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Monobond Plus

Scientific Documentation

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Monobond Plus is an universal primer for all types of restorative materials. It is used wherever an adhesive bond between the dental hard tissue and the restoration is necessary or desired.

1. Introduction

In modern dentistry, a large variety of different materials are offered to fabricate all types of restorations. Depending on the application, dental materials have to meet different requirements in terms of price, material strength, biocompatibility and aesthetics. The same applies to the cementation of restorations. In this field, longevity, aesthetics and the material's biological effect also play a certain role. In conjunction with retentive crown preparations, the use of conventional cements is usually sufficient. Even though these materials only demonstrate a limited sealing effect, the risk of secondary caries is relatively low because they usually release bioactive components due to erosion. For less retentive tooth preparations, adhesive cementation is indicated. Adhesive luting protocols involve the use of luting composites which are used in combination with dentin adhesives. In addition, a special primer is employed to establish a chemical bond to the restorative material.

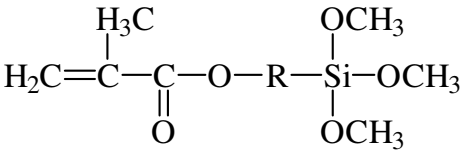
It is generally accepted that conventional cementation techniques are suitable if conventional crown preparations are present, while an adhesive luting protocol should be preferred in all other cases. These include most types of inlay, onlay, adhesive bridge and veneer preparations. Moreover, glass-ceramic restorations made of e.g. IPS Empress and indirect composite restorations are adhesively cemented to enhance their service life. The adhesive cementation technique has proved to be extremely successful in clinical application. The adhesive system that mediates a bond to the dental hard tissue, and to the dentin surface in

particular, as well as the coupling agent which creates a bond to the restoration have been shown to play an important role in this respect.

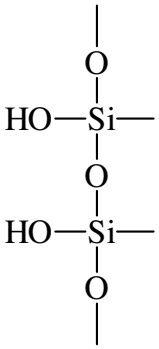
While dentin adhesion is a field in which consistent further development has taken place over the past few years so that the mechanisms responsible for adhesion are increasingly well understood, bonding to different substrates, i.e. different restorative materials, is a relatively new field of research. What makes this issue even more complex is the fact that a very large number of different materials are used in the restoration of teeth.

1.1 Glass-ceramics, silicate

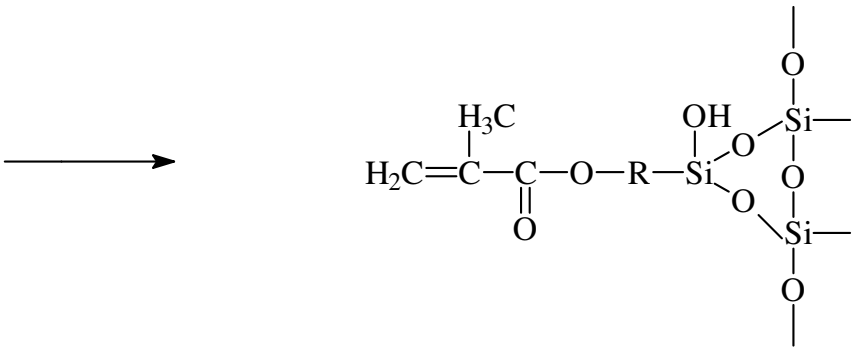
All silicate-based ceramics can be etched with hydrofluoric acid. By doing this, a micro-retentive etching pattern is created which considerably enlarges the bonding surface. The next step is the silanization of the restoration surface. Normally, methacrylic monomers, which possess a trialkoxy silane group, are used for this purpose. This functional group allows a bond to the silicate surface to be established.



Silane methacrylate

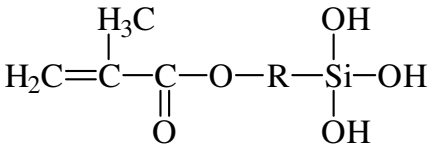


Silicate surface (schematic)



Methacrylate silicate compound

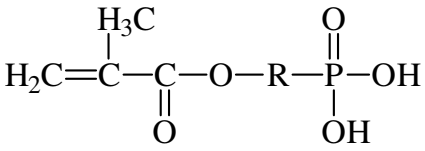
From a chemical point of view, the trimethoxy silane is first hydrolized. The intermediate product then reacts with the silicate surface in a condensation reaction.



