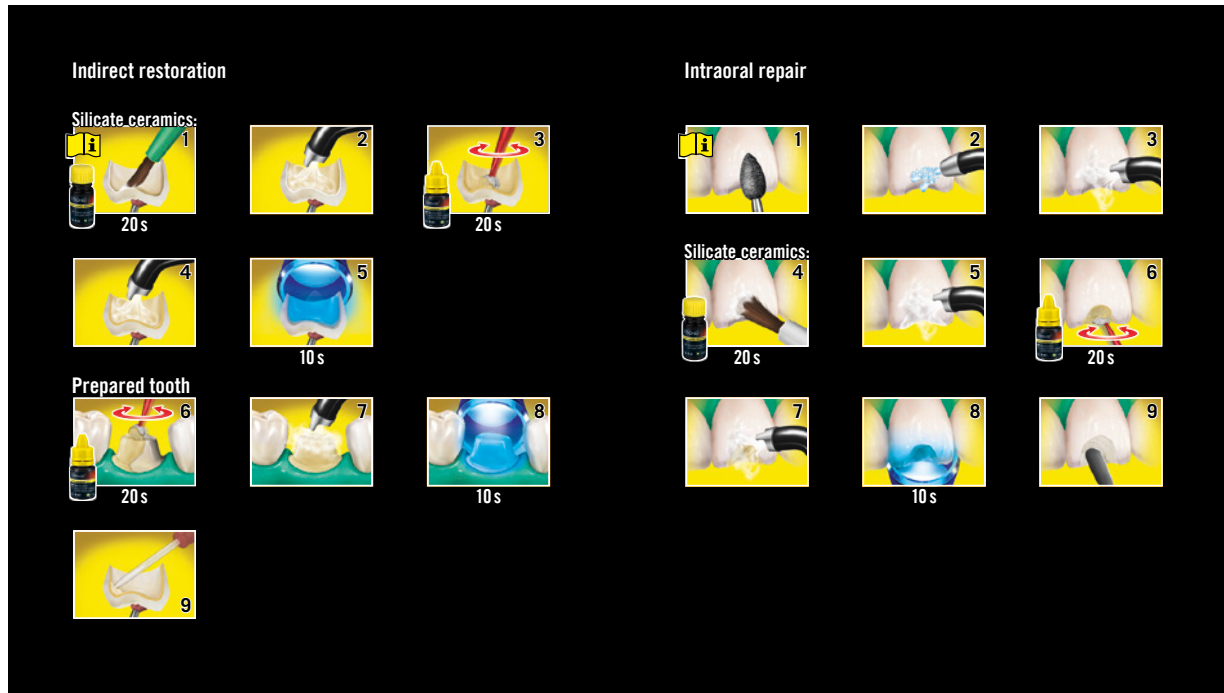
The new dropper, with its drop control system, allows simple and economical dosage adapted to the amount required. The drop separates cleanly and contamination of the filler neck is effectively prevented.

The microbrushes are available in two versions: green microbrushes for small cavities, and red ones for larger cavities. This also allows for sufficient wetting of small cavities where a normally sized microbrush does not fit.

The technique sensitivity is reduced because iBOND Universal is a one-bottle adhesive and does not require an activator for adhesion to dual-curing or self-curing composite materials (e.g. composite cements, composite core build-up materials). The components therefore cannot be accidentally mixed up or omitted.

Instead of using different products for different indications as before, only one adhesive in one bottle is required. Additional pre-treatment of restoration surfaces with iBOND Ceramic Primer is required only for silicate ceramics. iBOND Ceramic Primer is available in a glass bottle so that it can be easily distinguished from the adhesive.

The following instruction card shows the ease of use on various surfaces for the bonding of indirect restorations and intraoral repair.



## Benefits of iBOND Universal at a glance

iBOND Universal combines the best characteristics of earlier adhesive systems in a single bottle and provides significant clinical benefits due to its advanced development. It has a very “universal” character extending beyond the selection of different bonding techniques to include bonding on all relevant dental materials in all relevant indications and not requiring an activator for use with self-curing resin-based materials.

### Overview of the benefits of iBOND Universal:

- Immediate, long-lasting bonding success
- For all dental materials
- For all indications, including intraoral repair
- Can be used with all bonding techniques (etch & rinse, selective enamel etch and self-etch)
- Unique moisture control
- Simple handling
- Exact dosage from the bottle thanks to the “drop control” system





# Studies

## Bond strength



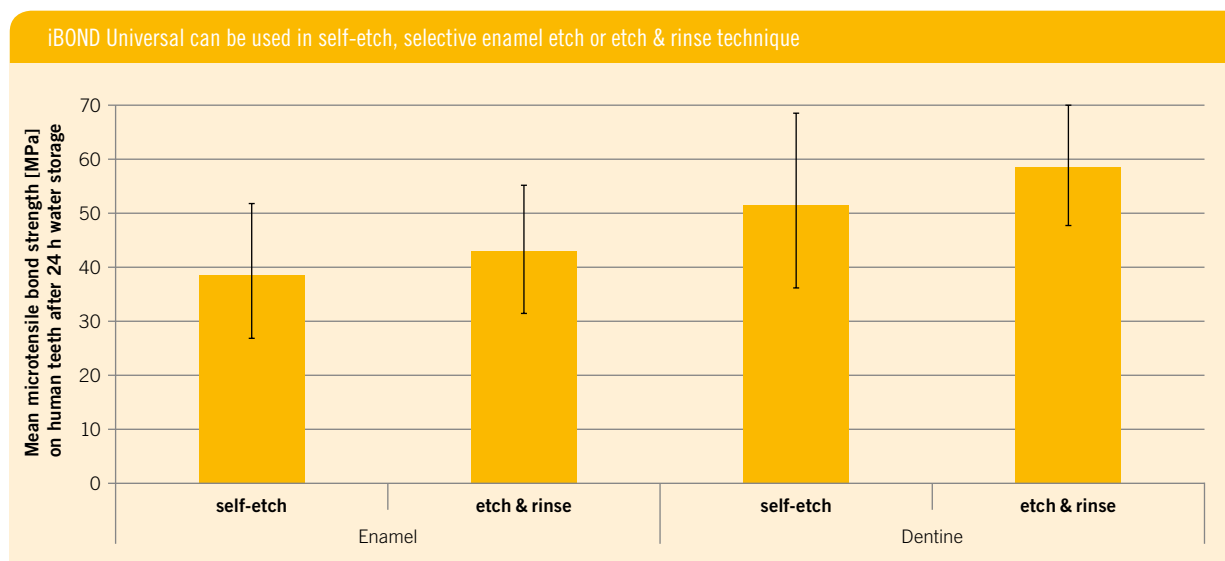
# Different bonding techniques (microtensile strength) – Kulzer, R&D, Wehrheim, Germany

## Bond strength evaluations of iBOND Universal

### Materials & Methods

Flat human dentine & enamel surfaces were prepared and roughened using SiC 320 paper. In the etch & rinse mode phosphoric acid was applied first and rinsed off. Afterwards iBOND Universal was applied and light cured. A composite restoration was done afterwards on top using Venus Diamond A2. The restoration was light cured, sectioned and microtensile bond strength was performed after 24 h at 37°C water storage.

### Results



No statistical significant differences were detected between application modes,  $p < 0.05$ .

### Conclusion

iBOND Universal can be used in every bonding strategy.

### Comment

This study also found no difference between the etch & rinse and the self-etch bonding technique. The dentist can use his preferred technique.

### Source

Kastrati A, Lechmann-Dorn M, Eppinger R, Schaub M, Quinque B, Schweppe J: Bond Strength Evaluations of a New Universal Adhesive. J Dent Res 94, Spec Iss A: # 360, 2015 ([www.iadr.org](http://www.iadr.org)).

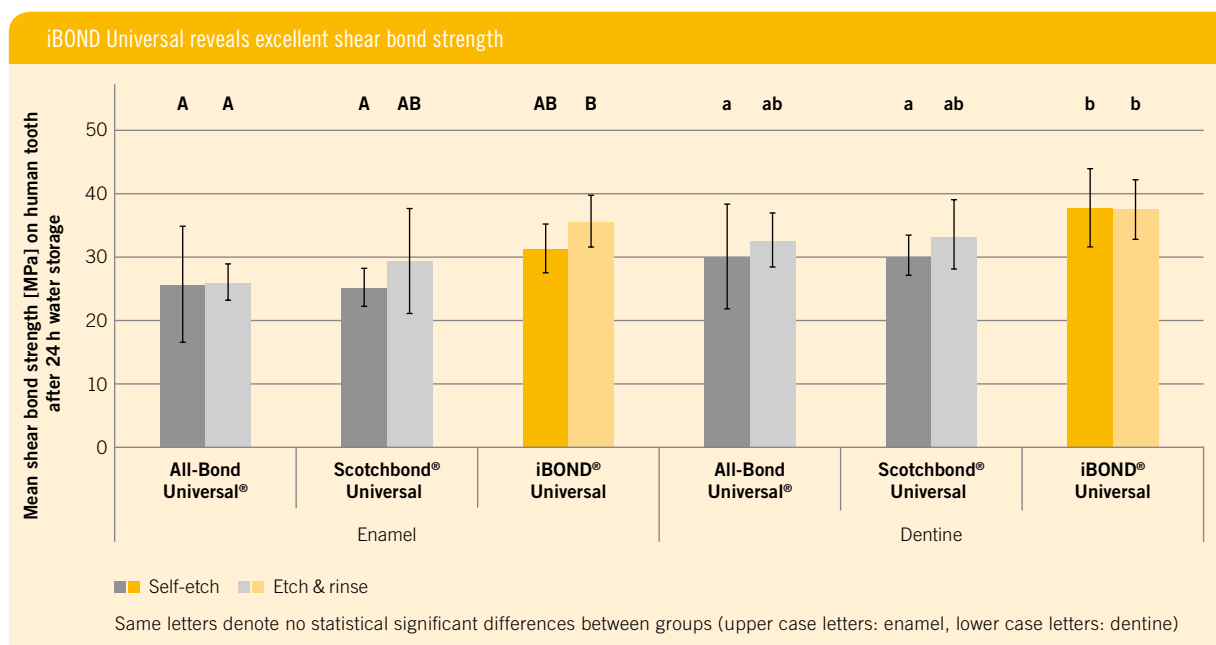
## Different bonding techniques (shear bond strength) – Kulzer, R&D, Wehrheim, Germany

### Bond strength evaluations of iBOND Universal

#### Materials & Methods

Flat dentine surfaces from human molars were prepared and roughened using SiC 320 paper. Different universal adhesives were used in self-etch and etch & rinse mode. For the etch & rinse approach dentine was etched with phosphoric acid and rinsed prior to the application of the adhesives according to their instructions for use. Adhesives were light cured and composite cylinders (Venus Diamond A2) were placed onto the bonded surfaces and were light cured. After 24 h water storage at 37°C shear bond strength was determined using the Ultradent method at a crosshead speed of 1 mm/min. ANOVA and LSD post-hoc tests for the comparison of the adhesives were done. Independent t-Test was used between application modes of each adhesive. ( $p < 0.05$ ).

