Tokuyama Universal Bond II

Technical Report

USA Ver. 1.1

Tokuyama Dental Corp.
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The data contained in this report are obtained in Tsukuba Research Laboratory in Tokuyama Dental Corporation. The data are measurement representative values, not guaranteed values.

1. Introduction

1.1 Development Background

Recently, "universal" type products have been widely used in the dental bonding material market because they are simple to handle. Although the definition of "universal" has not been standardized, according to THE DENTAL ADVISOR[1], the definition of "universal" is meeting one or more of the following three requirements:

1. Compatibility with different etching techniques: total-, self-, or selective-etch.
2. Compatibility with dual- and self-cure materials without the use of a separate activator.
3. Can be used as a primer for silica-based and/or zirconia-based and metallic restorations.

Tokuyama Dental Corp. intended to commercialize a bonding material that meets all of the three requirements mentioned above.

We have succeeded in covering all the etching modes for adhesion to tooth substance by improving our unique adhesive monomer (3D-SR monomer). This improved 3D-SR monomer also enhanced bond strength to zirconia, metals and it particularly enabled a strong bond to not only tooth substance but various materials including ceramics, CAD/CAM blocks or metal in combination with various functional monomers such as a new silane coupling agent or adhesive monomer to precious metals.

In addition, we have achieved a stable bond strength that does not require photopolymerization by applying our own polymerization initiator (BoSE Technology).=Conventionally, a process when no photopolymerization is applied to resin materials such as composite resin or resin cement used in a combination, decreased bond strength has been generally observed[2]. However, application of BoSE Technology could make the adhesives available with the dual-curing and self-curing type resin materials, leading to the development of "TOKUYAMA UNIVERSAL BOND" with performance worthy of being called "universal."

After the launch of "TOKUYAMA UNIVERSAL BOND", we further improved it and developed "Tokuyama Universal Bond II". Tokuyama Universal Bond II inherits the performance of TOKUYAMA UNIVERSAL BOND and is even easier to use.

1.2 Product Description

Tokuyama Universal Bond II is a two-component self-cured dental adhesive system for both direct and indirect restorations that can be used with Self-etch, Selective-enamel-etch and Total-etch techniques. However, for indirect restorations, its use is limited to the primer treatment of the prosthetic restoration.

Tokuyama Universal Bond II has the same bond strength of polymerizable resin material (adhesive resin cement, acrylic resin and composite resin) to indirect restorative materials such as glass-ceramics (porcelain), oxide-ceramics (zirconia and alumina), metals (precious and non-precious) and resin materials including inorganic filler as TOKUYAMA UNIVERSAL BOND.

Tokuyama Universal Bond II also has newly added features. Tokuyama Universal Bond II is easier to use due to visual confirmation that it is mixed by the color of the liquid and it can be stored at room temperature.

Features inherited from TOKUYAMA UNIVERSAL BOND

[Universal Use]

- Compatibility with self-etch, total-etch and selective-etch techniques
- Applicability to direct restoration and indirect restoration (limited to the primer treatment of the prosthetic restoration) with light-curing, dual-curing and self-curing composite materials without the use of a separate activator
- Can be used as a primer for silica-based, zirconia based and metallic restorations

[Simple Handing]

- No need to apply separately to tooth and restoratives
- No need to wait after bond application
- No need to light-cure

[Reliable]

- Stable bond strength

<u>Newly added features</u>

[Ease of mixing confirmation]

- Can be visually confirmed that it is mixed by the color of the liquid

[Ease of Storage]

- Can be stored at room temperature

2. Composition and Instructions

2.1 Composition

The composition of Tokuyama Universal Bond II is presented in *Table 1*.

Tokuyama Universal Bond II contains the following: adhesive monomer new 3D-SR monomer (phosphoric acid monomer), 6-methacryloyloxyhexyl 2-thiouracil- 5-carboxylate (MTU-6), γ-methacryloxypropyl triethoxysilane (γ-MPTES), which are adhesive monomers for adhesion to tooth and various prosthetics; several monomers (HEMA, Bis-GMA, and TEGDMA) to form bonding layers; acetone, ethanol, and water as solvents; and a borate catalyst and peroxide as polymerization initiators.

Tokuyama Universal Bond II has excellent storage stability as these functional ingredients are separated into two liquids, and bond strength is not inferior to that of light-curing type adhesive.

Table 1 Composition of Tokuyama Universal Bond II

Bond A

Basic components	**Function**
Phosphoric acid monomer （New 3D-SR monomer）	Adhesion to tooth Formation of bonding layer Adhesion to zirconia, alumina, and non-precious metal
MTU-6	Adhesion to precious metal
HEMA	Penetration into the tooth substance Formation of bonding layer
Bis-GMA	Formation of bonding layer
TEGDMA	Formation of bonding layer
Acetone	Solvent

Bond B

Basic components	**Function**
γ-MPTES	Adhesion for glass ceramics and resin composite
Borate	Polymerization catalyst
Peroxide	Polymerization catalyst
Acetone, Ethanol	Solvent
Water	Solvent

2.2 Estimated Adhesion Mechanism

Tokuyama Universal Bond II enables reliable adhesion to the tooth due to the implementation of 3D-SR technology using a new 3D-SR monomer, and BoSE Technology using a borate initiator.

Tokuyama Universal Bond II also contains the following adhesion monomers that are effective for a range of prosthetics: new 3D-SR monomer (for adhesion to non-precious metal, zirconia, and alumina), MTU-6 (for adhesion to precious metals), and γ-MPTES (for adhesion to glass ceramics and resin composite). New 3D-SR monomer has effective adhesion on both tooth and some prosthetics (non-precious metal, zirconia and alumina).

The mechanism of adhesion to tooth and each prosthetic is described in detail below.

2.2.1 Estimated mechanism of adhesion to tooth substance

Tokuyama Dental Corp. developed 3D-SR technology to improve adhesion of the bonding agent TOKUYAMA BOND FORCE to the tooth substance[3, 4]. This 3D-SR monomer (1st generation), has several functional groups that can interact with calcium and polymerizing groups per molecule *Fig. 1*, interacting with calcium in the tooth substance at multiple points to create adhesion to the tooth structure surface. Further, a three-dimensional cross-linking reaction occurs via calcium, and copolymerization between adhesive 3D-SR monomers and other monomers which contribute to the formation of a layer. *Fig. 2*

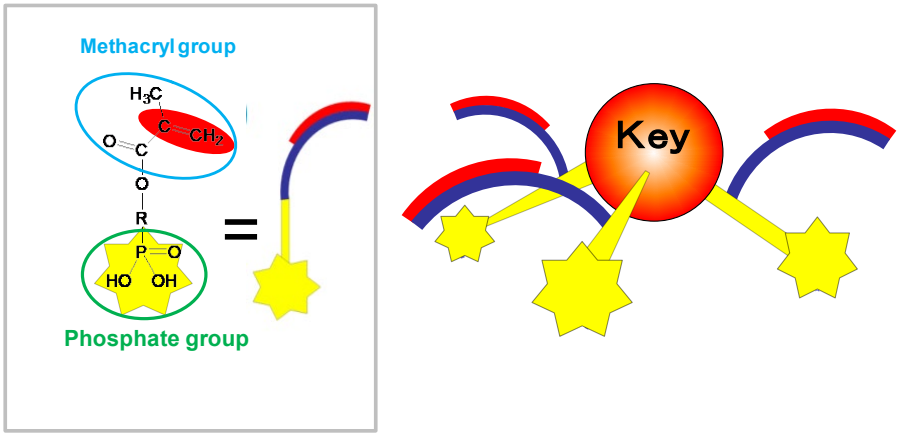


Fig.1 1st Generation 3D-SR Monomer (Estimated structure) [5,6,7]

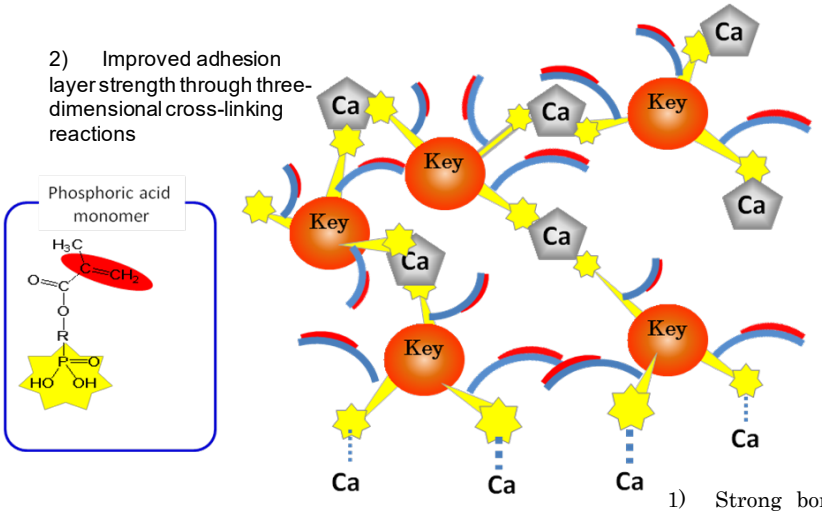


Fig.2 Three-dimensional cross-linking reactions of adhesive SR monomers and calcium ions (Estimated mechanism) [5,6,7)]

To achieve the enhanced properties, our patented 3D-SR monomers were improved and the chemistry was optimized (2nd generation, *Fig. 3*). In comparison to the previous BOND FORCE generation, the number of groups interacting with calcium groups and polymerizing groups per molecule of new 3D-SR monomer has been successfully increased.

Furthermore, the 2nd-generation 3D-SR monomer was implemented for TOKUYAMA UNIVERSAL PRIMER as a zirconia adhesive monomer.

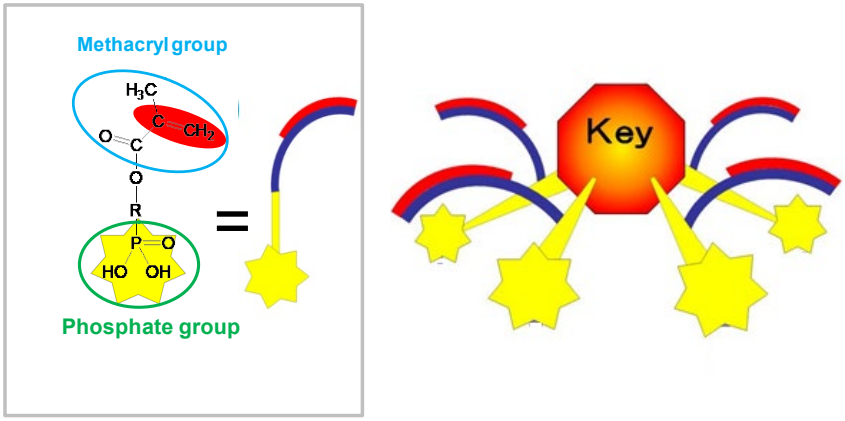


Fig.3 2nd Generation 3D-SR Monomer (Estimated structure) [5,6,7)]

Tokuyama Universal Bond II has an enhanced response to tooth calcium and durability by combining several phosphoric acid monomers having different chain lengths of the main chain, the alkylene group (the 3rd-generation 3D-SR monomer, *Fig. 4*).

Furthermore, this 3rd-generation 3D-SR monomer contributes to adhesion to non-precious metal as well as tooth and zirconia.

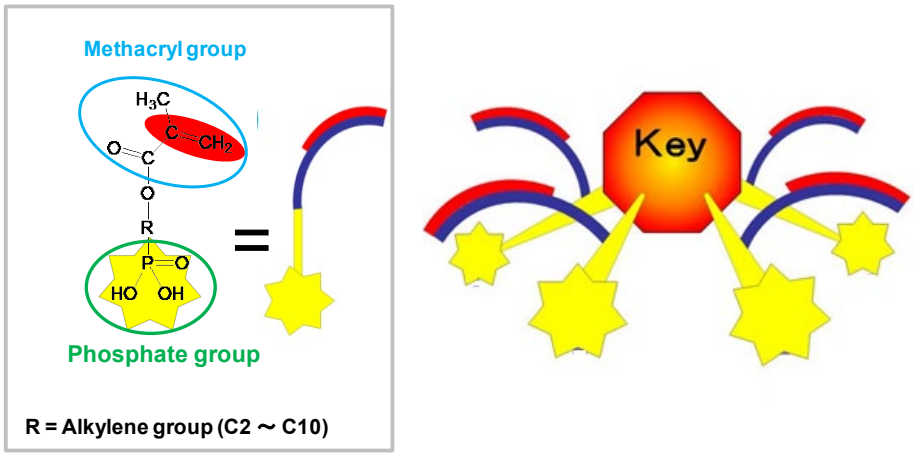


Fig.4 3rd Generation 3D-SR Monomer(Estimated structure) [5,6,7]

2.2.2 Estimated mechanism of adhesion to precious metal

The adhesive monomer for precious metal is MTU-6. As shown in *Fig. 5*, the sulfur atom in the thiouracil group of MTU-6 interacts with precious metal (covalent bond) and additionally, the methacryl group co-polymerizes with monomers in dental-curable materials (resin cements, bonding agents, resin composites, etc.) for adhesion.