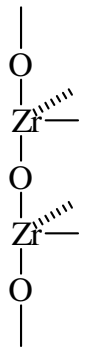
Trihydroxy silane (reactive intermediate product)

1.2 Zirconium oxide, aluminium oxide, base metals

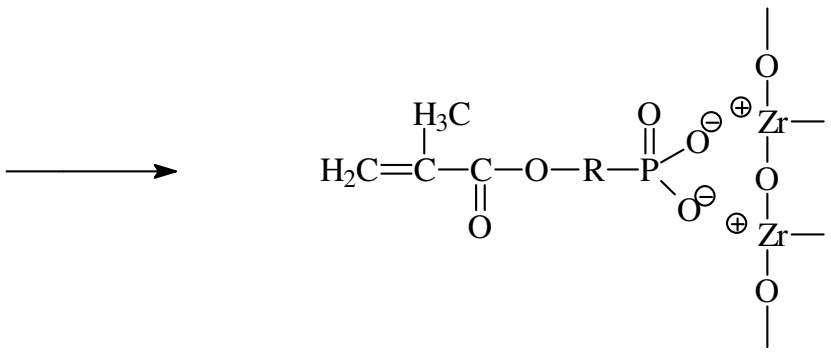
High affinity to phosphoric acid is typical of this category of materials. When used in conjunction with phosphoric acid, base metals form phosphates, which possess a low solubility. In order to establish a bond to restorations made of these materials, methacrylate monomers with a functional phosphoric acid group are used. By creating a very stable phosphate link, a strong adhesive bond is achieved which is resistant to hydrolysis. In addition, the restorative material is sandblasted with aluminium oxide prior to the application of the coupling agent in order to create mechanical micro-retentions.



Phosphoric acid methacrylate



Zirconium oxide (schematic)



Methacrylate zirconium oxide compound

The high reactivity of these metals when used in combination with phosphoric acid also needs to be taken into account when restorations are cleaned. Phosphoric acid gel forms a stable phosphate layer on the restoration surface and renders the surface resistant to the effect of the coupling agent. Therefore, the adhesive values achieved after the restoration surface has been cleaned with phosphoric acid are low.

Consequently, a restoration made of zirconium oxide, aluminium oxide or base metal alloy which is contaminated with e.g. saliva must never be cleaned with phosphoric acid. Either ethanol or other recommended agents should be used instead.