#### Results



#### Conclusion

iBOND Universal showed highest bond strength for each application mode in this test. No statistical significant difference was found between application modes of each adhesive.

#### Comment

iBOND Universal showed excellent bond strength and achieved comparable results of self-etch and etch & rinse bonding technique.

#### Source

Kastrati A, Lechmann-Dorn M, Eppinger R, Schaub M, Quinque B, Schweppe J: Bond Strength Evaluations of a New Universal Adhesive. J Dent Res 94, Spec Iss A: 360, 2015 ([www.iadr.org](http://www.iadr.org)).

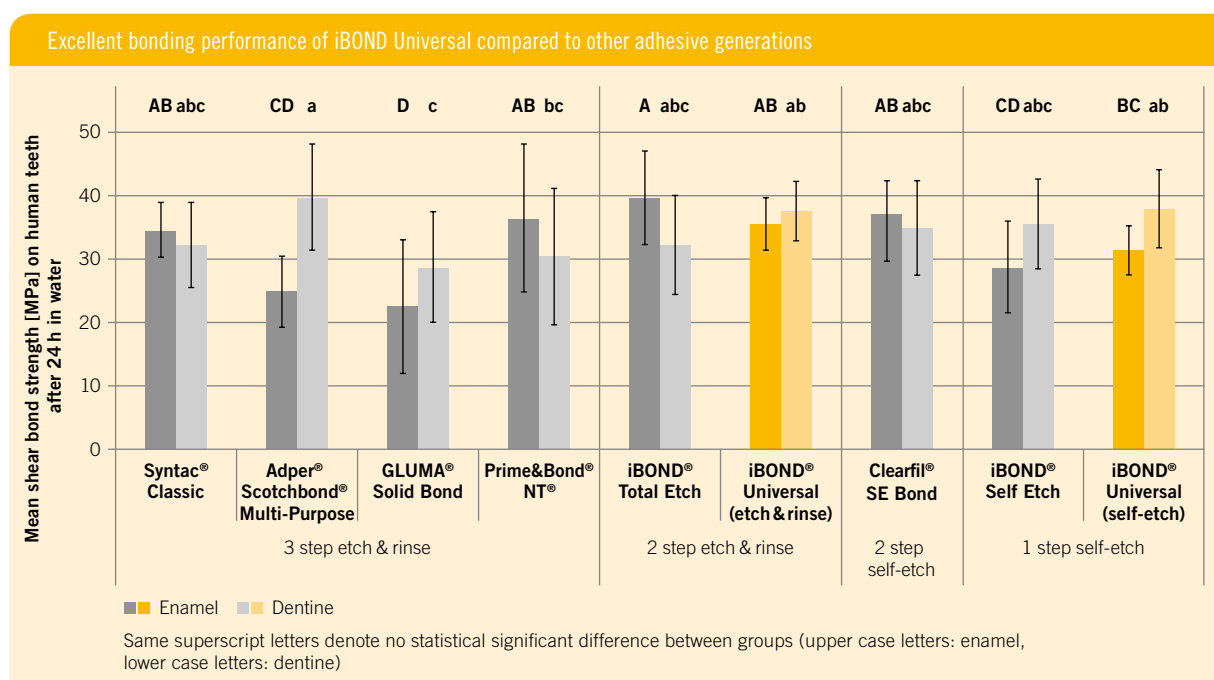
# Bond strength comparison – Kulzer, R&D, Wehrheim, Germany

## Shear bond strength comparison of different adhesive generations

### Materials & Methods

Flat dentine surfaces of human molars were prepared and roughened using SiC 320 paper. iBOND Universal was used in a self-etch and etch & rinse mode (after a phosphoric acid etching). All adhesives were used according to their instructions of use. After light-curing of the adhesives a composite cylinder (Venus Diamond A2) was placed on each bonded surface. After 24 h water storage at 37°C shear bond strength according to the Ultradent method (crosshead speed 1 mm/min) was measured. Statistics were done using ANOVA and LSD test ( $p < 0.05$ ).

### Results



### Conclusion

iBOND Universal showed comparable bond strength in self-etch and etch & rinse mode to 3-step etch & rinse adhesives.

### Comment

iBOND Universal offers all benefits of a universal adhesive (e.g. freedom in bonding technique) with high bond strength levels.

### Source

Kulzer R&D, Test report 2014. Data on file.



## Marginal integrity





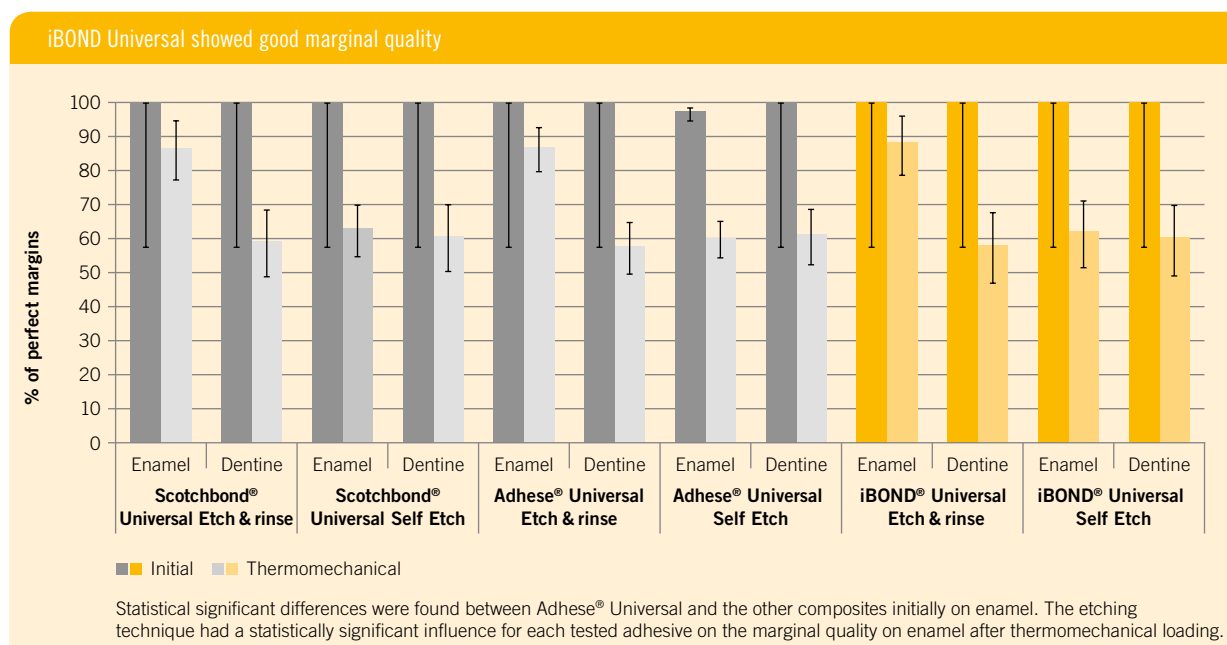
# Marginal integrity – University of Marburg, Germany

## Marginal quality of iBOND Universal in self-etch and etch & rinse mode vs. Scotchbond® Universal and Adhese® Universal

### Materials & Methods

48 MOD cavities with one proximal box beneath the cement-enamel-junction were prepared in extracted human third molars. Direct resin composite restorations (Venus Diamond, Kulzer) were bonded with different adhesives in different etching modes (etch & rinse and self-etch): iBOND Universal (Kulzer), Scotchbond® Universal (3M ESPE) and Adhese® Universal (Ivoclar Vivadent). Before and after thermomechanical loading (100,000 x 50N, 2,500 thermocycles between +5°C and +55°C), marginal gaps were analysed using SEM of epoxy resin replicas. Results were analysed with Kruskal-Wallis and Mann-Whitney U-tests (p<0.05).

### Results



### Conclusion

iBOND Universal showed good marginal quality irrespectively of the used bonding technique (etch & rinse vs. self-etch). On enamel, the etch & rinse technique obtained better results.

### Comment

iBOND Universal can be used in each bonding technique. The quality of enamel margins can be optimised by a preceding enamel etching step.

### Source

Frankenberger R, Hartmann VE, Krech M, Braun A, Roggendorf MJ: Marginal quality of iBOND Universal in self-etch and etch-and-rinse mode vs. Scotchbond® Universal Bond. Unpublished test report March 2015. Data on file.