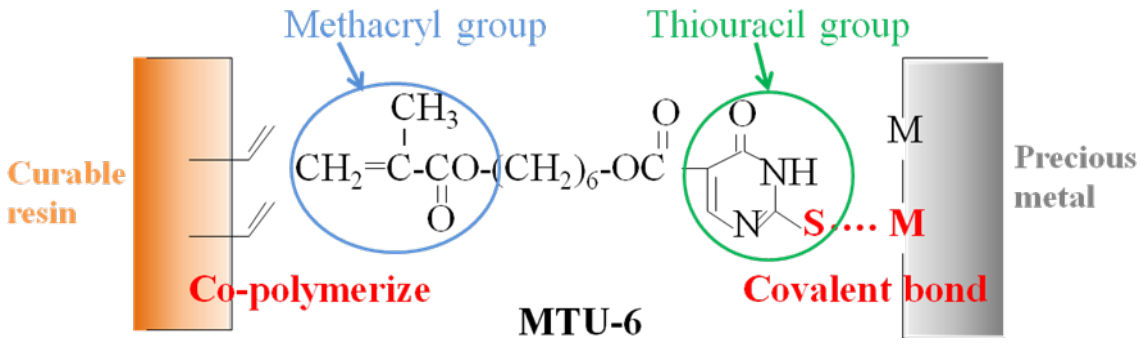


Fig.5 Estimated mechanism of adhesion to precious metal[6,8]

2.2.3 Estimated mechanism of adhesion to non-precious metal

The adhesive monomer for non-precious metal is new 3D-SR monomer. As shown in *Fig. 6*, the phosphate group of the new 3D-SR monomer interacts with the oxygen atom of the passive layer of a nonprecious metal surface (hydrogen bond) and additionally, the methacryl group co-polymerizes with monomers in dental curable materials(resin cements, bonding agents, resin composites, etc.) for adhesion.

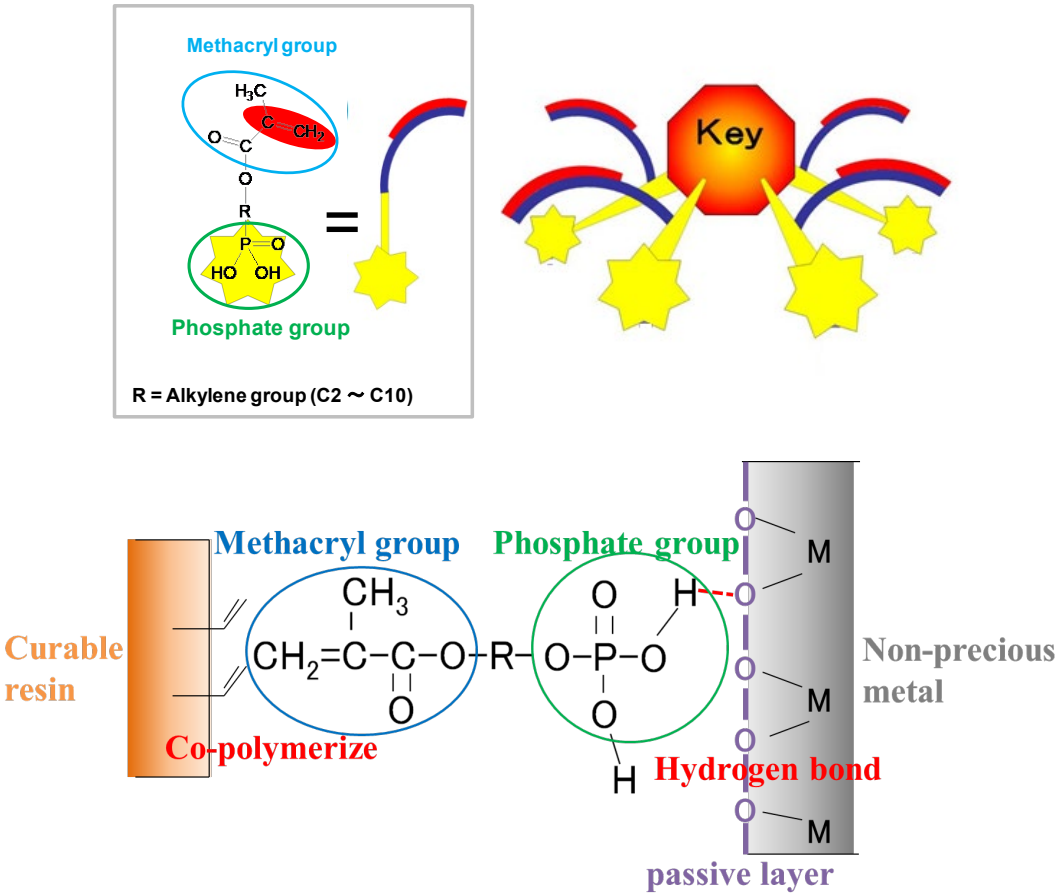


Fig.6 Estimated mechanism of adhesion to non-precious metal[6,9)]

2.2.4 Estimated mechanism of adhesion to glass-ceramics/resin

The adhesive monomer for glass-ceramics, porcelain and resin materials including inorganic filler is the new silane coupling agent, γ-MPTES. First, the alkoxy group in γ-MPTES reacts with water to form a silanol group *Fig. 7* and next, a siloxane bond is formed by a dehydration and condensation reaction with the silanol group on the ceramic surface. Additionally, the methacryl group co-polymerizes with monomers in dental curable materials (resin cements, bonding agents, resin composites, etc.) for adhesion. *Fig. 8*

Tokuyama Universal Bond II is a two bottle-type product, and stabilization of

the silane coupling agent in the bottles is excellent, with the risk of deterioration of the silane coupling agent that may occur in a one bottle-type product[10] reduced. In addition, since the new silane coupling agent, γ-MPTES is more stable in the bottle compared to the conventional one (γ-MPS), the adhesion effect lasts for a long time.

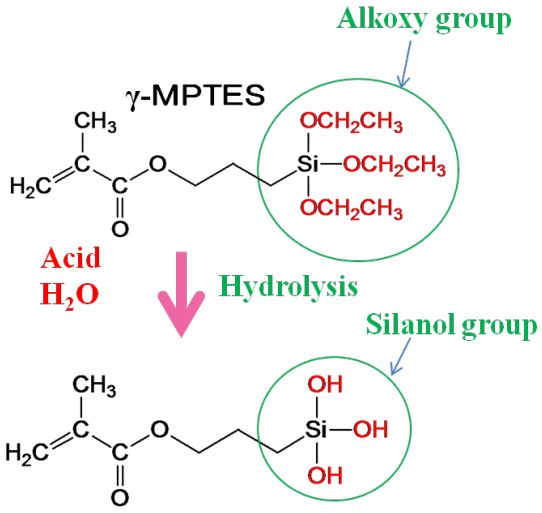


Fig.7 Hydrolysis of γ-MPTES[11]

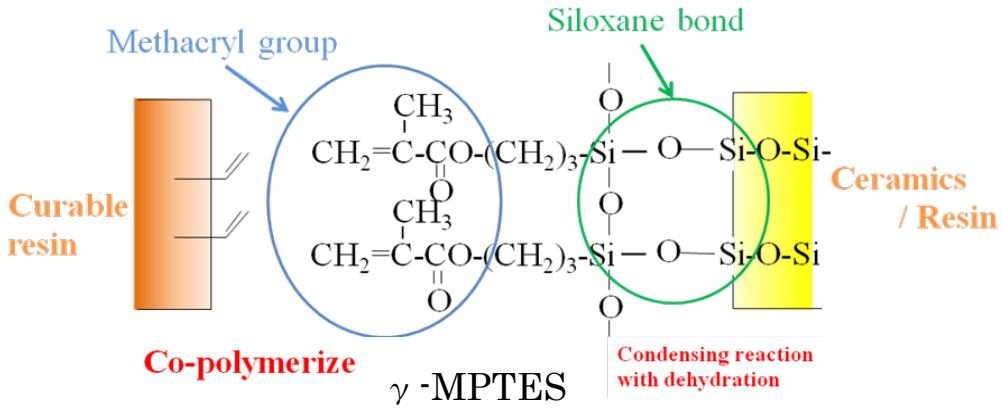


Fig.8 Estimated mechanism of adhesion to glass-ceramics/resin[11]

2.2.5 Estimated mechanism of adhesion to zirconia/alumina

The adhesive monomer for zirconia/alumina is the new 3D-SR monomer (phosphoric acid monomer). It is believed that the phosphate group of new 3D-SR monomer forms chemical bonds with the zirconia/alumina surface for adhesion. *Fig. 9*.

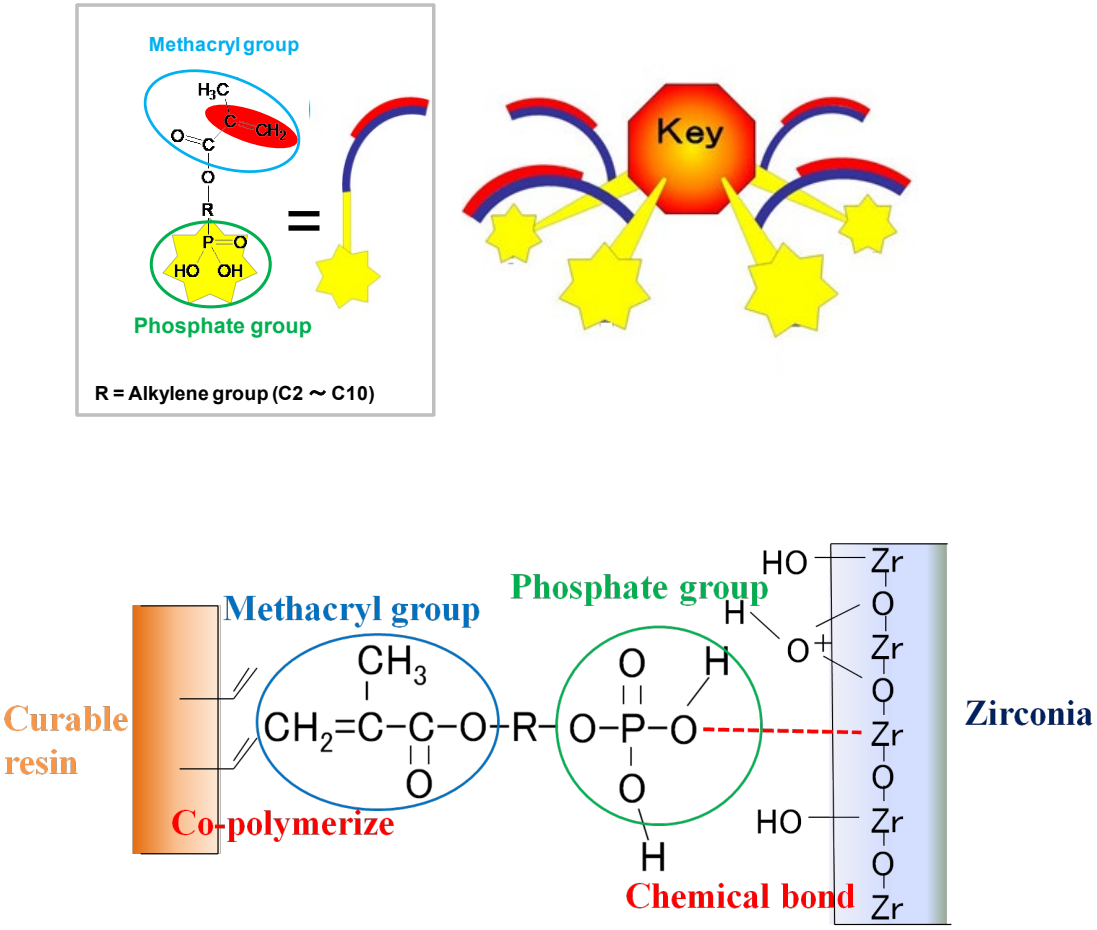


Fig.9 Estimated mechanism of adhesion to zirconia[7)]

2.2.6 Estimated mechanism of polymerization initiator "Contact Cure"

Tokuyama Universal Bond II employs our original BoSE Technology with a borate initiator. The borate initiator is decomposed by acid (phosphoric acid monomer) and transformed into a borane compound which produces free radicals. In addition, Tokuyama Universal Bond II contains a peroxide that accelerates degradation of the borane compound and serves as a highly active chemical polymerization initiator *Fig. 10*.