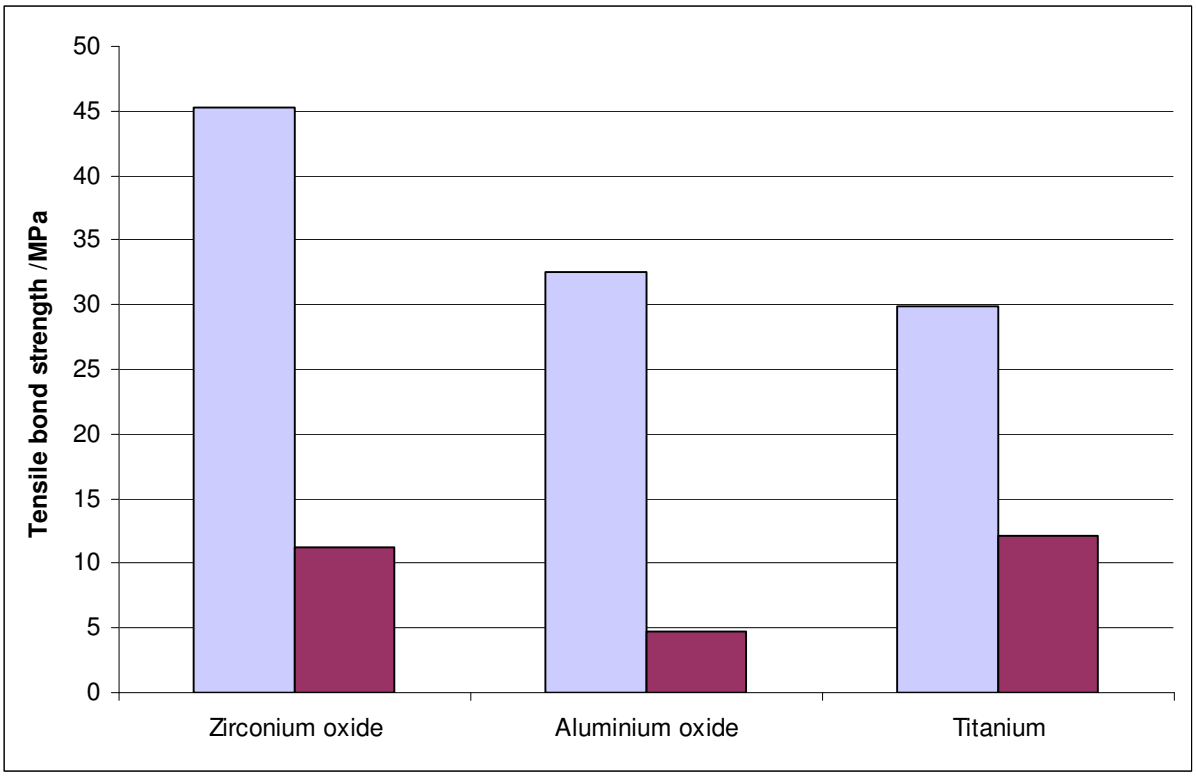


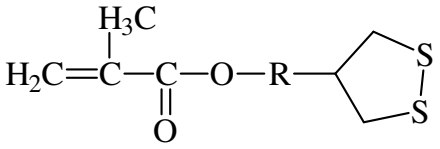
Fig. 1: Tensile bond strength achieved with Monobond Plus and Multilink Automix without (light) and after (dark) pre-treatment with phosphoric acid (Ivoclar Vivadent, R&D 2008)

In this test, the test specimens were sandblasted and subsequently cleaned in an ultrasonic unit. One half of the specimens were in contact with phosphoric acid gel (Total Etch) for one minute prior to being rinsed with water and air-dried. After having treated the surface with Monobond Plus, a composite block was cemented onto it using Multilink Automix. The tensile strength was measured after the test specimens had been subjected to thermocycling (5000 cycles, 5°C - 55°C).

1.3 Gold and precious metals

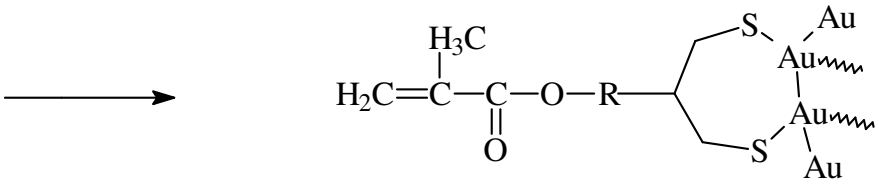
In conjunction with these materials, the slight sulfide layer that forms on these materials is used to advantage. This reaction is familiar to most of us, as it is responsible for tarnishing silver. Ideally, a thiol or mercaptan group reacts with the precious metal surface by forming a sulfide compound. Unfortunately, these mercaptan groups are not compatible with methacrylate groups, so that chemical alternatives need to be used.

Monobond Plus is based on a methacrylate monomer which contains a cyclic disulfide group. If a reaction occurs on the metal surface, this ring-shaped structure is opened and the monomer bonds to the metal by means of a sulfur atom. In this case as well, micro-mechanical retentions are created by previously sandblasting the restoration surface.



Disulfide methacrylate

Gold



Methacrylate gold compound

2. Monobond Plus

Monobond Plus unique feature is that it contains different coupling agents in one bottle. It is applied in the same way on all types of materials. Monobond Plus is allowed to react for 60 s. Within this period of time, it forms a layer together with the monomer that is active in each case. Any monomer excess is subsequently evaporated together with the solvent. Due to the layer that forms, the previously hydrophilic surface turns hydrophobic. Consequently, the luting composite is able to optimally wet the restorative material. As the free methacrylate groups are chemically incorporated into the composite matrix, a reliable bond is established in the course of the polymerization procedure.

3. Technical data

Standard Composition	(in wt%)
Adhesive monomers	4
Ethanol	96

Physical Properties

Refractive index n_D^{20}	1.3646
Density (22.1 °C)	0.7938 g/ml

4. Studies and investigations

4.1 Tensile bond strength on different substrates

At the University of Kiel, the tensile bond strength of Variolink II and Multilink Automix was evaluated on various substrates after 3 and 160 days of immersion in water. Additionally, the specimens used for long-term measurement were subjected to thermocycling (75,000 cycles).