## **Technique sensitivity**



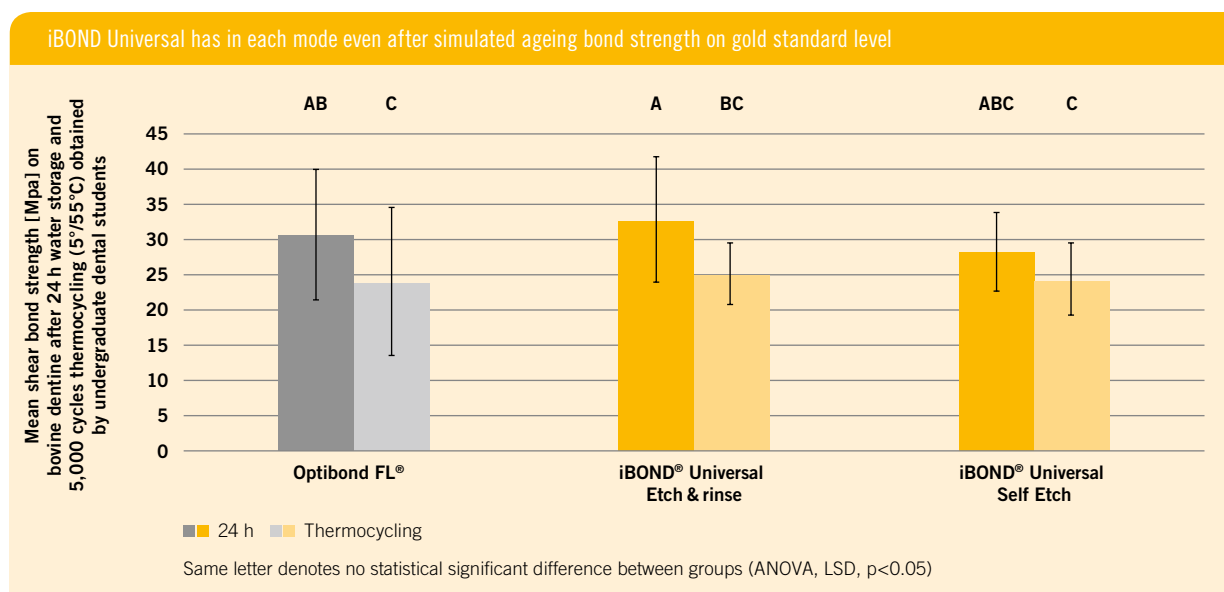
# Technique sensitivity – University of Mainz & Kulzer R&D, Wehrheim, Germany

Shear bond strength comparison of a new universal adhesive applied by dental students compared to gold standard

## Materials & Methods

Flat bovine dentine surfaces were prepared and roughened using SiC paper 320. 28 undergraduate dental students from the University of Mainz applied the adhesives according to their instruction for use. Optibond FL was used in an etch & rinse technique and iBOND Universal was applied in a self-etch and in an etch & rinse technique. After light-curing, a composite cylinder made from Venus Pearl A2 was placed and light cured. Shear bond strength was determined using the Ultradent method (crosshead speed 1 mm/min). Half of the specimens (n = 14) of each adhesive/ bonding technique combination were tested after 24 h in water at 37°C. The other half was tested after additional 5,000 cycles of thermocycling (5°/55°C). Statistics were done using ANOVA followed by LSD test (p<0.05).

## Results



## Conclusion

iBOND Universal showed bond strength comparable to Optibond FL both in etch & rinse and self-etch bonding technique.

## Comment

Even undergraduate students were able to achieve high bond strength in both bonding techniques. The bond strength of all tested adhesives remained after a simulated aging on a high level.

## Source

Ehlers V, Ernst C-P, Kastrati A, Gerlach M, Eppinger R, Willershausen B: Bond strength comparison of a new universal adhesive to a gold-standard. J Dent Res 94 (Spec Iss B), # 0544 CED, 2015, (<http://www.iadr.org>).

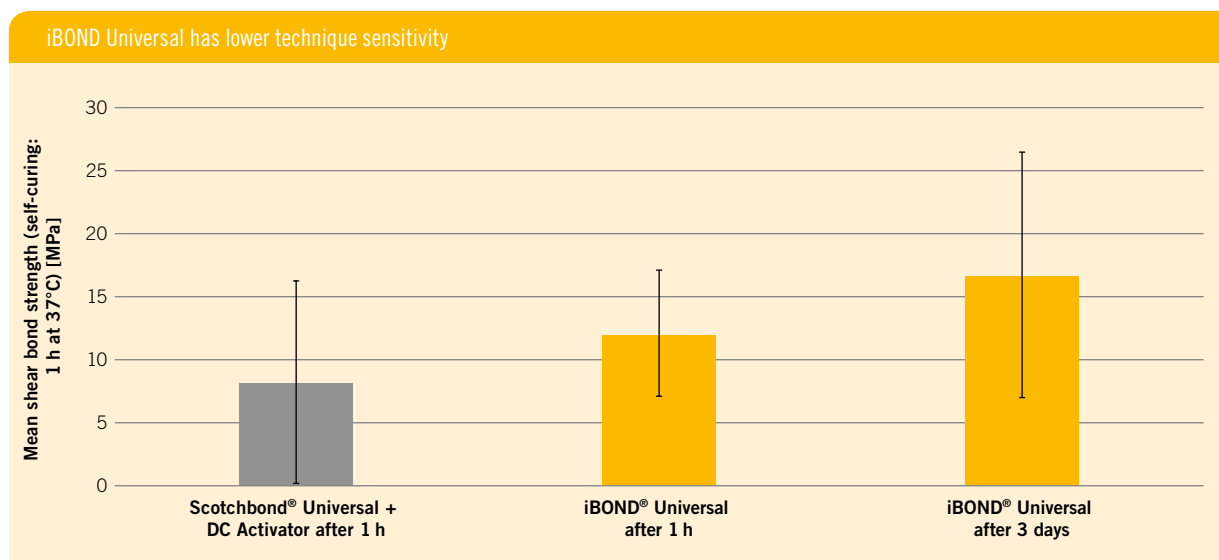
## Technique sensitivity – Kulzer R&D, Wehrheim, Germany

### Compatibility of universal adhesives with composite cements in different curing modes

#### Materials & Methods

Flat bovine dentine surfaces were prepared and roughened using SiC paper 320. Adhesives were applied by 6 general dental practitioners according to their instructions for use. Scotchbond® Universal was used after mixing with dual-curing activator. Afterwards resin cement cylinders made of Clearfil® Esthetic Cement (Kuraray) were applied. The cement was self-cured for 1 h at 37°C. Afterwards shear bond strength testing (SBS) was performed using the Ultradent method and a cross-head speed of 1 mm/min. Shear bond strength of 7 iBOND Universal samples was tested after 3 days in water at 37°C.

#### Results



No significant statistical differences were found between groups.

#### Conclusion

iBOND Universal showed higher bond strength values compared to Scotchbond® Universal + DC-Activator. Bond strength of iBOND Universal is increasing over time.

#### Comment

This study indicates that the usage of iBOND Universal has a lower technique sensitivity because it does not need to be mixed with a DC-activator.

#### Source

Lechmann-Dorn M, Eppinger R, Kastrati A, Loh W, Schaub M, Schweppe J: Compatibility of Universal Adhesives with Composite Cements in Different Curing-Modes. J Dent Res 94, Spec Iss A: # 2285, 2015 ([www.iadr.org](http://www.iadr.org)).

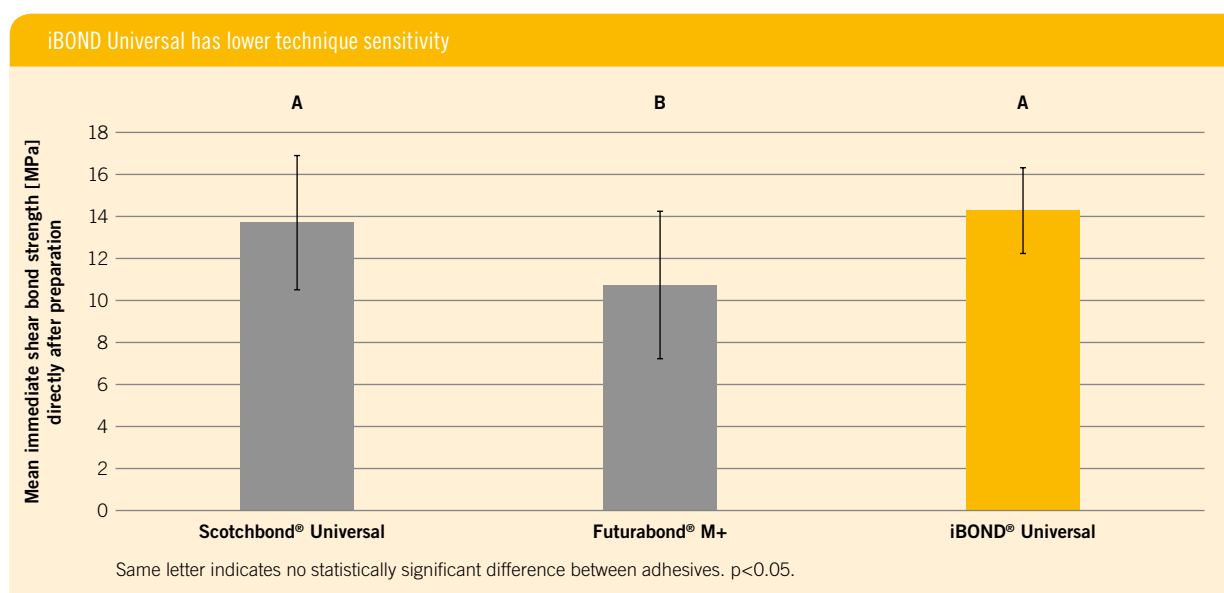
# Immediate bond strength/Low technique sensibility – Kulzer R&D, Wehrheim, Germany

## Immediate shear bond strength comparison by layperson adhesive application

### Materials & Methods

Flat bovine dentine surfaces were prepared and roughened using SiC paper 320. Adhesives were applied according to their instruction for use and light cured for 10s by a Translux Wave curing light by 15 laypersons who never applied adhesives previously. Composite cylinders were afterwards placed on the bonded surfaces and were light cured. Immediately after this the immediate shear bond strength testing was done using the Ultradent method (crosshead speed 1 mm/min). ANOVA followed by LSD test were used for statistics ( $p < 0.05$ ).

### Results



### Conclusion

iBOND Universal achieved bond strength values on the Scotchbond® Universal level.