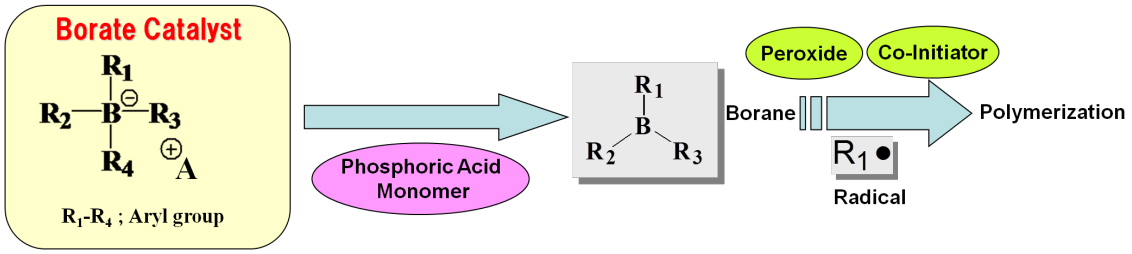


Fig.10 Estimated mechanism of polymerization initiator[12)]

2.3 Indications

- Direct anterior and posterior restorations with light-curing, dual-curing, and self-curing composite materials
- Intraoral repair of composite restorations, porcelain fused to metal, metal, and all-ceramic restorations without an additional primer
- Cementation of indirect restorations and veneers when (limited to the primer treatment of the prosthetic restoration) combined with light-cure, dual-cure, and self-curing resin cements
- Bonding of core build-ups made of core build-up materials
- Bonding of denture resin to metal base, clasp or attachment
- Repair of denture with metal base, clasp or attachment
- Bonding of opaque resin to a metal base in the fabrication of resin-faced crowns

3. Features - Universal Use

Although the definition of "universal bond" has not been standardized, the following three requirements are listed by THE DENTAL ADVISOR[1]. *Fig. 11*. The applicability of commercially available "universal" type bonding materials is shown in *Table 2*. Tokuyama Universal Bond II is the product satisfying requirements 1, 3 and partially satisfying requirement 2.

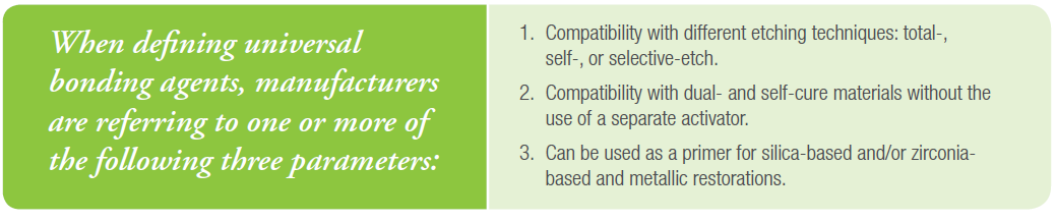


Fig.11 Definition of universal bonding agents by THE DENTAL ADVISOR

Table 2 Applicability of "universal" type bonding materials

Manufacture	Tokuyama Dental	3M	GC	Voco	Bisco	Kuraray Noritake Dental	Dentsply	Ivoclar Vivadent	Heraeus Kulzer	Kerr
Product	Tokuyama Universal Bond II	Scotchbond Universal Plus Adhesive	G-Premio BOND	Futurabond U	All-Bond Universal	Clearfil Universal Bond Quick	Prime & Bond Active	Adhese Universal	iBond Universal	OptiBond Universal
1. Total-etch, Self-etch, Selective-etch	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
2. Compatible with all light-curing, dual-curing or self-curing composites	✓	✓	−*2	✓	✓	△*3	△*4	✓	✓	✓
2-1. Direct restorations	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
2-2. Indirect restorations	△*1	✓	△*5	✓	✓	△*3	△*4	✓	✓	✓
2-3. Intraoral repair	✓	✓	△*6	✓	△*6	✓*7	△*6	△*7	△*5	✓
3. Primer for prosthesis	✓	✓	−	−	△*6	△*3	△*4 *6	−	△*5	✓

*1 Primer for prosthesis use only. Cementation: follow the cement manufacturer's IFU.
*2 Bonding of dual-cured core build up composites to tooth structure as long as these materials are light-cured
*3 Requires DCA unless it is used with CLEARFIL DC CORE PLUS
*4 Requires DCA unless it is used with Calibra Ceram
*5 Requires DCA
*6 Requires Primer
*7 Primer recommended
*8 Only composite repair

3.1 Compatibility with all etching protocols

Tokuyama Universal Bond II can be used with self-etch, total-etch and selective-etch techniques for adhesion to dentin and enamel. *Table 3*.

Table 3 Compatibility with etching protocols

	Tokuyama Universal Bond II	TOKUYAMA BOND FORCEII
Self-etch	✓	✓
Total-etch	✓	⊖
Selective-etch	✓	OPTIONAL

3.2 Compatibility with light-curing, dual-curing and self-curing composite materials

Tokuyama Universal Bond II can be used for both direct restoration and indirect restoration (limited to the primer treatment of the prosthetic restoration) and it can also be used with light-curing, dual-curing and self-curing composite materials without the use of a separate activator.

3.3 Can be used as a primer for silica-based, zirconia based and metallic restorations

Tokuyama Universal Bond II can be used as a primer for silica-based, zirconia-based and metallic restorations without the use of separate primers. It can reduce the risk of adhesion failure caused by incorrect material selection and wrong handling and it may make inventory management easier, as bonding materials/primers specific to various objects to be bonded are not required.

4. Features - Simple Handing

As Tokuyama Universal Bond II is applicable to the tooth substance and various prosthetics; for example, it reduces the need to identify the material substance of an object to be bonded or apply it in a different manner according to material substance for intraoral repair. Therefore, it can reduce the risk of adhesion failure caused by incorrect material selection and wrong handling. Furthermore, the product can shorten chair time, as waiting time after application and photoirradiation are not necessary. *Fig. 12.*

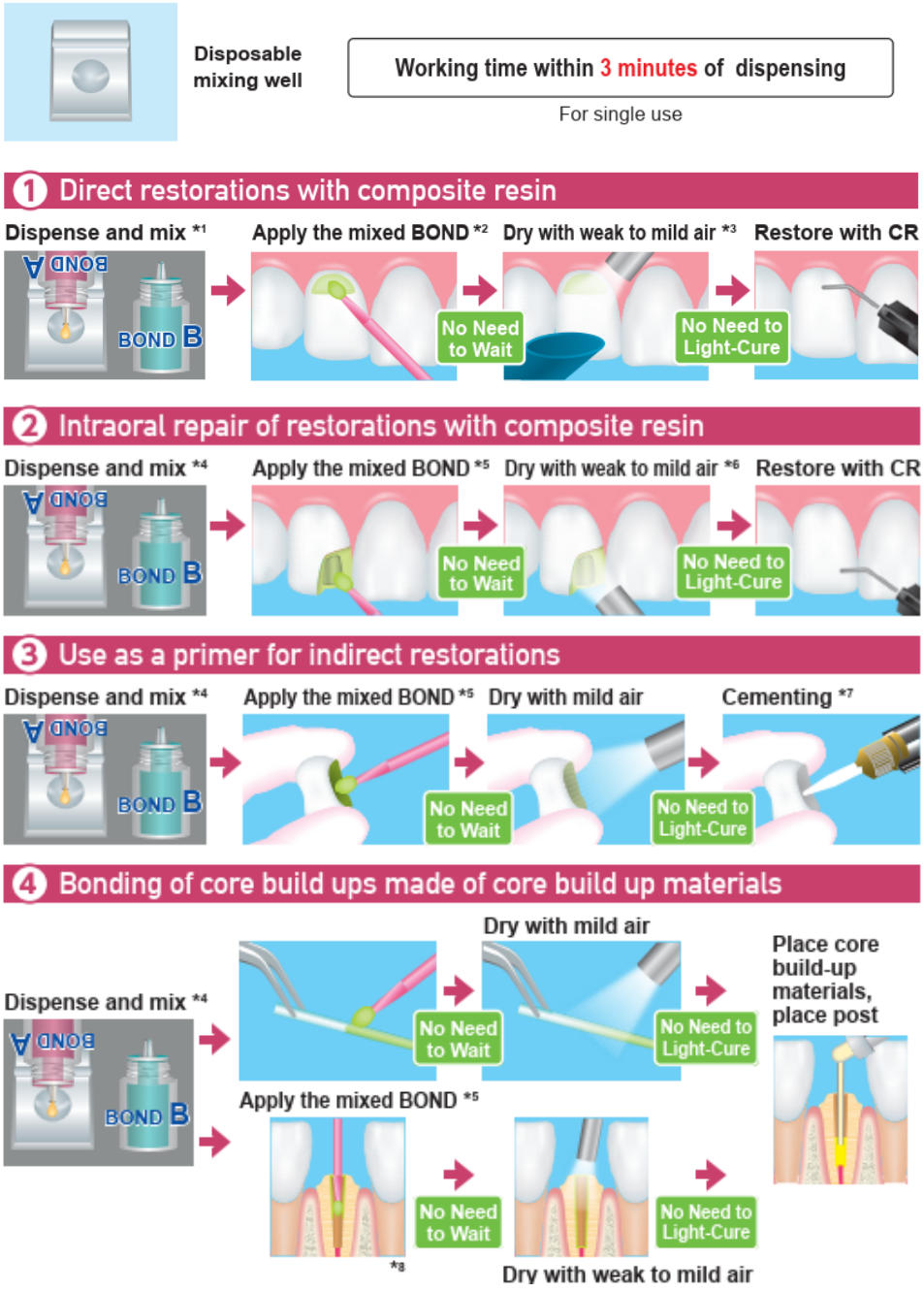


Fig.12 Instruction of Tokuyama Universal Bond

4.1 Chair Time (Direct Restoration)

Tokuyama Universal Bond II is a two bottle-type bonding material and it takes time to collect and mix the two liquids. However, as time after application and photoirradiation are not necessary, it shortens total chair time compared with competitors' products. In particular, the material can reduce risk of adhesion failure induced by saliva and blood contamination as well as patient burden because of the shorter intraoral chair time.

Comparison of chair time between competitors' universal-type bonding materials is shown below. *Fig. 13*.

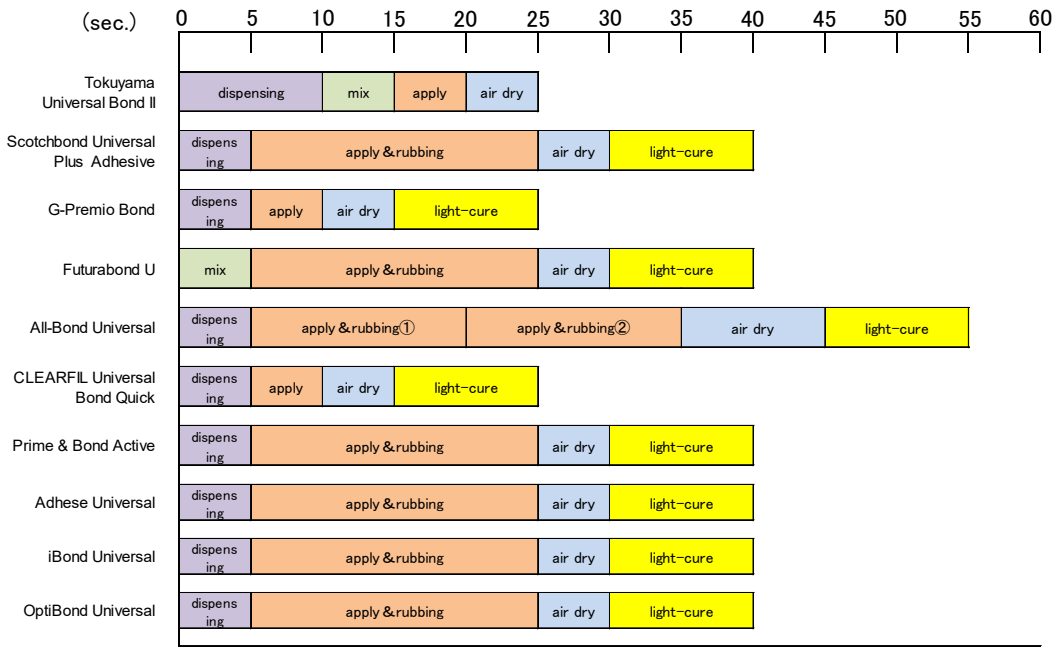


Fig.13 Chair time comparison of composite restoration
(Made based on the IFU of each product as of October 2021)

4.2 Chair Time (Intraoral Repair)

For intraoral repair including PFM fracture, the surface to be bonded is often composed of multiple kinds of materials. Tokuyama Universal Bond II is applicable to any kind of material and can shorten chair time substantially, as it is unnecessary to apply it in a different manner according to the material substance using a metal primer, ceramics primer or other designated primers. *Fig. 14*.