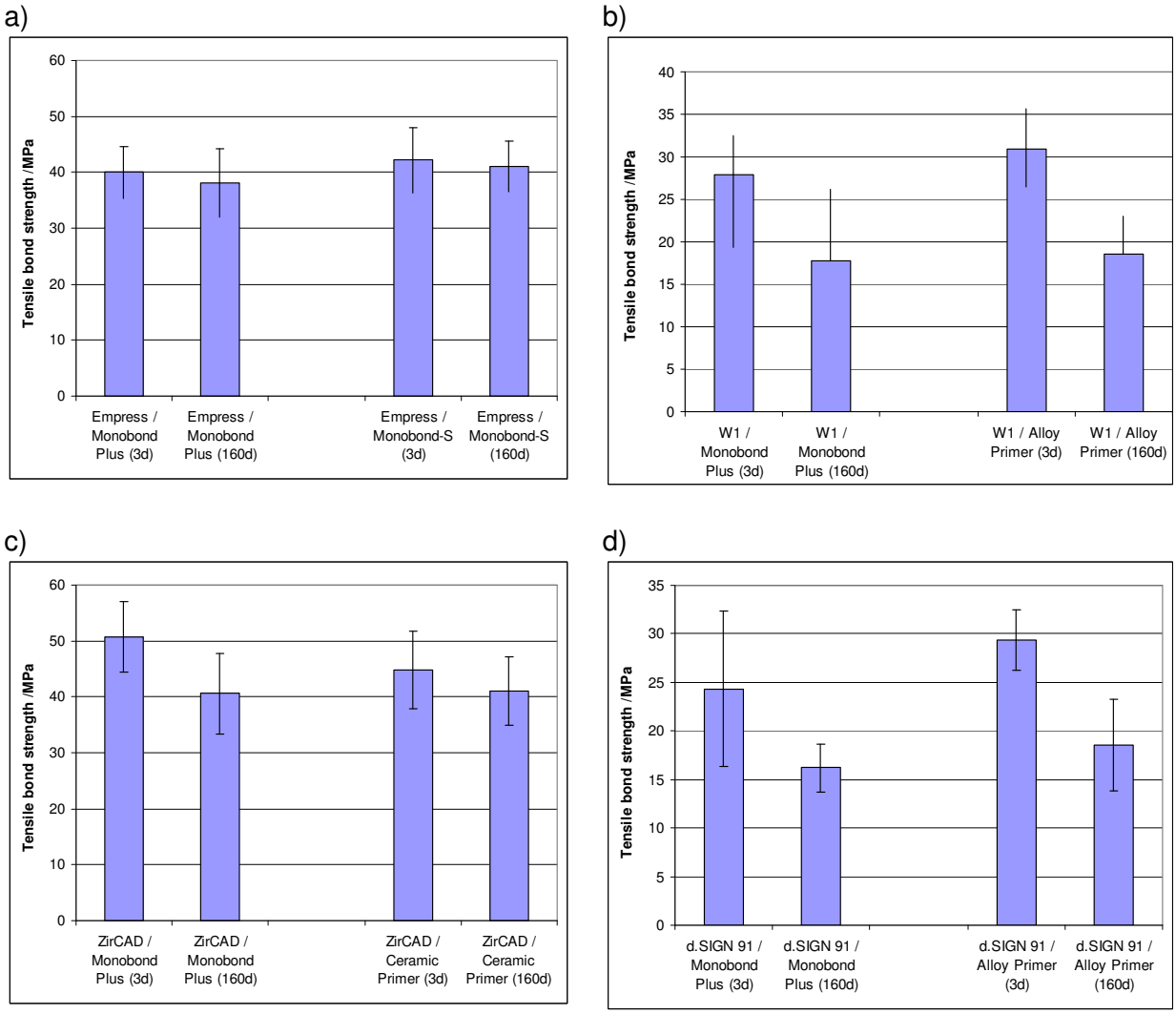


Fig. 2: *Tensile bond strength of Monobond Plus on different substrates in comparison with Monobond-S, Ceramic Primer and Alloy Primer after 3 or 160 days of immersion in water: a) leucite glass-ceramic IPS Empress b) Pd-based alloy W1 c) Y-TZP IPS e.max ZirCAD d) gold alloy d.SIGN 91 (Prof. Kern, University of Kiel, 2008)*

When used in conjunction with IPS Empress glass-ceramic, the universal primer proved to be equally effective as Monobond-S. In this case, the luting composite Variolink II was used for the cementation of the test specimens. When used on zirconium oxide together with Multilink Automix, Monobond Plus showed a behaviour similar to that of Ceramic Primer from Kuraray, which uses a similar chemistry. With the alloys W1 and d.SIGN 91, adhesion was shown to slightly decrease after long-term storage. However, this decrease was comparable to that of Alloy Primer from Kuraray.

4.2 Shear bond strength in comparison with Monobond-S and Metal / Zirconia Primer

The Dental Advisor evaluated the shear bond strength of different materials according to the Ultradent method. This investigation also involved an analysis of the behaviour of Monobond Plus in comparison with Monobond-S (Empress) and Metal/Zirconia Primer.