### Comment

iBOND Universal is easy to use and shows a low technique sensibility allowing also unexperienced users an instant bonding success. As bond strength increase over 24 h after light-curing, all adhesive show the immediate bond strength only.

### Source

Kulzer R&D, Test report 2014. Data on file.



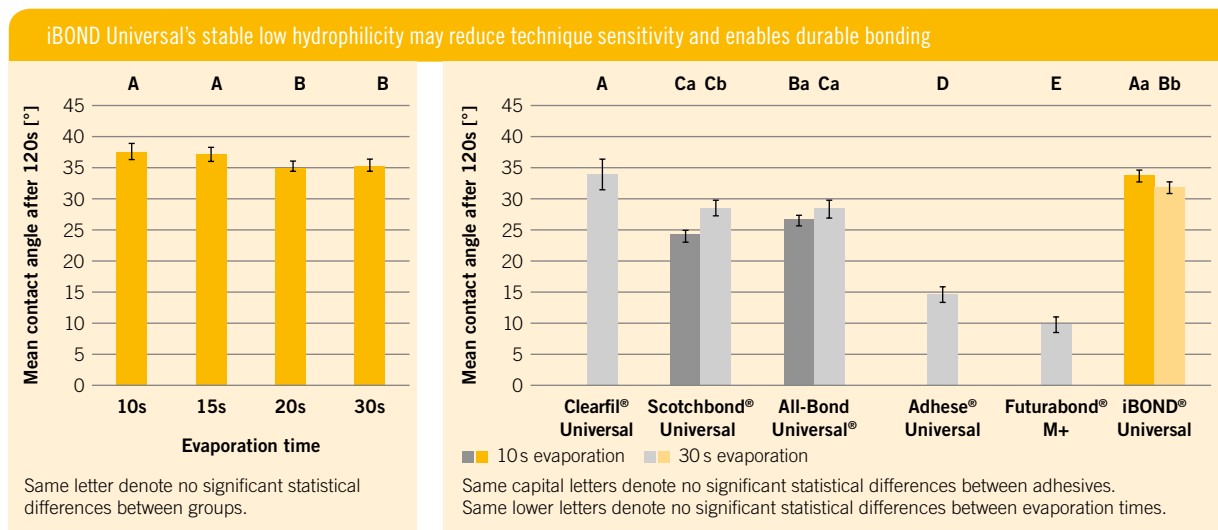
## Technique sensitivity – Kulzer R&D, Wehrheim, Germany, Mitsui Chemicals R&D, Japan

### Influence of evaporation time on hydrophilicity of different universal adhesives

#### Materials & Methods

Flat bovine dentine surfaces were prepared by grinding with SiC paper (P120 and P400) under water cooling. Adhesives were applied according to their instructions for use. The evaporation time was varied between 10s and 30s. The adhesives were light cured for 40s and contact angle measurement was directly done (n=5/adhesive): 2  $\mu$ l deionized water droplets were placed on the adhesive film. The high-speed camera was started simultaneously. Time-dependent contact angles were evaluated from the movie via software. Statistical analysis of different evaporation times of iBOND Universal and between adhesives were performed using ANOVA followed by LSD ( $p < 0.05$ ). Comparisons between different evaporation times was done by t-test ( $p < 0.05$ ).

#### Results



#### Conclusion

Contact angle of polymerised iBOND Universal seems to be less dependent from evaporation time, whereas Scotchbond® Universal shows evaporation time dependent hydrophilicity. Clearfil® Universal and iBOND Universal revealed the lowest hydrophilicity after 30s evaporation. A fast and thoroughly evaporation behaviour and low hydrophilicity are needed to reduce technique-sensitivity and to enable durable bonding.

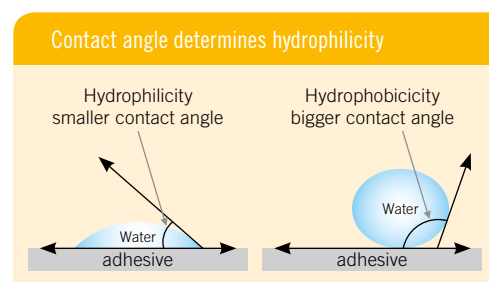
#### Comment

On the one hand, iBOND Universal exhibits high contact angles which means that this adhesive is less hydrophilic (as shown in the displayed drawing). A higher hydrophilicity of the adhesive layer may degrade more the resin-dentine bond over time (Tay & Pashley, 2003).

On the other hand, the hydrophilicity of iBOND Universal is only slightly dependent from duration of evaporation. This may lower the technique sensitivity.

#### Source

Matsumoto A, Kastrati A, Hamburg R, Loh W, Lechmann-Dorn M, Schweppe J, Leyer A: Influence of evaporation time on hydrophilicity of different universal adhesives. J Dent Res 95 (Spec Iss B): # 1117, www.iadr.org, 2016.



**Durability**



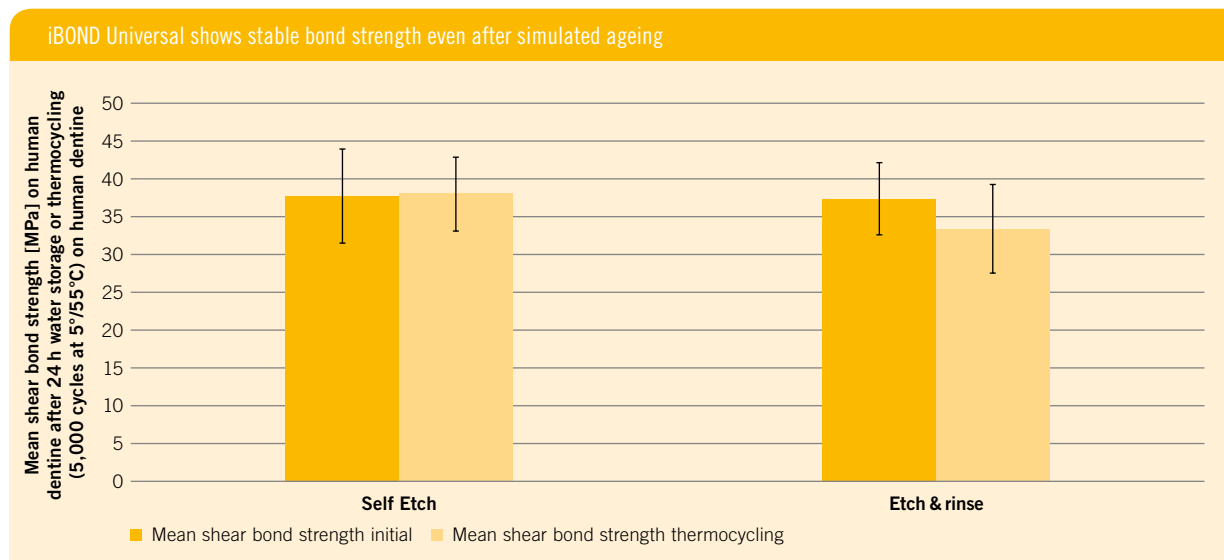
# Simulated ageing – Kulzer R&D, Wehrheim, Germany

## Shear bond strength after thermocycling

### Materials & Methods

Flat human dentine surfaces were prepared and roughened using SiC 320 paper. iBOND Universal was applied in a self-etch and in an etch & rinse (20s phosphoric acid etching) mode according to its instruction for use. The adhesive was then light cured and a composite cylinder of Venus Diamond A2 was placed using the Ultradent equipment and light cured. All specimens were then stored in water for 24 h at 37°C. Half of the samples were additionally thermocycled for 5,000 cycles at 5°C and 55°C. Shear bond strength (Ultradent method) was with a crosshead speed of 1 mm/min. Statistics were calculated using ANOVA followed by LSD-test.

### Results



No statistical significant difference between the initial and thermocycled bond strength values was detected ( $p < 0.05$ ).

### Conclusion

iBOND Universal showed stable bond strength on dentine after thermocycling.

### Comment

Restorations need to resist the oral conditions for a long time. Therefore, adhesive need to show also after ageing good bond strength values. In this test iBOND Universal demonstrated stable bond strength after simulated ageing by temperature changes.

### Source

Kulzer R&D, test report 2014. Data on file.



The background consists of several overlapping circles in various shades of gray, creating a layered, abstract effect. The circles vary in size and opacity, with some appearing more prominent than others. The overall color palette is monochromatic, ranging from dark charcoal to light gray.

## **Compatibility to different materials**



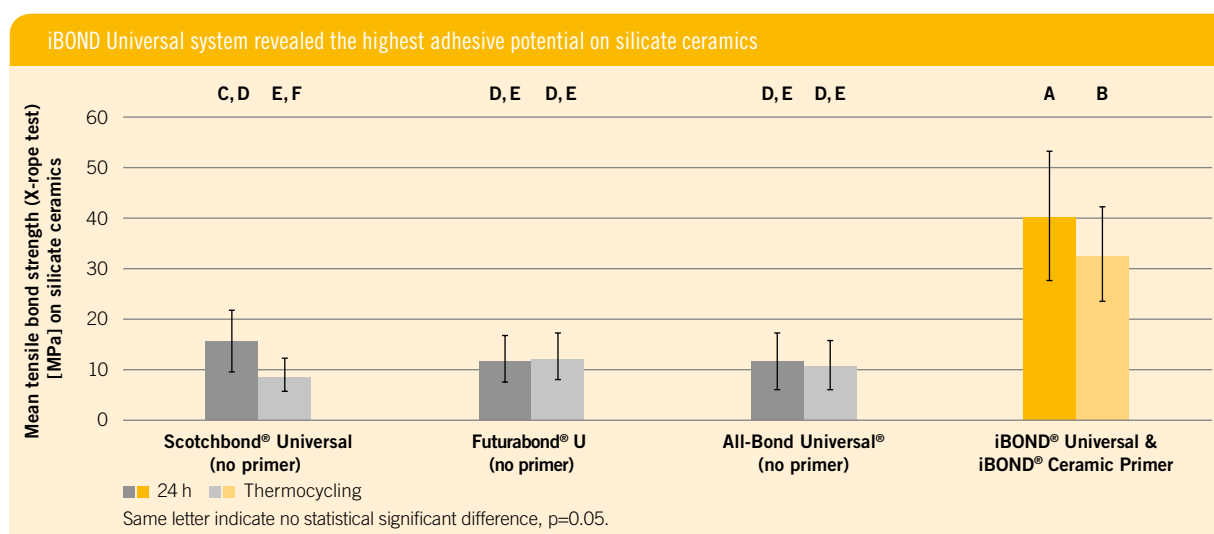
# Compatibility to silicate ceramics – University of Erlangen, Germany

## Adhesion of universal adhesives on lithium disilicate

### Materials & Methods

Rectangular bars were cut from lithium disilicate Cerec blocks, crystallised and afterwards hydrofluoric acid-etched. Adhesives were applied according to their instruction for use. Prior to the application of iBOND Universal, iBOND Ceramic Primer was applied on ceramic surfaces. All adhesives were light cured. Ceramics were luted with Variolink II and light cured. Afterwards, the specimens were stored in water for 24 h and half of specimens were later thermocycled (5k 5,000 cycles, 5°/55°C). A tensile bond strength test was performed using the x-rope-tensile test.