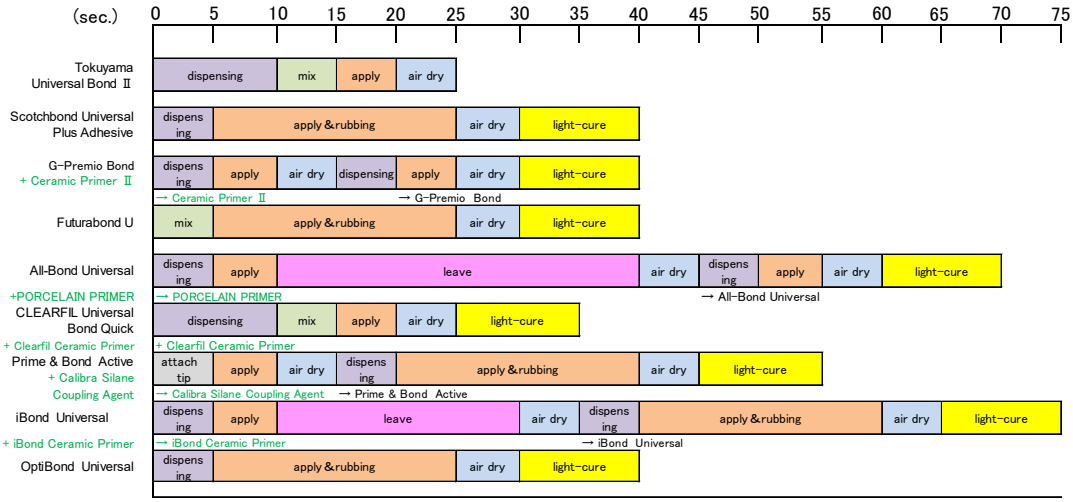


Fig.14 Chair time comparison of intraoral repair of ceramics
(Made based on the IFU of each product as of October 2021)

4.3 Influence of waiting time after application on bond strength

As mentioned above, Tokuyama Universal Bond II does not require a waiting time after it is applied to the surface to be bonded. *Fig. 15* and *16* show the effect of waiting time from bond application until air dry (0, 3, 5 and 10 seconds) on bond strength to tooth substance and prosthetics. Tokuyama Universal Bond II showed a bond strength on both tooth substance and prosthetics without waiting after bond application that was equal to the strength after a waiting time of 10 seconds.

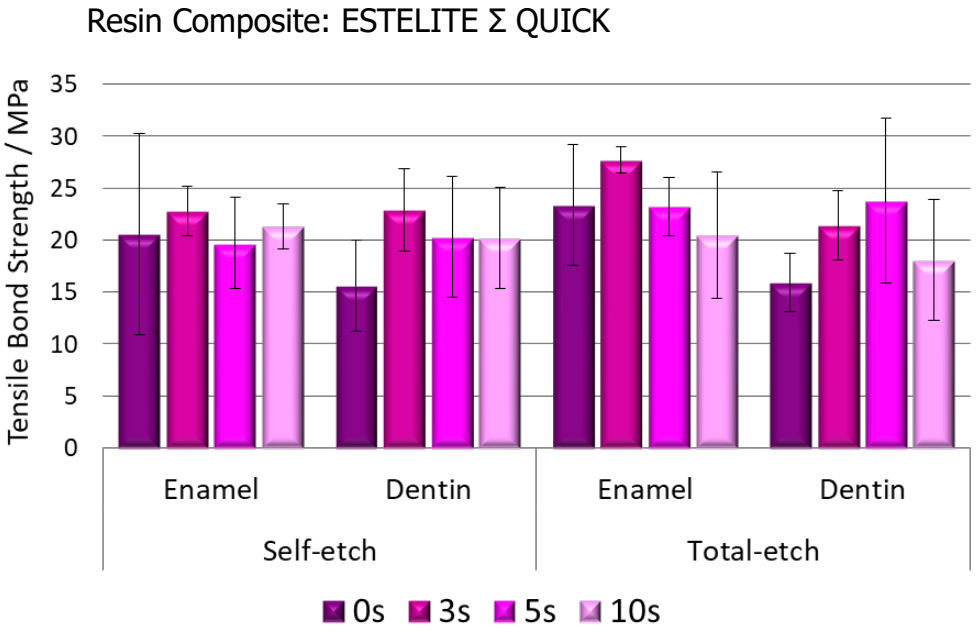


Fig.15 Tensile bond strength on enamel and dentin with varying waiting time when used with the self-etch and total-etch techniques

Table 4 Tested prosthetic materials and pre-treatment method

	Manufacturer	Product name	Composition	Pre-treatment
Precious metal	Tokuyama Dental	CASTMASTER12S	Au12/Pd20/Ag54 /Cu12/other2	1)Grind with P1500 SiC 2)Sandblast (50um of Al_2O_3)
Non-precious metal	Tokuyama Dental	ICROME	Co57.8/Cr31.6/Mo 5.6/other5	1)Grind with P1500 SiC 2)Sandblast (50um of Al_2O_3)
Ceramics (Silica-base ceramics)	Kuraray Noritake Dental	Super Porcelain AAA	—	Grind with P800 SiC
Indirect composite	Tokuyama Dental	ESTELITE BLOCK II	—	1)Grind with P1500 SiC 2)Sandblast (50um of Al_2O_3)
Zirconia	TOSO	TZ-3Y-E	Yttria stabilized Zirconia (Yttria 3%)	1)Grind with P120 SiC 2)Sandblast (50um of Al_2O_3)

Resin Cement: ESTECEM II PLUS (available in Europe) (without light-cure)

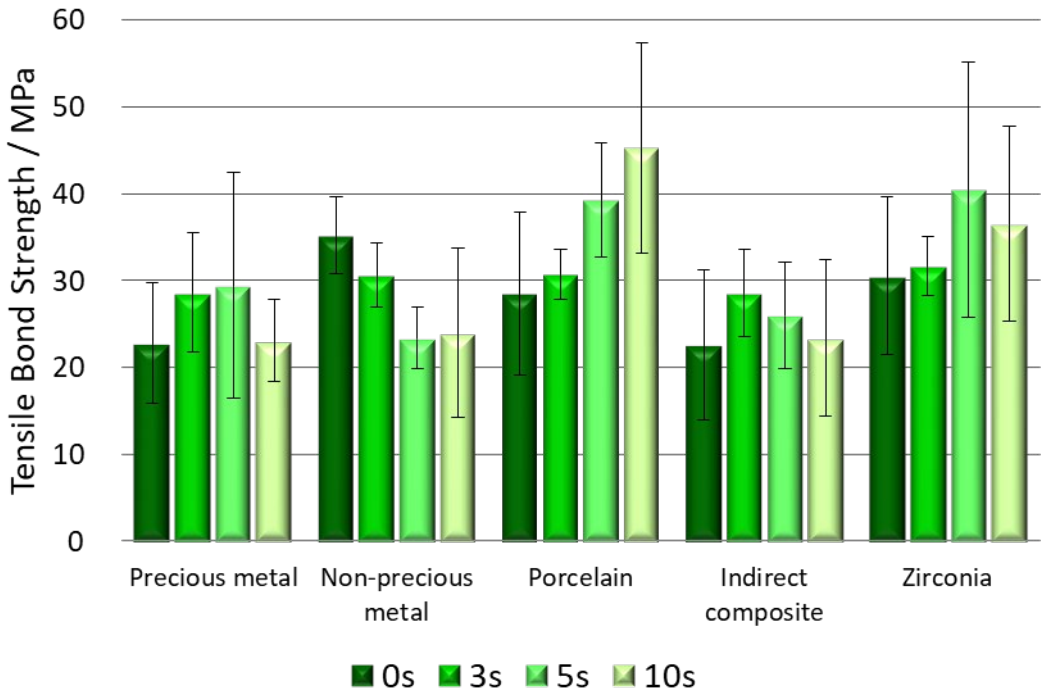


Fig.16 Tensile bond strength on prosthetic materials with varying waiting times

5. Features - Reliability

5.1 Compatibility with all etching protocols

5.1.1 Bond Strength

Tensile bond strength of Tokuyama Universal Bond II on dentin and enamel in the self-etch mode and total-etch mode was compared between competitive universal type products listed in *Table 5*. The results are shown in *Fig. 17–20*. In both self-etch mode and total-etch mode, Tokuyama Universal Bond II showed a bond strength that was equal or higher than the strength of competitors' products.

Table 5 Tested universal type bonding materials

Adhesive	Resin composite	Manufacturer	Abbreviation
Tokuyama Universal BondII	ESTELITE Σ-QUICK	Tokuyama Dental	UB
Scotchbond Universal Plus Adhesive	Filtek Supreme Ultra	3M	SU
Adhese Universal	Tetric N-Ceram	Ivoclar Vivadent	AU
iBond Universal	Venus	Heraeus Kulzer	IB
Clearfil Universal Bond Quick	CLEARFIL MAJESTY ES-2	Kuraray Noritake Dental	CU
G-Premio Bond	SOLARE	GC	GP
Prime &Bond Active	ceram.x SphereTEC one	Dentsply	PB
OptiBond Universal	Harmonize	Kerr	OU
All-Bond Universal	Aelite All-Purpose Body	BISCO	AB

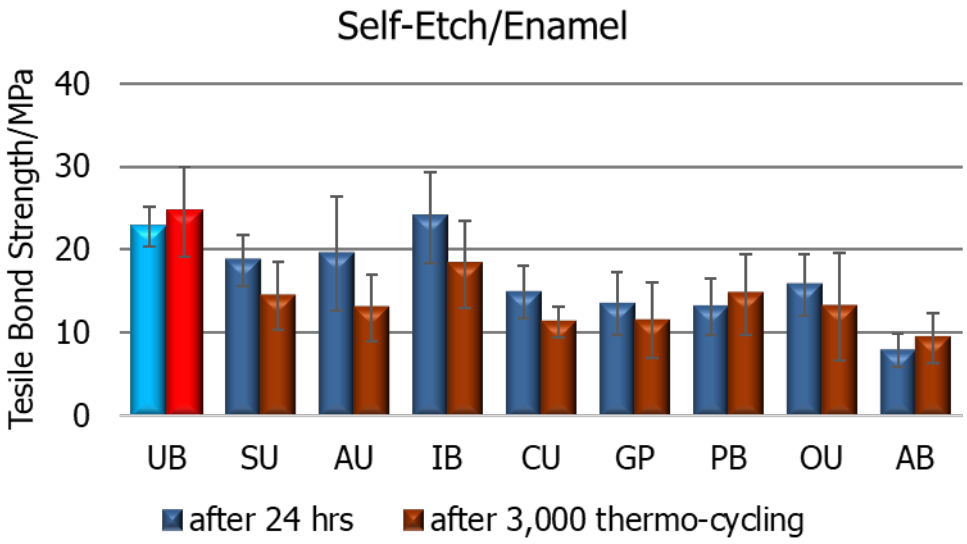


Fig.17 Tensile bond strength of universal adhesives in self-etch technique on enamel, before and after thermo-cycling.

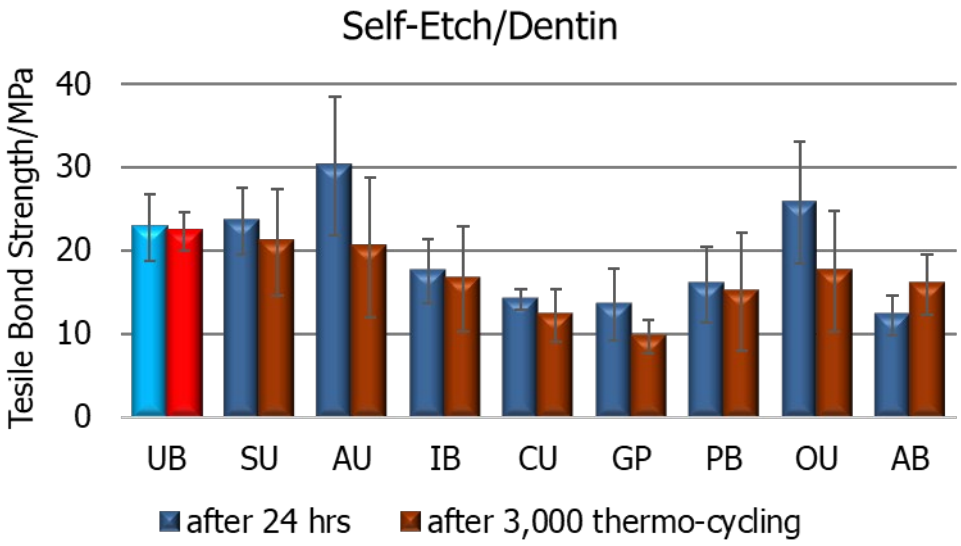


Fig.18 Tensile bond strength of universal adhesives in self-etch technique on dentin, before and after thermo-cycling.