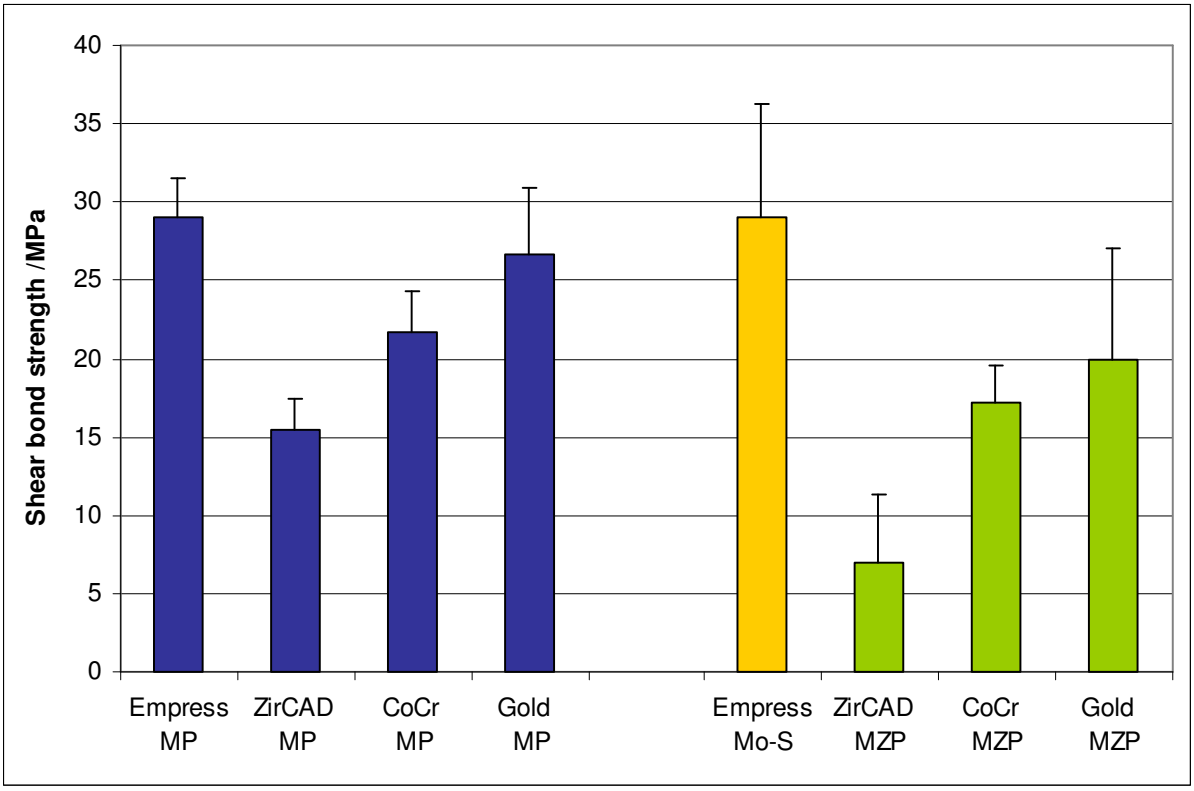


Fig. 3: *Shear bond strength of Monobond Plus (MP) in comparison with Monobond-S (Mo-S) and Metal/Zirconia Primer (MZP) on IPS Empress, IPS e.max ZirCAD, chromium-cobalt alloy and high-gold alloy (Prof. Powers, Dental Advisor, 2008)*

When used in conjunction with Monobond Plus, Multilink Automix achieves the same bond strength on Empress as Monobond-S, while it shows better adhesive values than Metal/Zirconia Primer.

4.3 Shear bond strength on zirconium oxide

Prof. Irie from Tokyo cemented a composite pattern made of Filtek Z250 on Lava (zirconium oxide) ceramic using different materials and sheared it off.