### Results



Scotchbond® Universal, Futurabond® U and All-Bond Universal® were used without silane primer as described in their instruction for use.

### Conclusion

Within the limits of this study, it cannot be generalised that universal adhesives can be used as bonding agents for lithium disilicate without a silane. Silane is recommended to assure higher long term bond strength of universal adhesives to lithium disilicate ceramics.

### Comment

This study simulated the cementation of indirect silicate ceramics restorations. The combination of iBOND Ceramic Primer and iBOND Universal led to the highest bond strength in this test. The other adhesives might also achieve higher bond strength when combined with a silane. All adhesives were used according to their instructions for use. That means that Scotchbond® Universal and All-Bond Universal® are cleared to be used without silane primer.

### Source

Zorzin J, Wendler M, Belli R, Petschelt A, Lohbauer U: Tensile bond strength of universal adhesives to lithium disilicate ceramic. Poster P62 presented at European Dental Materials Meeting in Nuremberg, 2015.



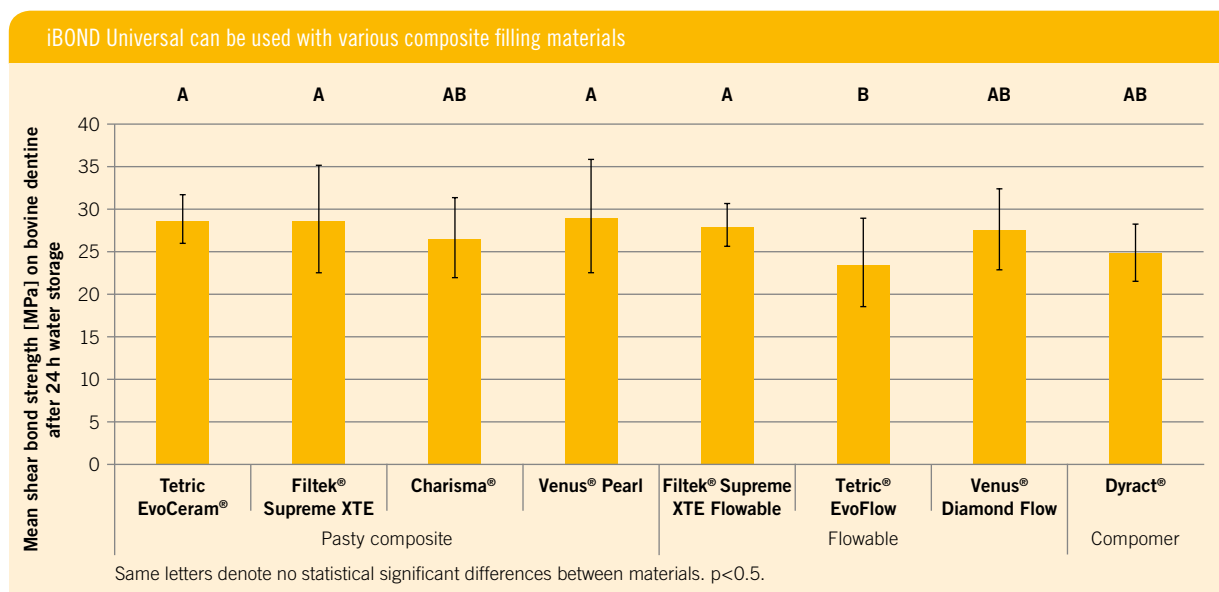
## Compatibility to composites – Kulzer R&D, Wehrheim, Germany

### Evaluation of shear bond strength to different composite materials

#### Materials & Methods

Flat bovine dentine surfaces were prepared and roughened using SiC 320 paper. iBOND Universal was applied and light cured according to its instruction for use. Afterwards composite cylinders of different composites were placed using the Ultradent equipment and light cured according to their instruction for use. After 24 h of water storage (37°C) shear bond strength was determined using the Ultradent method (1 mm/min crosshead speed).

#### Results



#### Conclusion

iBOND Universal achieved with all tested types of composite materials good shear bond strength values.

#### Comment

iBOND Universal can be used with all light-curing methacrylate composites.

#### Source

Kulzer R&D, Test report 2014. Data on file.

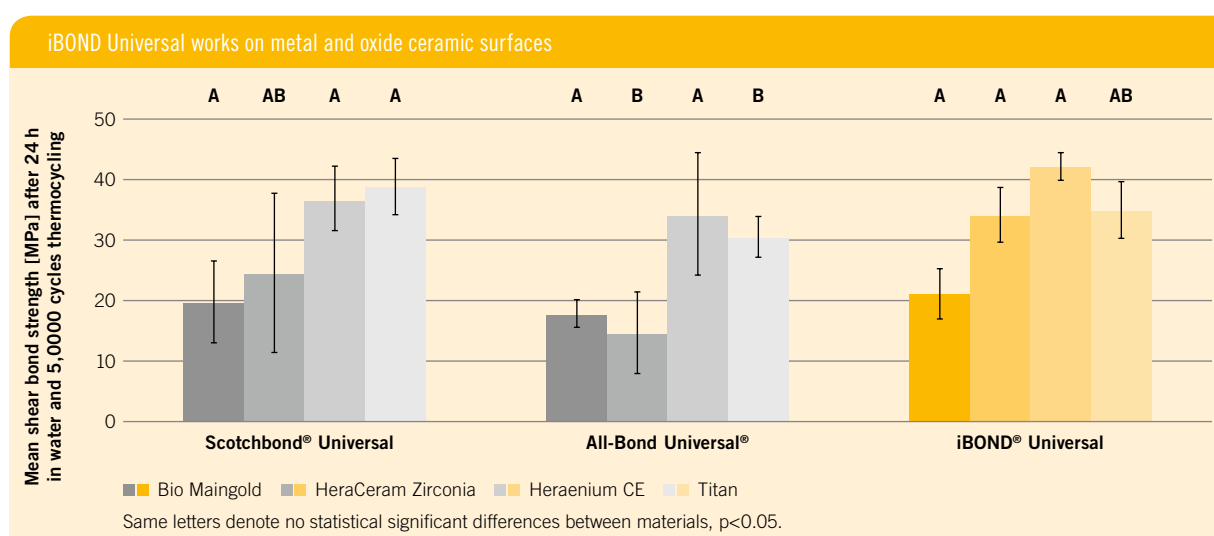
# Bonding to metals and oxide ceramics – Kulzer, R&D, Wehrheim, Germany

## Bond strength evaluations of iBOND Universal

### Materials & Methods

Zirconia, non-precious metal (Heraenium CE), precious metal (Bio Maingold SG) and titan disks were sandblasted using Aluminiumoxide (50µm, 1.5 bar). Afterwards the specimens were rinsed and dried. Then the adhesives were applied and light cured according to their instruction for use. Later composite cylinders were placed on the bonded surfaces (Venus Diamond A2) and light cured. After 24 h water storage followed by 5,000 cycles thermocycling (5°C/55°C) shear bond strength was measured (Ultradent method, 1 mm/min).

### Results



### Conclusion

iBOND Universal shows good bond strength to different surfaces after simulated ageing.

### Comment

iBOND Universal is compatible to precious and non-precious metals and oxide ceramics. This allows also the repair of metal and oxide ceramic restorations using only one bottle of adhesive.

### Source

Kastrati A, Lechmann-Dorn M, Eppinger R, Schaub M, Quinque B, Schweppe J: Bond Strength Evaluations of a New Universal Adhesive. J Dent Res 94, Spec Iss A: # 360, 2015 (www.iadr.org).