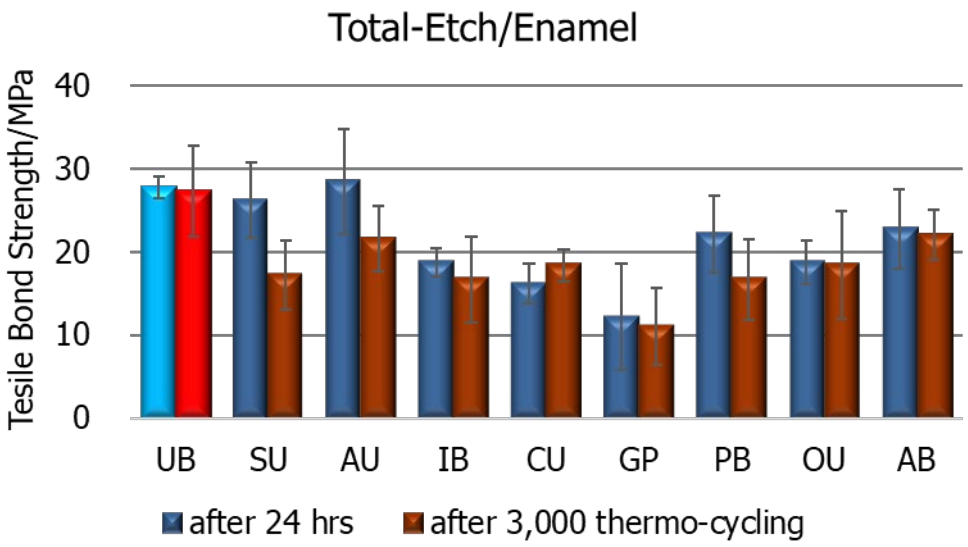


Fig.19 Tensile bond strength of universal adhesives in total-etch technique on enamel, before and after thermo-cycling.

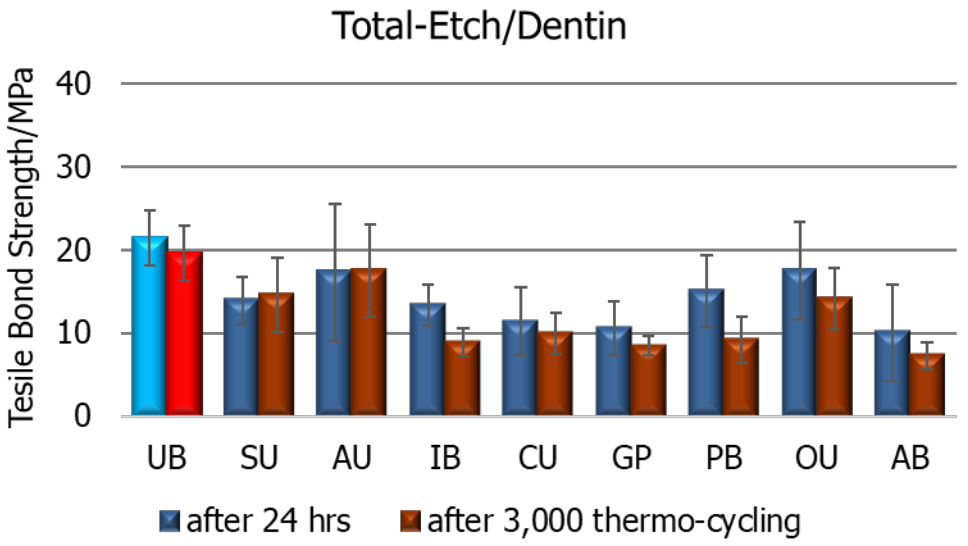


Fig.20 Tensile bond strength of universal adhesives in total-etch technique on dentin, before and after thermo-cycling.

5.1.2 Analysis of Adhesive Interface

[SEM images (Self-etch)]

In the self-etch mode, we performed SEM observation of adhesion interfaces of Tokuyama Universal Bond II to the enamel and dentin (FE-SEM XL30SFEG, PHILIPS). *Fig. 21, 22*. No gap between the enamel and dentin adhesive interfaces was seen and good adhesion to enamel and dentin as well as uniform and thin bonding layers were present. This result was based on formation of strong bonding layers on tooth substance surface to be bonded by polymerizing reaction products of the new 3D-SR monomer, an ingredient of Tokuyama Universal Bond II, and calcium in the tooth substance.

Resin composite: OMNICHROMA FLOW

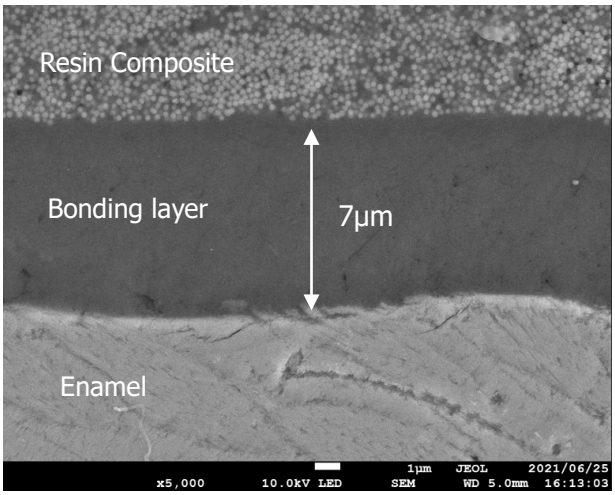


Fig. 21 Enamel (x 5,000)

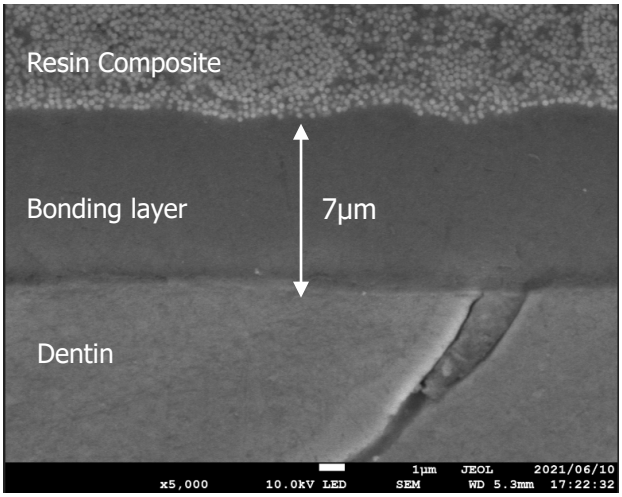


Fig. 22 Dentin (x 5,000)

[SEM images and micro-Raman spectroscopy analysis (Total-etch)]

We performed SEM observation and micro-Raman spectroscopy observation of tooth adhesive interface in the total-etch mode (FE-SEM XL30SFEG, PHILIPS). *Fig. 23*. There was no gap between the bonding layer and tooth, but a 1.5–3μm layer that was considered to be a hybrid layer on dentin was observed.

Resin composite: OMNICHROMA FLOW

Etching condition：Etched 15 sec. with TOKUYAMA ETCHIN GEL HV and rinse 15 sec. with water, then dry with cotton pellets.

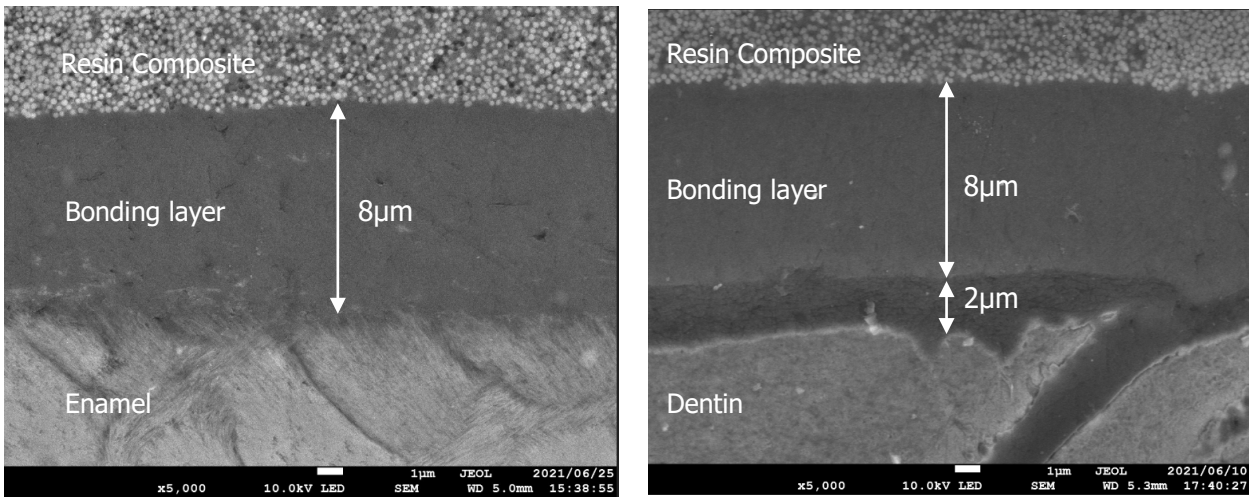


Fig. 23 Enamel and Dentin (x 5,000)

In the total-etch technique, there is a concern that durability may deteriorate because of tooth decalcification by phosphate etching and penetration gap between monomer ingredients of the bonding agent[13].

Using a micro-Raman spectroscopy, penetration of Tokuyama Universal Bond II into phosphate-etched dentin was measured. The measurement result is shown in *Fig. 24, 25*. The location where the peak of dentin Hydroxylapatite decreases is consistent with the one where the peak of bonding agent starts to be detected (line ①). The decrease in the peak of Hydroxylapatite and increase in the peak of monomer is transitional (line ② and ③). Therefore, it is estimated that the monomer penetrates into the phosphate-decalcified dentin part.

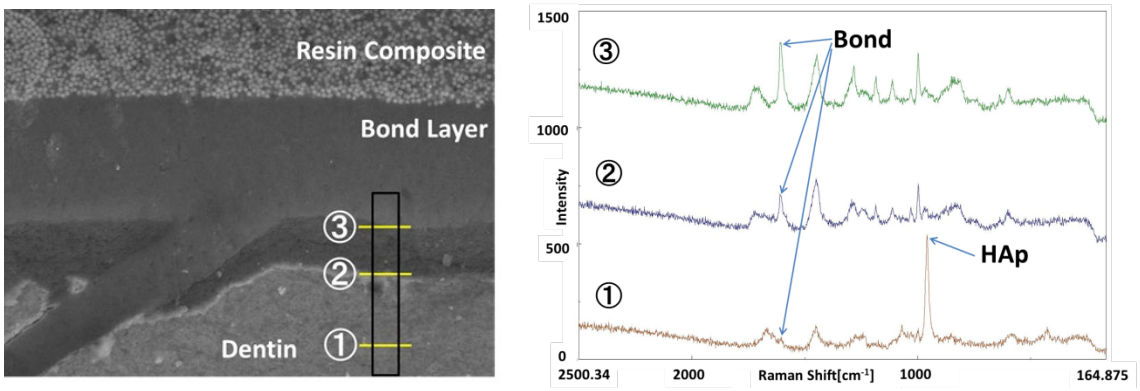


Fig. 24 Raman spectrum of Tokuyama Universal Bond II

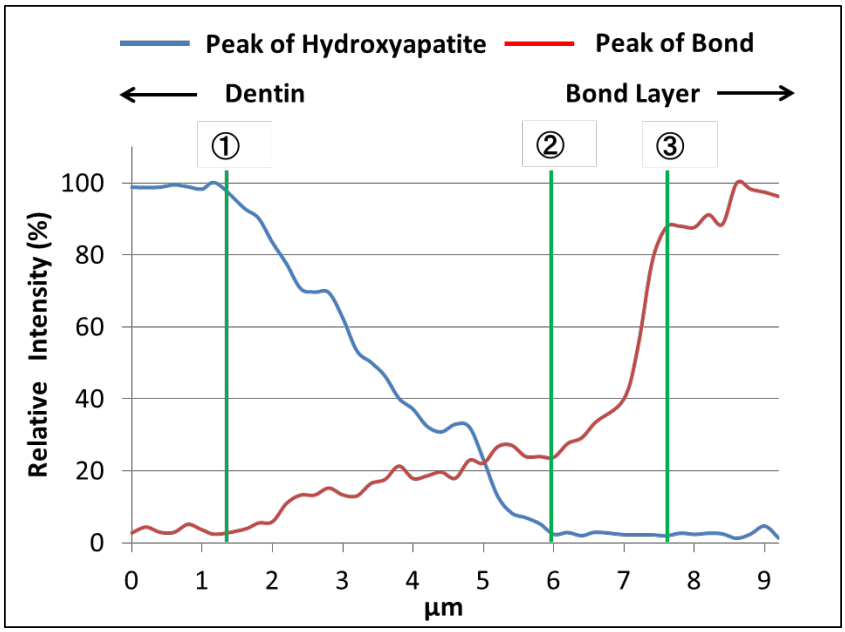


Fig. 25 Raman analysis of Tokuyama Universal Bond II

5.2 Applicability to direct restoration

-Can be used with light-cured, self-cured and dual-cured composite materials-

Tokuyama Universal Bond II has been designed to be used with light-cured, self-cured and dual-cured composite materials. We evaluated tensile bond strength of Tokuyama Universal Bond II combined with resin materials that are commercially available.