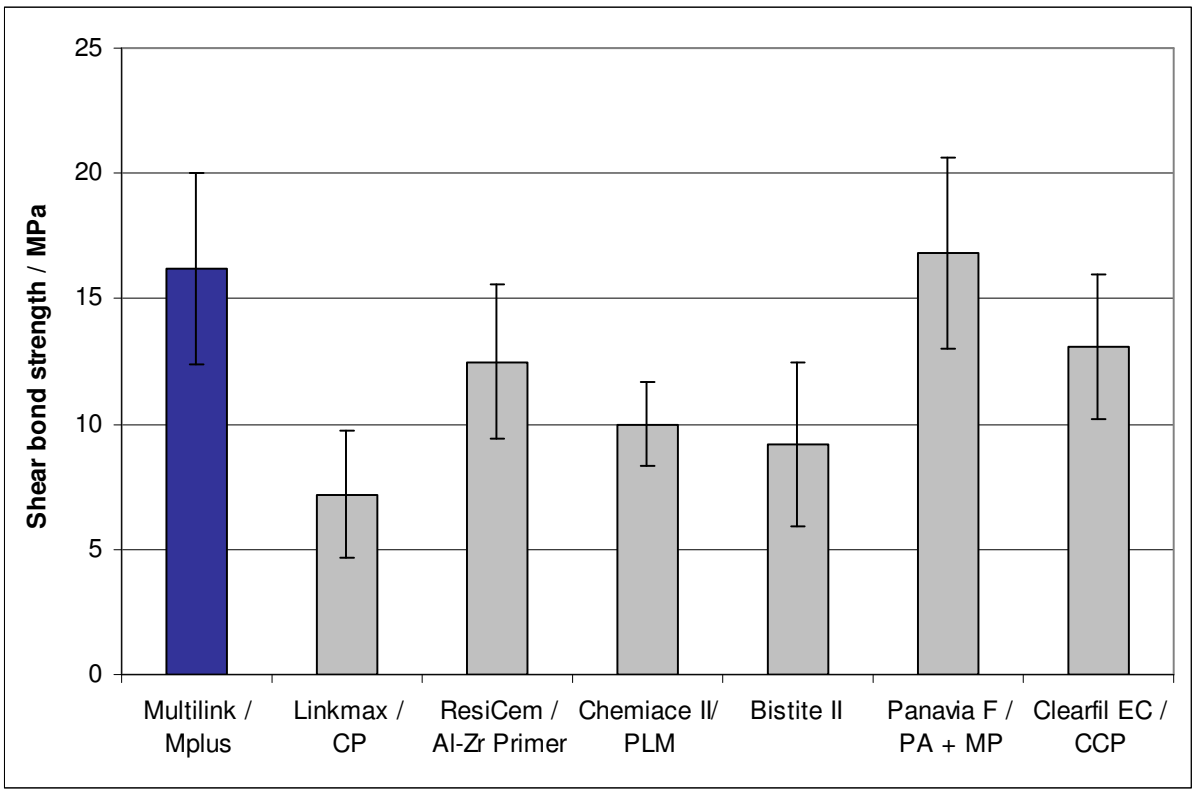


Fig. 4: *Shear bond strength of Multilink Automix in the presence of Monobond Plus on the zirconium oxide material Lava. Tested systems: Multilink Automix/Monobond Plus (Ivoclar Vivadent), Linkmax/Ceramic Primer (GC), ResiCem/Al-Zr Primer (Shofu), Chemiace II/Porcelain Liner M (Sun Medical), Bistite II (Tokuyama Dental), Panavia F 2.0/Porcelain Activator/Mega Primer (Kuraray Medical) and Clearfil Esthetic Cement/Clearfil Ceramic Primer (Kuraray Medical) (Prof. Irie, Tokyo, 2008).*

The system Multilink Automix / Monobond Plus showed shear bond values similar to those of Panavia F 2.0 / Porcelain Activator / Mega Primer from Kuraray Medical after immersion in water for 24 hours. All the other systems were clearly inferior.

4.4 Pull-out tests with the endodontic post FRC Postec Plus

Fibre-reinforced composite posts such as FRC Postec Plus are adhesively cemented in the root canal. A silane is used as the coupling agent.

An *in vitro* investigation involving a pull-out test revealed that Monobond Plus shows a behaviour similar to that of clinically proven coupling agents.

The endodontic posts were cleaned with Total Etch for 60 seconds, rinsed with distilled water and blown dry. Following this, the posts were conditioned with the primer (Monobond-S or Monobond Plus) and incorporated using Multilink Automix or MultiCore Flow.