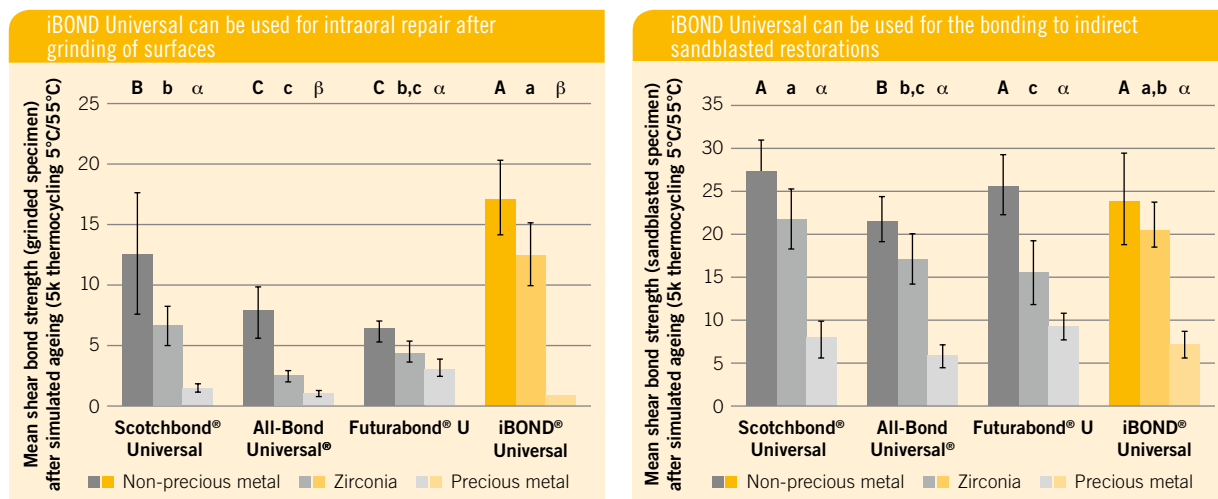
## Bonding to metals and oxide ceramics – University of Pennsylvania, Philadelphia, USA

### Bond strength evaluations of iBOND Universal

#### Materials & Methods

Specimens (n=15/material-adhesive combination) were fabricated from the non-precious metal alloy Heraenium CE (Kulzer), the precious metal alloy Platin Lloyd (BEGO) and zirconia (Kulzer). The specimens were split into 2 main study groups. The top surfaces of one half were sandblasted with Al<sub>2</sub>O<sub>3</sub> (50µm, 1.5 bar) to simulate the pre-treatment for the cementation of indirect restorations and the other half were grinded with SiC-paper (320 grid) to simulate the intraoral repair. The adhesives were applied to the surfaces according to the manufacturers' recommendations and light cured for 10s using a light-curing unit (>500mW/cm<sup>2</sup>). Acrylic plastic tubes with an inner diameter of 2.9mm and a height of 3.0mm were filled with composite material (Venus Diamond A2 shade from Kulzer), bonded to the specimen surfaces with an alignment apparatus and light cured for 40s. The prepared specimens were stored in water at 37°C for 24h and exposed to 5,000 thermal cycles (5°C/55°C). Shear bond strength was then tested with a universal shear bond strength testing machine (crosshead speed 1 mm/min). The mode of failure was determined using a stereo microscope. Statistics were done using the Kruskal-Wallis-Test between adhesives and Mann-Whitney U test between pre-treatment groups (p<0.05).

#### Results



Identical letters denote no significant differences between adhesive for each material (Upper case letter: on non-precious metal, lower case letters: on zirconia, Greek letters: on precious metal)

Significant differences between the pre-treatment procedures (grinding and sandblasting) could be found on non-precious metal for all adhesives except iBOND Universal. For the other materials sandblasting revealed better bond strength for all adhesives.

#### Conclusion

iBOND Universal shows better bond strength performance on non-precious metal surfaces and zirconia than the precious metal alloy surfaces.

### Comment

iBOND Universal bonds to different dental materials. Therefore, it can be used for the cementation of indirect restorations in combination with an adhesive cement after sandblasting the restoration surfaces. It offers also the opportunity for a minimal-invasive intraoral repair of metal and zirconia restorations in cases where the restoration surface can be ground by a fine diamond bur only.

Of course, if an intraoral sandblasting unit is available, bond strength, especially to precious metal, can be significantly improved.

### Source

Özer F, Blatz MB: Shear bond strength testing of the new adhesive iBOND Universal on different substrates. Final report December 2015. University of Pennsylvania, Philadelphia, USA. Unpublished data. Data on file.

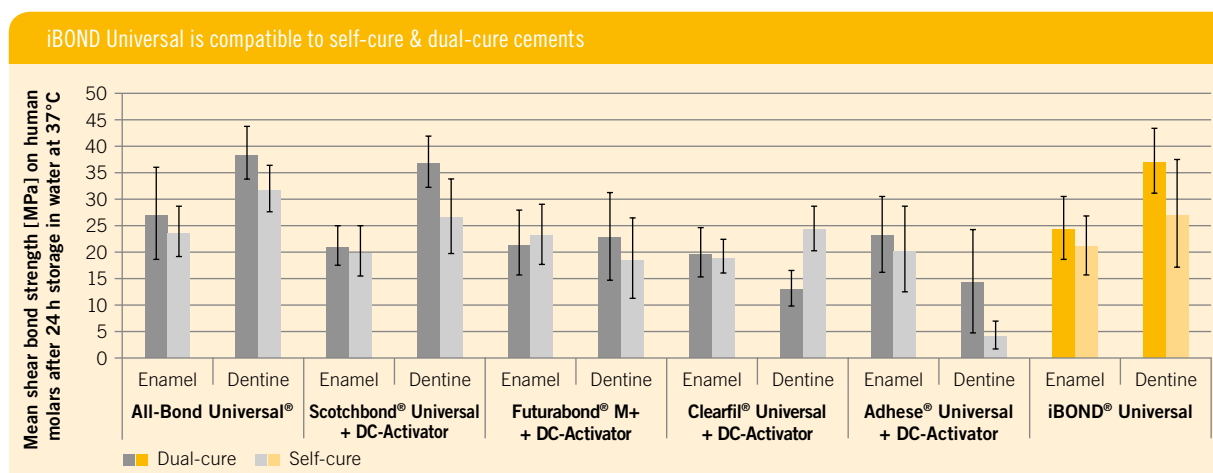
## Compatibility to different curing modes (adhesive cement) – Kulzer, R&D, Wehrheim, Germany

### Compatibility of universal adhesives with composite cements in different curing-modes

#### Materials & Methods

Flat human dentine & enamel specimens were prepared and roughened by SiC paper 320. The adhesives were applied according to their instruction for use and light cured. Scotchbond® Universal was used with its dual cure activator. Afterwards resin cement cylinders made of Clearfil® Esthetic Cement (Kuraray) were applied and in two different ways cured: Self-curing mode (1 h at 37°C) or dual-curing-mode (20s light-curing) followed by a 15 min self-curing at 37°C. After 24 h at 37°C water storage shear bond strength testing was performed using the Ultradent method and a cross-head speed of 1 mm/min. Statistics were done using an ANOVA followed by LSD post-hoc analysis ( $p < 0.05$ ).

#### Results



Statistical significant differences between materials:

- **Enamel dual-cure mode:** between All-Bond Universal® and Clearfil® Universal.
- **Dentine dual-cure mode:** iBOND Universal, Scotchbond® Universal and All-Bond Universal® performed best, followed by Futurabond® M+, Clearfil® Universal and Adhese® Universal.
- **Dentine self-cure mode:** between All-Bond Universal® and Clearfil® Universal and between iBOND Universal, Scotchbond® Universal, All-Bond Universal® and Futurabond® M+ and between Adhese® Universal and the other adhesives.

#### Conclusion

Even without an activator system iBOND Universal shows reliable shear bond strength results on human dentine and enamel after 24 h. Except for Adhese® Universal in self-cure mode on dentine, all universal bondings seem to be efficient for cementation in self cure and dual-cure mode.

#### Comment

iBOND Universal can be used also in combination with dual- and self-curing resin materials.

#### Source

Lechmann-Dorn M, Eppinger R, Kastrati A, Loh W, Schaub M, Schweppe: Compatibility of Universal Adhesives with Composite Cements in Different Curing-Modes. J Dent Res 94, Spec Iss A: # 2285, 2015 (www.iadr.org).

# Compatibility to self-cured adhesive cement – Kulzer R&D, Wehrheim, Germany

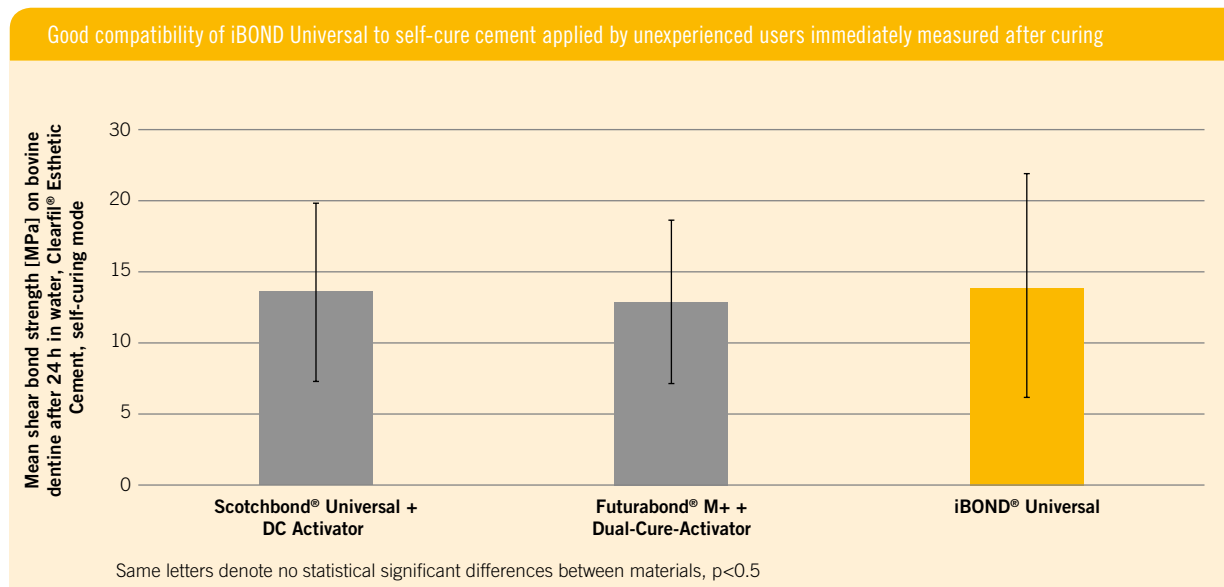
## Comparison of the compatibility of different universal adhesives applied by laypeople to self-cured resin-based cements

### Materials & Methods

Flat bovine dentine specimens were prepared and roughened by SiC paper 320.

Application of adhesives was done according to their instructions for use by laypeople. Scotchbond® universal and Futurabond® M+ were applied together with their dual cure activators, iBOND Universal was applied without dual cure activator. Adhesives were light cured. Afterwards resin cement cylinders (Clearfil® Esthetic Cement, Kuraray) were applied on top of the cured adhesives and were self-cured: 1 h at 37°C. Measurement of the shear bond strength (Ultradent method, 1 mm/min) was performed immediately after curing.