[Light-curing resin composite]

We evaluated the bond strength when combined with each company's light-curing resin composite (universal, flowable). The result in *Fig. 26, 27* showed an excellent bond strength for any resin composite.

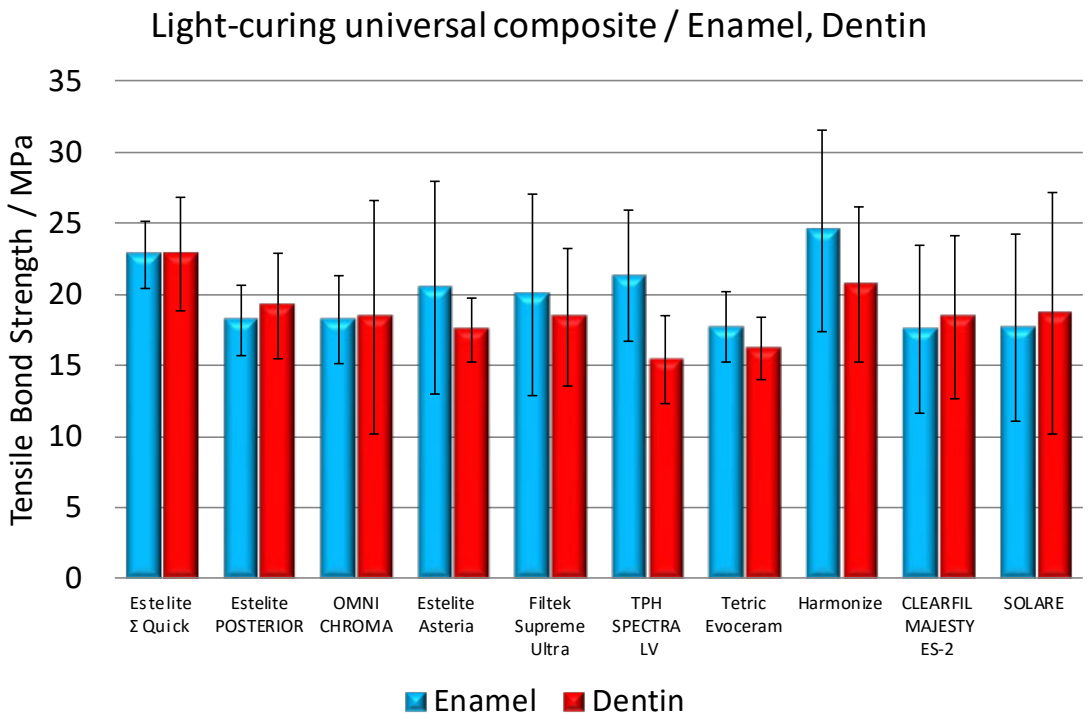


Fig.26 Tensile bond strength of Tokuyama Universal Bond II with various light-curing resin composite to enamel and dentin

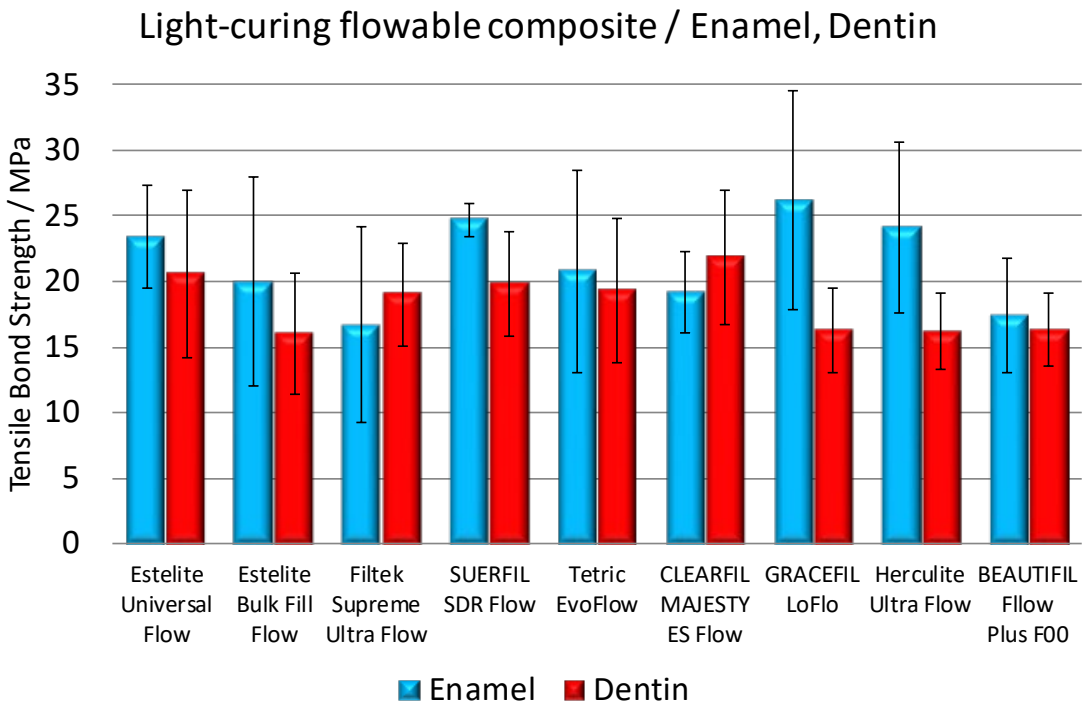


Fig.27 Tensile bond strength of Tokuyama Universal Bond II with various light-curing flowable resin composite to enamel and dentin

[Dual-cure resin composite (resin core material)]

Using a commercially available dual-curing resin core, bond strength was evaluated with or without photopolymerization. The result is shown in *Fig. 28*.

Bond strength was stable for any resin core. Furthermore, even without photopolymerization, it was equal to dual-curing bond strength with photopolymerization. Therefore, bond strength was stable regardless of the curing conditions of materials.

Curing Mode:

Dual-cure: with light cure

Self-cure: without light cure

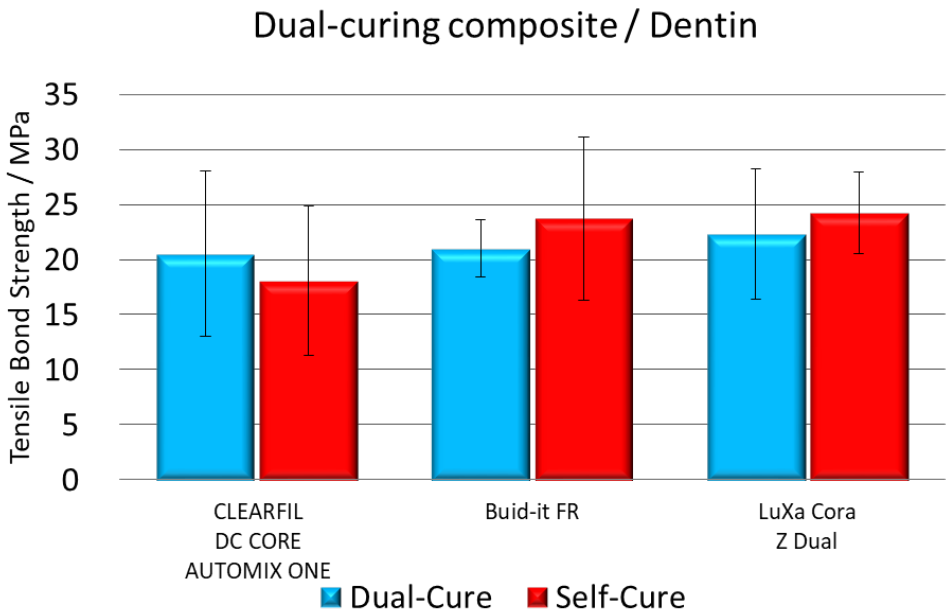


Fig.28 Tensile bond strength of Tokuyama Universal Bond II with various dual-curing resin core to dentin

5.2.1 Direct restoration

[Bond Strength]

The micro-tensile bond strength of Tokuyama Universal Bond II on dentin was measured. The result is shown in *Fig. 29*.

According to the micro-tensile method, bond strength of Tokuyama Universal Bond II was about 50MPa.

・Resin composite : ESTELITE POSTERIOR (available in Europe)
・Sample :Beam-shape 1mm square

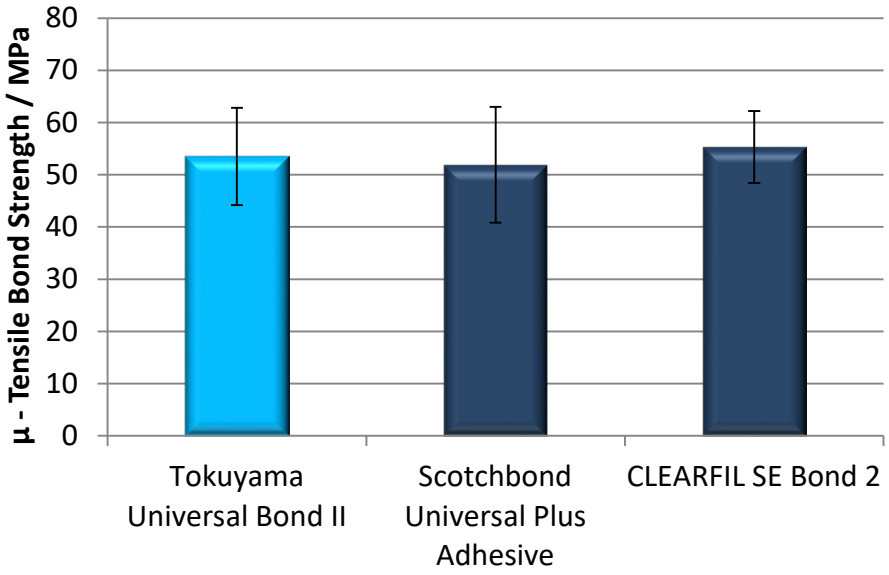


Fig.29 μ -tensile bond strength of Tokuyama Universal Bond II and commercial products on dentin

Using a light-curing resin composite, a shear bonding test was performed to examine the bond strength of Tokuyama Universal Bond II on tooth substance immediately after light-curing. The result is shown in *Fig. 30*. The result of the shear bonding test performed 5 minutes after curing resin composite showed that the bond strength was comparable with that measured 24 hours later. A feature of Tokuyama Universal Bond II is that curing of bonding layers increases rapidly once chemical polymerization is initiated and it comes into contact with resin materials after air dry due to the borate catalyst. Therefore, a high bond strength can be obtained immediately after curing, even without photopolymerization of the bond.

Resin Composite: OMNICHROMA FLOW

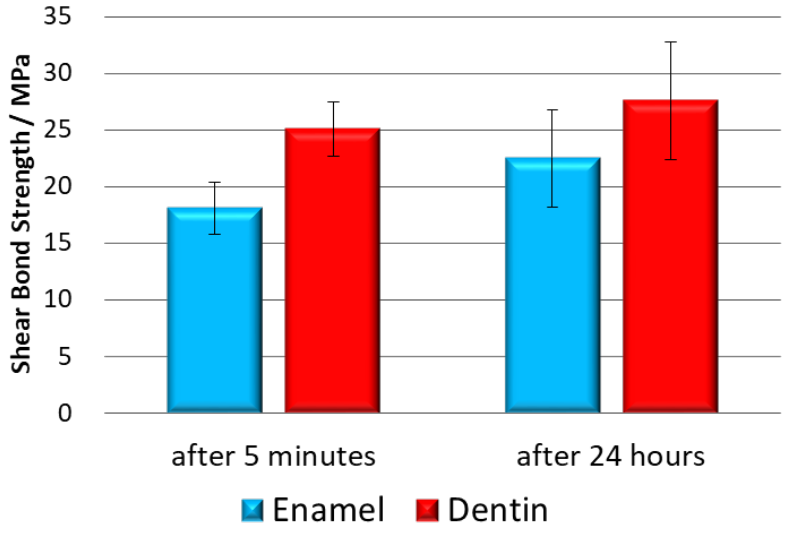


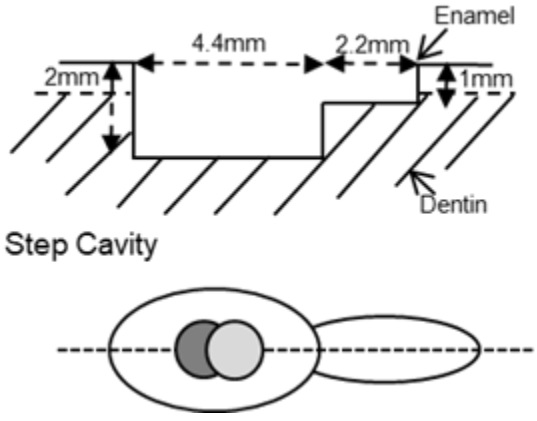
Fig.30 Shear bond strength immediately after curing

[Cavity Adaptation]

Cavity adaptation of Tokuyama Universal Bond II was compared with that of Scotchbond Universal Plus Adhesive (3M), as shown in *Fig.31*. Gap free bonding layer and uniform thickness were observed on the cavity floors, corners, and edges.