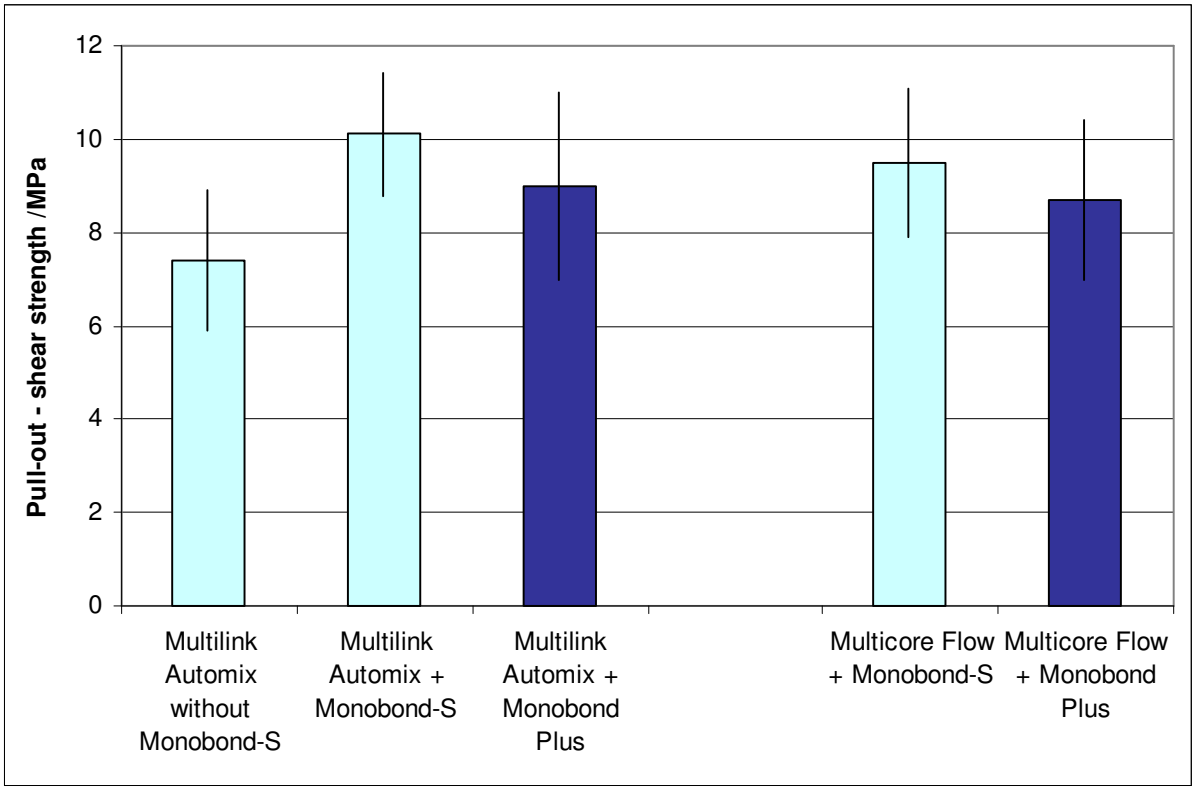


Fig. 5: *Pull-out tests with FRC Postec Plus following adhesive cementation in the presence of Monobond-S or Monobond Plus (Ivoclar Vivadent, R&D 2008)*

The strength required to pull out the FRC post after treating it with Monobond Plus was in the same range as that required when the post was treated with the clinically proven Monobond-S. The endodontic posts were previously cleaned with phosphoric acid gel.

4.5 Storage stability at room temperature

Monobond Plus is a strongly diluted alcohol-based solution of three active reagents: a silane, a phosphoric acid derivative and a disulfide (see sections 1 to 1.3). In this combination, the three active reagents remain stable. This behaviour has been confirmed in real-time stability tests (see Fig. 6)

In the test series conducted, composite test specimens were cemented on etched lithium disilicate glass-ceramic (IPS e.max CAD) and corundum-blasted zirconium oxide (IPS e.max ZirCAD) bases using Multilink Automix and Monobond Plus. Monobond Plus was applied immediately after opening the bottle (zero months) and then after four, eight, twelve and sixteen months.