### Results



### Conclusion

iBOND Universal without dual cure activator shows comparable results on self-cured resin-based cement as universal adhesives applied with dual cure activator.

### Comment

iBOND Universal performs with self-curing cements without a difference to the other tested universal adhesives plus their corresponding dual cure activator. This study demonstrates the low technique-sensitivity of iBOND Universal. Even without experience, good results can be obtained easily.

### Source

Kulzer R&D, Wehrheim, Germany. Test report 2014. Data on file.

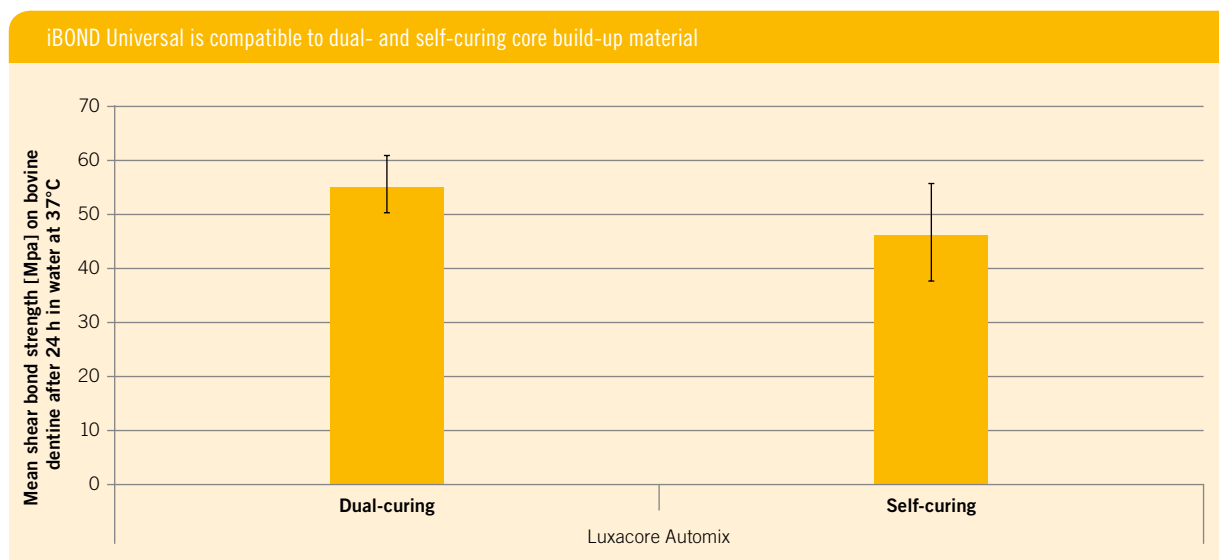
## Compatibility to different curing modes (core build-up material) – Kulzer, R&D, Wehrheim, Germany

### Shear bond strength of iBOND Universal to core build-up materials

#### Materials & Methods

Bovine teeth were embedded and flat dentine surfaces produced. Surfaces were prepared using SiC paper 320. iBOND Universal was applied in self-etch mode and light cured according to its instruction for use. Then, a Luxacore Automix-cylinder (A3) was applied on the bonded surface using the Ultradent-equipment. The core build-up material was cured in two different ways (n=8): dual-cure: 15 min self-curing at 37°C and 40s light-curing. Self-cure: 1 h self-curing at 37°C. The specimens were afterwards stored for 24 h in water at 37°C followed by a shear bond strength test (Ultradent-method, crosshead speed 1 mm/min). Statistics were done using the independent t-test.

#### Results



There was a weak statistical significant difference between both groups ( $p=0.03$ ).

#### Conclusion

iBOND Universal shows good bond strength to Luxacore Automix in dual- and self-curing mode.

#### Comment

iBOND Universal can be used with dual- and self-curing core build-up materials. However, we recommend to always light cure dual-curing materials.

#### Source

Kulzer R&D, Test report 2014. Data on file.

# **Intraoral repair of different dental materials**





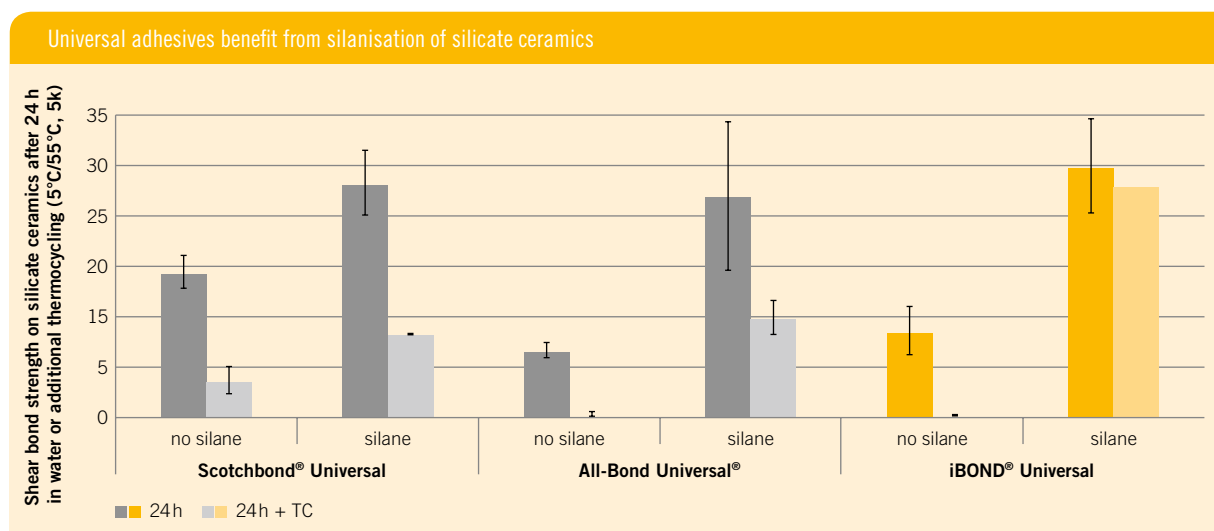
# Repair of silicate ceramics – Kulzer, R&D, Wehrheim, Germany

## Influence of ceramic pretreatment on shear bond strength of three universal adhesives

### Materials & Methods

Silicate ceramic disks surfaces were roughened with SiC paper 320. iBOND Universal, Scotchbond® Universal or All-Bond Universal® with and without the previous conditioning of the silicate ceramic surface using iBOND Ceramic Primer were applied according to their instruction for use and later light cured. Afterwards composite cylinders (Venus Diamond A2) were applied and light cured. Shear bond strength (Ultradent method, 1 mm/min) was done after 24 h at 37°C water storage or after 24 h water storage and 5,000 cycles thermocycling (TC: 5°C/55°C, 30s dwell time).

### Results



Treatment with or without silane was statistically significantly different for each adhesive. At 24 h and 24 h with TC Scotchbond® Universal differed significantly from the other adhesives. In the silanised group iBOND Universal showed significantly higher results after TC than the other adhesives.

### Conclusion

Glass ceramic pretreatment using silane primer had a positive impact on bond strength of all adhesives. The included silane in Scotchbond® Universal according to the manufacturer's claim does not provide a reliable shear bond strength after thermocycling. All-Bond Universal® should also be used in combination with a primer on glass ceramics.

### Comment

This study indicates that all tested adhesive should be used together with an additional silane. Prior to usage of iBOND Universal on silicate ceramics, a silanisation of the silicate ceramic surface using iBOND Ceramic Primer always needs to be done first to ensure safe bonding.

### Source

Kastrati A, Lechmann-Dorn M, Eppinger R, Schaub M, Schweppe J, Loh W: Influence of Ceramic Pretreatment on Shear-Bond-Strength of three Universal Adhesives. J Dent Res 94, Spec Iss A: # 2282, 2015 (www.iadr.org).

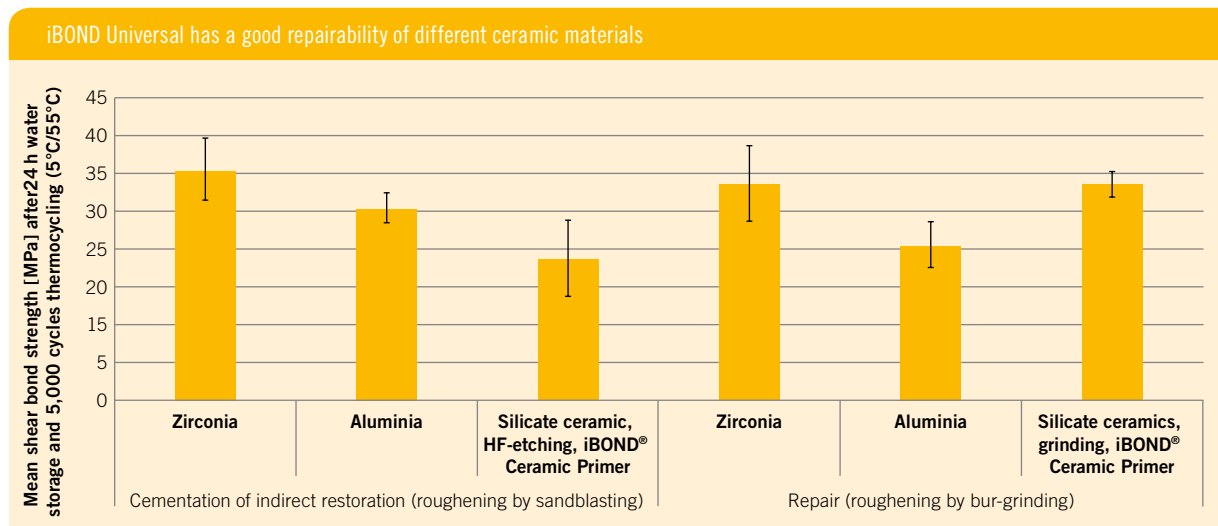
## Repair of silicate ceramics – Kulzer R&D, Wehrheim, Germany

### Shear bond strength to different substrates to simulate cementation of indirect restorations and intraoral repair

#### Materials & Methods

Flat disks were made from zirconia, alumina and silicate ceramics and were roughened with SiC paper 320. Half of the specimens received sandblasting pre-treatment using  $\text{Al}_2\text{O}_3$ , 50  $\mu\text{m}$ , 1.5 bar. The other half of samples was ground only. The silicate ceramic specimens in the sandblasting group were etched using hydrofluoric acid. On all silicate ceramics iBOND Ceramic Primer was used prior to the application of iBOND Universal which was used according to its instructions for use. Afterwards composite cylinders (Venus Diamond A2) were placed on top. The shear bond strength was determined using the Ultradent method (crosshead speed 1 mm/min) after 24 h water storage (37°C) and 5,000 cycles of thermocycling (5°C/55°C).