Test method:

1) Create simulated cavities in the form of steps on the labial aspect of an extracted bovine first anterior tooth.



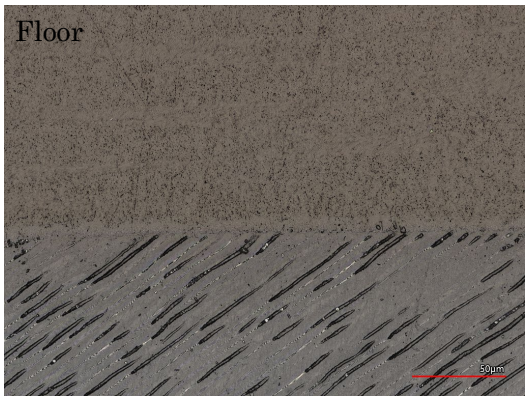
2) Apply Tokuyama Universal Bond II and air dry. When applying Scotchbond Universal Plus Adhesive, rub 20 secs before air drying. Light cure for 10 secs.
3) Fill with resin composite in layers (OMNICHROMA FLOW (OMCF)+ OMNICHROMA (OMC) / Tokuyama Dental Corp)
4) Cut perpendicular to the adhesion surface using a diamond cutter

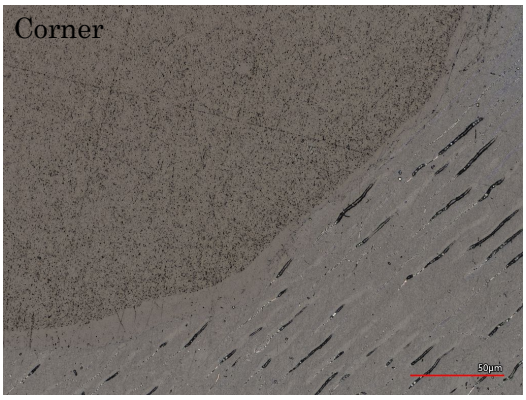
5) Polish the cut surface using diamond paste (final: 0.25μm)
6) Observe with laser microscope (VK-X 3000, Keyence Corp.)

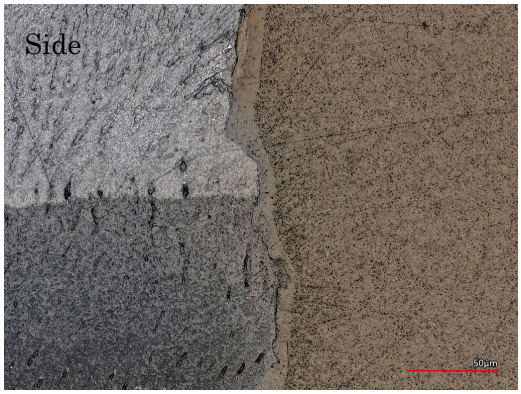
Tokuyama Universal Bond II (x 200)

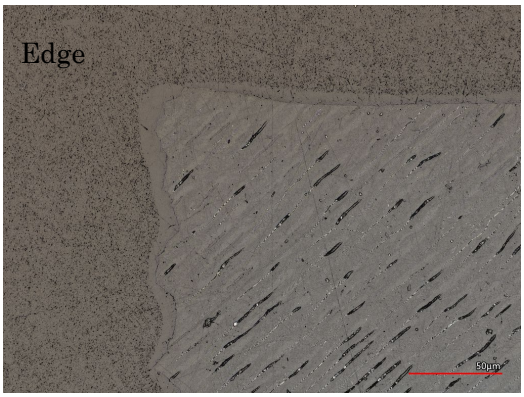


Tokuyama Universal Bond II (x 1,000)









Scotchbond Universal Plus Adhesive (x 200)



Scotchbond Universal Plus Adhesive (x 1,000)

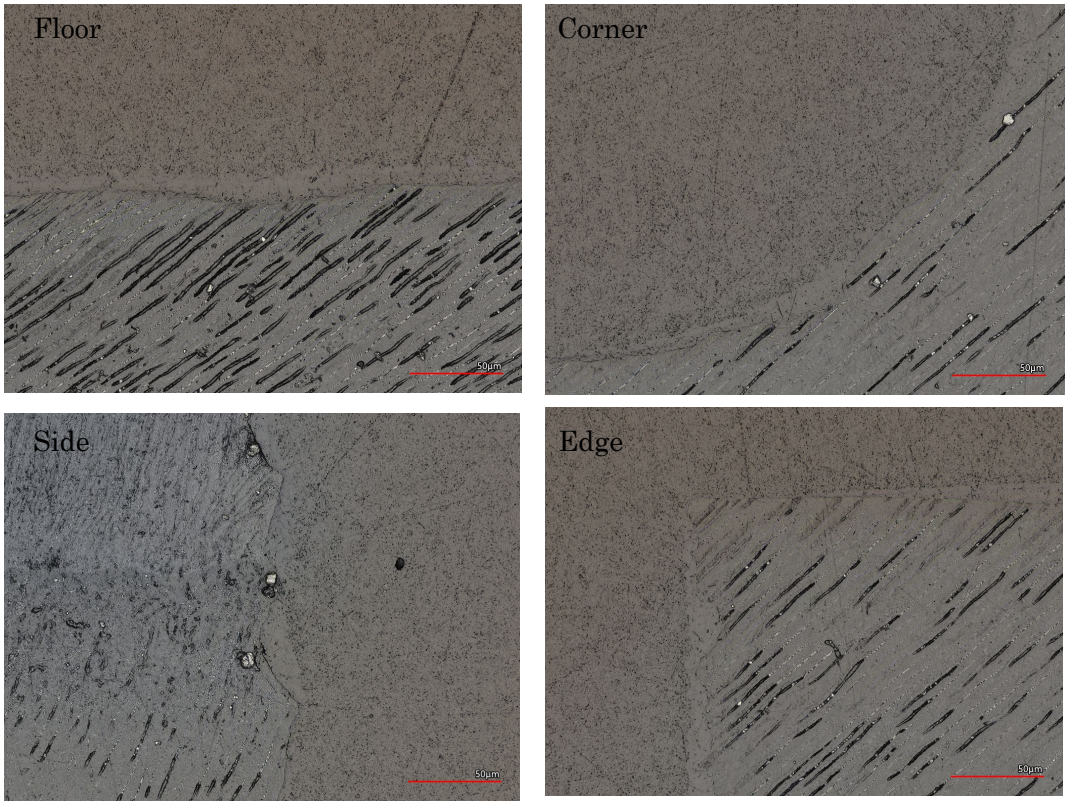


Fig. 31 Cavity adaptation

[Marginal Leakage]

The marginal leakage of Tokuyama Universal Bond II was evaluated *Table 6*. Pigment penetration was not observed, and Tokuyama Universal Bond II showed resistance to marginal leakage compared to other brands.

Test methods:

1) Create a simulated cavity in the form of a cylinder of 4 mm in diameter × 4 mm on the labial surface of an extracted bovine first anterior tooth.
2) Apply Tokuyama Universal Bond II and air dry. When testing Scotchbond Universal Plus Adhesive, apply and wait for 20 seconds, and air dry. Then light cure for 10 seconds.
3) Fill with resin composite (OMNICHROMA FLOW (OMCF)+ OMNICHROMA (OMC) / Tokuyama Dental Corp) in layers
4) Immerse the specimens in water at 37°C for 24 hours, and then in 0.1% fuchsin solution at 37°C for 24 hours
5) Cut in a perpendicular direction to adhesion surface using a diamond cutter
6) Polish the cut surface using Si-C paper (final: P3000)
7) Observe pigment penetration with a laser microscope (Laser Scanning Microscope VK- 9700, Keyence Corp.)

Table 6 Marginal leakage

Bonding Agent	Marginal leakage (n=10)									
Tokuyama Universal Bond II	—	—	—	—	—	—	—	—	—	—
Scotchbond Universal Plus Adhesive	—	—	—	—	—	—	—	—	—	+

– : no pigment penetration + : penetration into enamel

++ : penetration into dentin +++ : penetration into cavity floor

5.2.2 Intraoral repair

Tokuyama Universal Bond II can be used as a bond for intraoral repair, as it is applicable not only to tooth substance but silica-based, zirconia-based and metallic restorations. We performed a tensile bonding test to examine the bond strength of Tokuyama Universal Bond II when bonded to various prosthetic materials and to compare the strength with that of competitors' products.

[Bond Strength]

Bond strength was evaluated by a tensile bonding test. *Table 7, 8* show materials and pre-treatment methods used for the test and competitors' universal bond products used for comparison, while *Fig. 32–36* show the test result.

Tokuyama Universal Bond II showed stable bond strength when bonded to various materials.

Table 7 Tested prosthetic materials and pre-treatment method

	Manufacturer	Product name	Composition	Pre-treatment
Precious metal	Towagiken	CASTMASTER12S (12S)	Au12/Pd20/Ag54/Cu12/other2	1)Grind with P1500 SiC 2)Sandblast (50um of Al_2O_3)
Non-precious metal	i-CAST	Wirobond (WB)	Co60.2/Cr25/W6.2/ Mo4.8	1)Grind with P1500 SiC 2)Sandblast (50um of Al_2O_3)
Ceramics (Silica-base ceramics)	Kuraray Noritake Dental	Super Porcelain AAA	—	Grind with P800 SiC
Indirect composite	Tokuyama Dental	ESTELITE BLOCK II	—	1)Grind with P1500 SiC 2)Sandblast (50um of Al_2O_3)
Zirconia	TOSO	TZ-3Y-E	Yttria stabilized Zirconia (Yttria 3%)	1)Grind with P120 SiC 2)Sandblast (50um of Al_2O_3)

Table 8 Tested universal type bonding materials

Adhesive	Resin composite	Manufacturer	Abbreviation
Tokuyama Universal BondII	ESTELITE Σ-QUICK	Tokuyama Dental	UB
Scotchbond Universal Plus Adhesive	Filtek Supreme Ultra	3M	SU
iBond Universal	Venus	Heraeus Kulzer	IB
Clearfil Universal Bond Quick	CLEARFIL MAJESTY ES-2	Kuraray Noritake Dental	CU
G-Premio Bond	SOLARE	GC	GP
Prime &Bond Active	ceram.x SphereTEC one	Dentsply	PB
OptiBond Universal	Harmonize	Kerr	OU
All-Bond Universal	Aelite All-Purpose Body	BISCO	AB

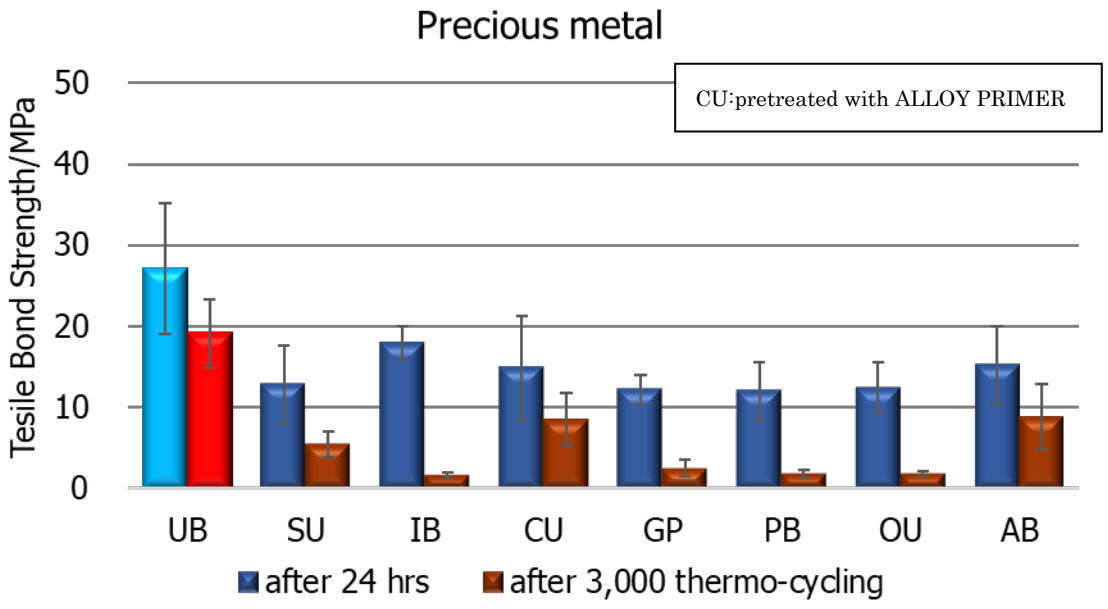


Fig.32 Tensile bond strength of universal adhesives on precious metal.