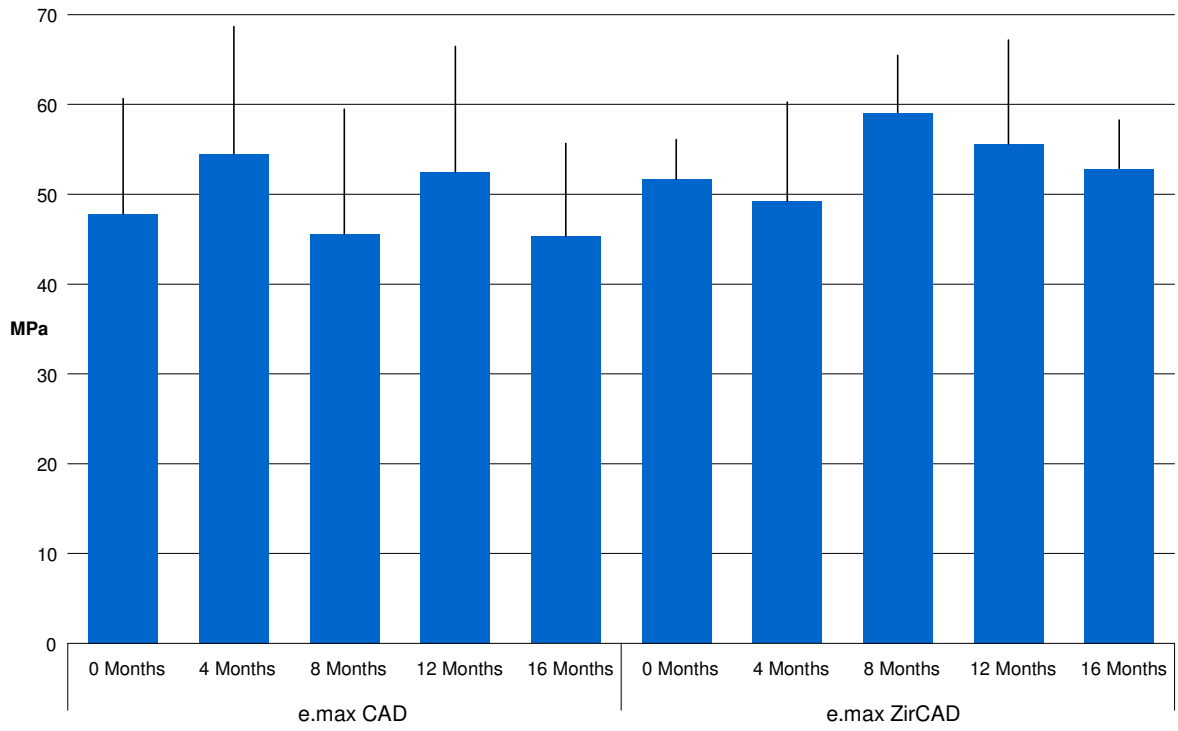
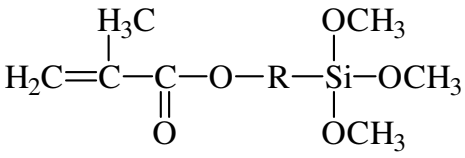


Fig. 6: Tensile strength values on IPS e.max CAD and IPS e.max ZirCAD following luting with Multilink Automix and Monobond Plus after storage at room temperature (Ivoclar Vivadent R&D, 2010)

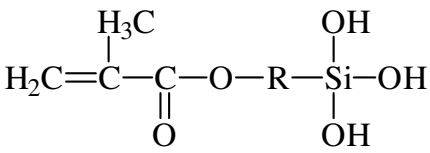
Neither the glass-ceramic nor the zirconium oxide test specimens showed a drop in tensile bond strength. This proved that after six months storage, the two active components silane (for glass-ceramics) and phosphoric acid derivative (for oxide ceramics) had not changed significantly.

Competitors sell such primers in several bottles, indicating that silanes will not remain stable in the presence of acids on principle. Usually, the argument is brought forward that silanes exhibit a low pH and are prone to hydrolysis.

In acidic systems with a low pH, trialkoxysilanes hydrolyze into reactive silicic acid derivatives, which continue to react with each other through condensation reaction.



Trimethoxysilane



The reactive trihydroxysilane is formed after hydrolysis.

For this purpose, it is necessary for phosphoric acid to dissociate, i.e. to dissolve into phosphate and hydrogen ions (H^+-ions) in water. The strength of the acid, which is indicated by the pH, is the (negative logarithmic) concentration of hydrogen ions in water!!

Monobond Plus is **not** an aqueous system with a low pH. Under the recommended storage conditions, Monobond Plus will not absorb critical amounts of water.

As a matter of fact, under the conditions prevalent in Monobond Plus the silane will remain stable. Both the silane and the phosphoric acid derivative did not change noticeably at room temperature during the entire period of observation.

5. Biocompatibility

Monobond Plus is a dilute ethanolic solution of three different adhesive monomers. The results of biocompatibility tests, in particular cytotoxicity and mutagenicity tests, which have been conducted with the monomers are available. XTT (cytotoxicity) and Ames (mutagencity) tests were carried out with Monobond Plus. According to these tests, the product neither poses a mutagenic nor a cytotoxic risk. In general, Monobond Plus is applied outside the patient's mouth. Any unreacted excess is dispersed with air or it polymerizes together with the luting composite. The greatest risk for the user lies in the sensitization by methacrylate components. Due to the small amount used and the very low concentration of active substance, however, this risk is to be viewed as uncritical.

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