#### Results



#### Conclusion

iBOND Universal demonstrates good bond strength to the tested substrates after different pre-treatments of the materials.

#### Comment

iBOND Universal can be used for the cementation of indirect restorations together with a luting cement (the results for the different materials can be found on the left side of the graph). But iBOND Universal can also be used for the intraoral repair of these materials (right side of the graph). The dentist can repair all common dental materials with only one adhesive system and an easy approach (bur-grinding only). Of course, for silicate ceramics iBOND Ceramic Primer needs to be used additionally.

#### Source

Kulzer R&D, Wehrheim, Germany. Test report 2014. Data on file.

# Repair of composite – University of Turku, Finland

## Different methods of composite repair

### Materials & Methods

A total of 64 Venus Pearl composite cylinder (8mm diameter and 6mm height) were incrementally built and incrementally (layer thickness of 2 mm) light cured in silicone molds (Elipar S10, 3M ESPE 1186Mw/cm<sup>2</sup> measured with CheckMARC, Blue Light Analytics) according to the manufacturers' recommendations. A glass slide was used to make the bottom of the silicone mold and to achieve flat-ended specimens. After polymerization the blocks were divided into two subgroups: fresh and aged substrates.

The groups were:

- **Group 1:** Composite resin was added incrementally up to 6mm (control)
- **Group 2:** 400-grid abrasive paper + iBOND Universal + composite resin
- **Group 3:** 400-grid abrasive paper + silane + iBOND Universal + composite resin
- **Group 4:** 400-grid abrasive paper + sand-blasting (2 bar; Aluminum oxide 30µm sand) + iBOND Universal + composite resin

After preparation the composite blocks were water stored at 37°C for 24 h and sectioned into 1x1x11 mm beams. The beams from each group were further divided into two groups.

Fresh composites:

The first group was water stored at 37°C for 24 h and tested using a microtensile tester at a cross head speed of 0.5 mm/min (Bisco). The other groups were thermocycled between 5°C/55°C for 6,000 cycles with a dwell time of 30s in each bath and 24 h after thermocycling they were tested with microtensile tester.

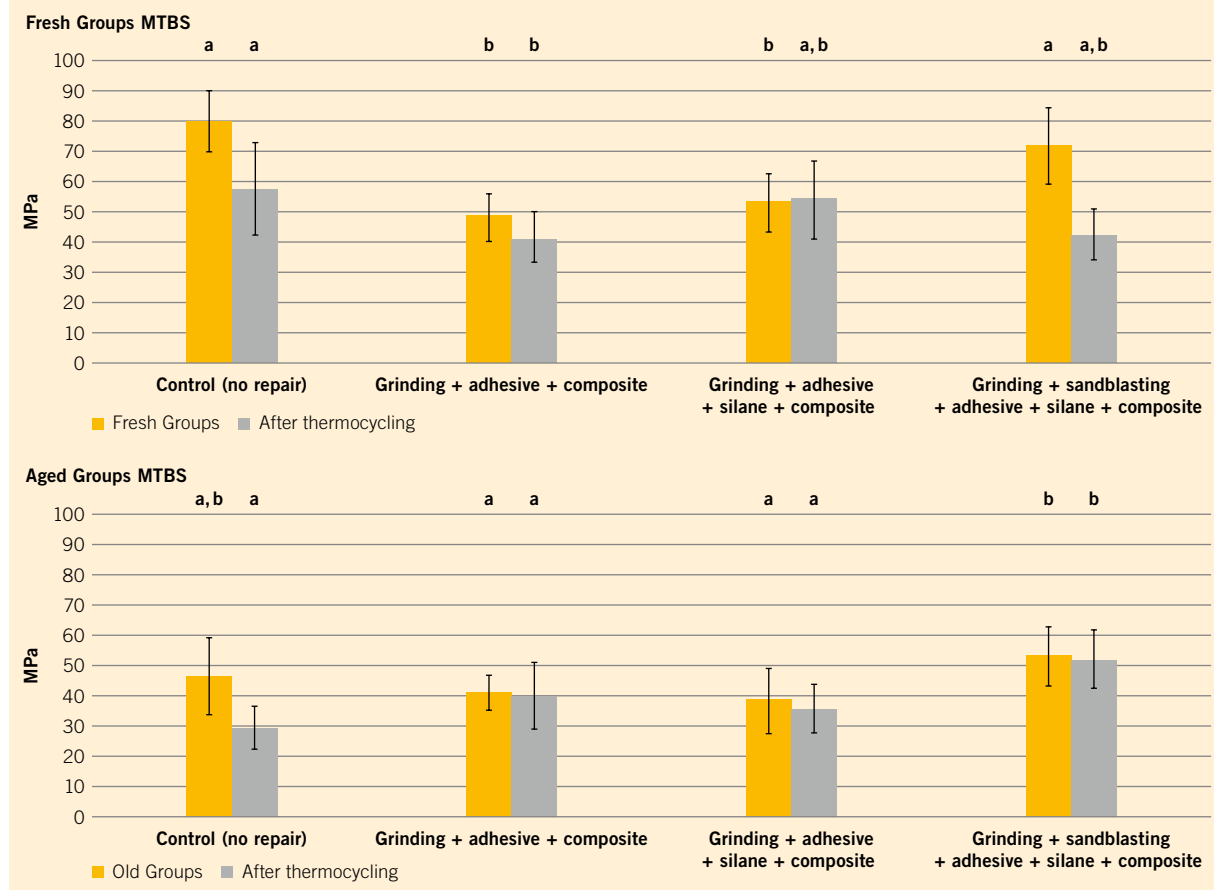
Old composites:

After preparation the composite blocks were water stored at 37°C for 24 h and kept at 90°C for 8 h. After that they were water stored (37°C) for 3 weeks before sample preparations.

After preparation the composite blocks were water stored at 37°C for 24 h and sectioned into 1x1x11 mm beams. The beams from each group were further divided into two groups. The first group was water stored at 37°C for 24 h and tested using a microtensile tester at a cross head speed of 0.5 mm/min (Bisco). The other groups were thermocycled between 5°C/55°C for 6,000 cycles with a dwell time of 30s in each bath and were tested with microtensile tester. Statistical analysis consisted of a multiple analysis of variance with appropriate post-hoc pairwise comparisons being made using the Tukey's test. Where appropriate within a specific graph, individual statistical analyses were performed to interpret differences within that limited data set, and are explained below, in those sections. All statistical testing was performed at a pre-set *alpha* of 0.05 using IBM SPSS Statistics version 22.

## Results

iBOND Universal allows repair of fresh and old composite restorations



## Conclusion

Within the limitations of this study, it can be concluded that the use of the iBOND Universal is recommended when a sandblasting surface preparation method was used followed by silane application.

## Comment

Sandblasting and silane pretreatment showed best results in repairing fresh and old composites. But as sandblasting is not available in each dental surgery, also good results can be obtained by grinding the composite and using only iBOND Universal as described in the instruction for use.

## Source

Tezvergil-Mutluay A, University of Turku, Finland. Test report 2015. Unpublished data. Data on file.

## **In vivo evaluation**



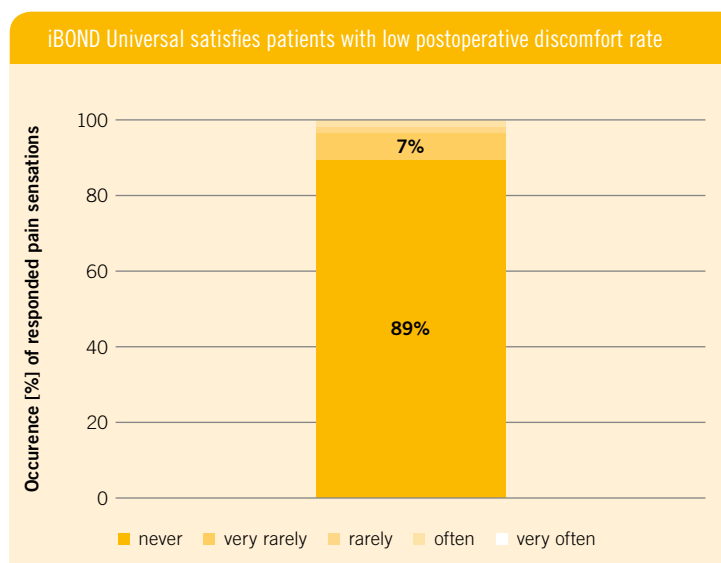
# Clinical handling evaluation – Kulzer, PA, Dormagen, Germany

## Post-operative sensitivity

### Materials & Methods

60 dentists from 3 countries (20 Italy, 29 Germany, 11 UK) have tested clinically iBOND Universal. Approximal 2,000 restorations were placed. Dentists had to complete a questionnaire.

### Results



### Conclusion

iBOND Universal exhibits low rate of post-operative discomfort.

### Comment

iBOND Universal had a very low rate of post-operative pain. Nearly 90% of the dentist reported no post-operative pain and in cases where it was reported it was mainly rarely.

### Source

Kulzer Product Application, Dormagen, Germany. Test report 2015. Data on file.





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