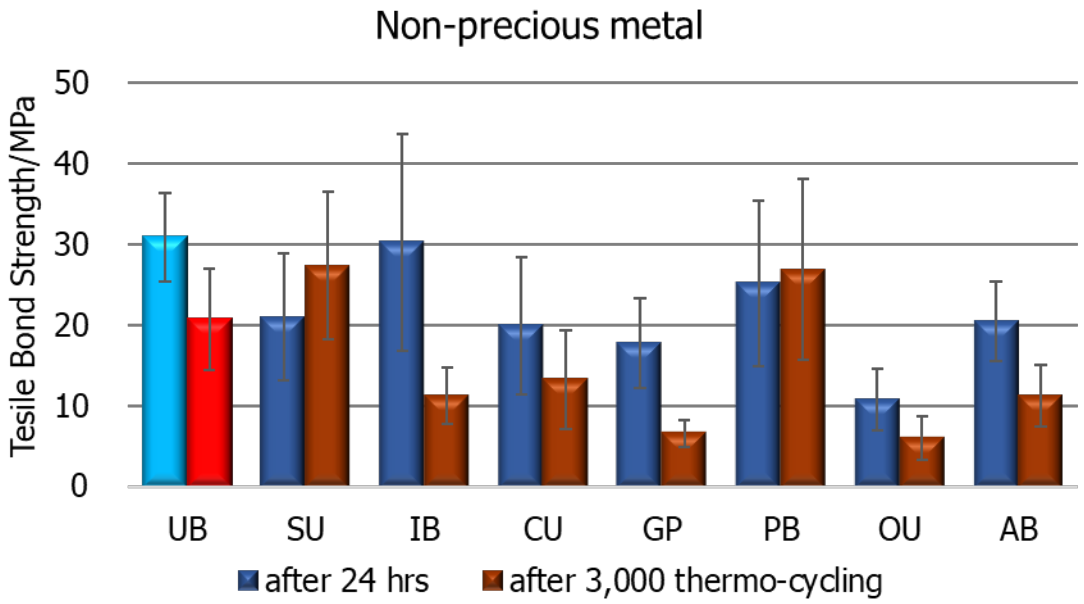


Fig.33 Tensile bond strength of universal adhesives on non-precious metal.

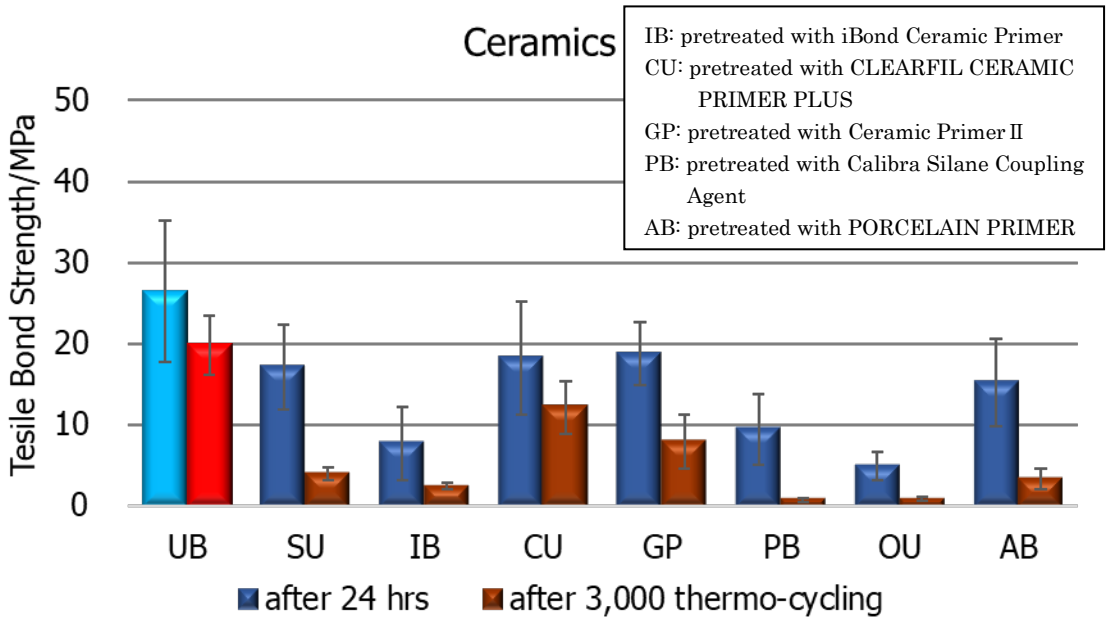


Fig.34 Tensile bond strength of universal adhesives on ceramics.

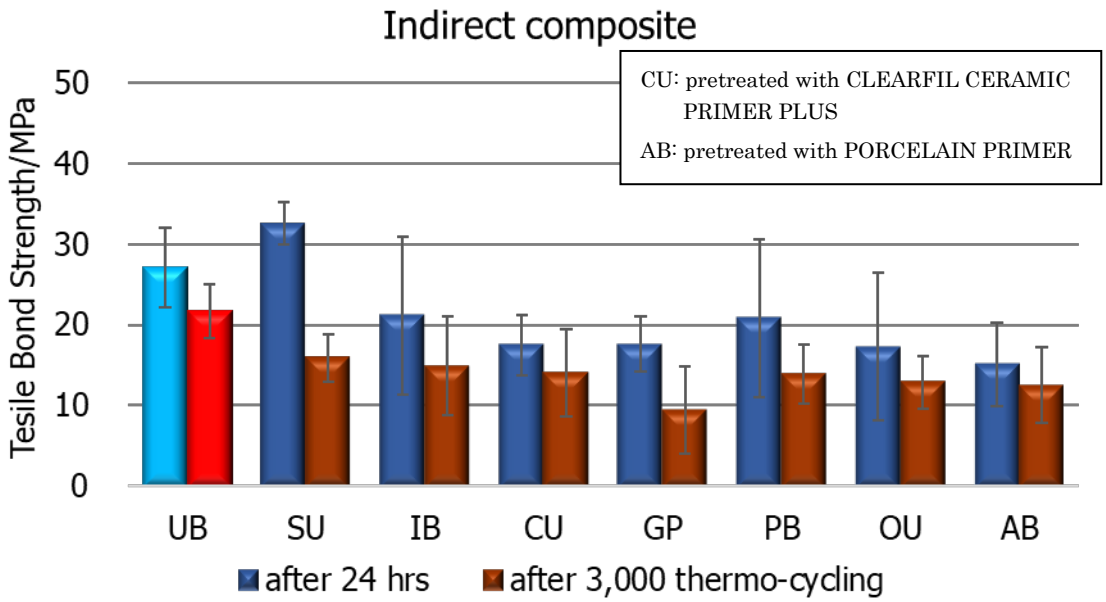


Fig.35 Tensile bond strength of universal adhesives on indirect composite.

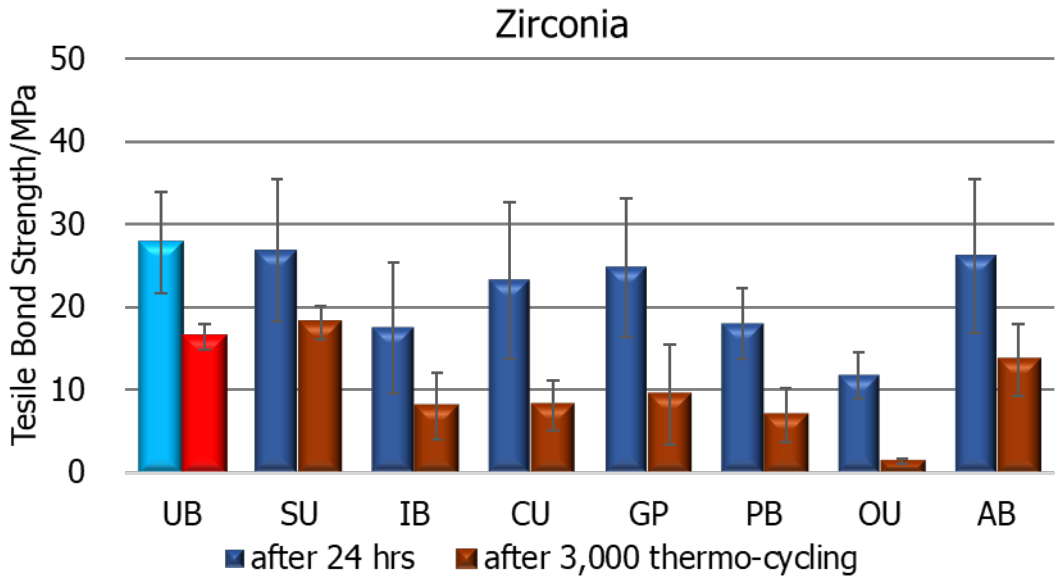


Fig. 36 Tensile bond strength of universal adhesives on zirconia.

5.3 Adhesion to Various Indirect Substrates

-Used as a primer for silica-based, zirconia based and metallic restorations-

Tokuyama Universal Bond II can be used as a primer for silica-based, zirconia-based and metallic restorations without the use of separate primers. Therefore, treatment of tooth substance and prosthetics can be completed with Tokuyama Universal Bond II for cementation and no other bonds or primers are required.

[Bond strength]

The tensile bond strength of Tokuyama Universal Bond II on various prosthetics for indirect restoration was evaluated. *Fig. 37* and *38*. show the bond strength on various prosthetics listed in *Table 9*.

Tokuyama Universal Bond II showed stable bond strength on any material. These results are based on reaction of adhesive monomer (MTU-6, New 3D-SR monomer, γ-MPTES), an ingredient of TOKUYAMA UNIVERSAL BOND.

Resin Cement: ESTECEM II PLUS (available in Europe)
Curing condition: Self-cure (without light irradiation)

Table 9 Tested prosthetic materials and pre-treatment method

	Manufacturer	Product name (abbr.)	Composition	Pre-treatment
Precious metal	Towagiken	CASTMASTER12S (12S)	Au12/Pd20/Ag54/Cu12/other2	1)Grind with P1500 SiC 2)Sandblast (50um of Al_2O_3)
	GC	Casting Gold M.C. TYPEⅣ (CG4)	Au70/Pd3/Ag8/Cu16/Pt2/other1	
		Casting Gold M.C. TYPEⅢ (CG3)	Au75/Pd3/Ag5/Cu16/other1	
		Casting Gold M.C. TYPEⅡ (CG2)	Au76/Pd2/Ag7/Cu14/other1	
		MIRO BRIGHT (MB)	Ag72/Zn13/Sn9/In6	
	DENTSPLY SANKIN	SUNSILVER CB (SS)	Ag77/Zn10/In7/Cu5/other1	
Non-precious metal	i-CAST	Wirobond (WB)	Co60.2/Cr25/W6.2/Mo4.8	1)Grind with P1500 SiC 2)Sandblast (50um of Al_2O_3)
	Towagiken	TITADENT (TI)	Ti≧99.5%	
		TITADENTⅡ(TI2)	Ti90/Al6/V4	

Ceramics (Silica-base ceramics)	Kuraray Noritake Dental	Super Porcelain AAA (SP)	—	1)Grind with P800 SiC
	Ivoclar Vivadent	IPS Empress (IE)	—	
		IPS e.max CAD (EC)	—	
Indirect composite	SHOFU	CERAMAGE (CE)	—	1)Grind with P1500 SiC 2)Sandblast (50um of Al_2O_3)
	Kuraray Noritake Dental	ESTENIA C&B (ES)	—	
CAD/CAM BLOCK	VITA	Enamic (EM)	—	1)Grind with P1500 SiC 2)Sandblast (50um of Al_2O_3)
	SHOFU	Block HC Hard (BH)	—	
	Kuraray Noritake Dental	KATANA AVENCIA Block (KA)	—	
	DENTSPLY SANKIN	KZR-CAD HR2 (KH)	—	
Zirconia	TOSO	TZ-3Y-E (TZ)	Yttria stabilized Zirconia (Yttria 3%)	1)Grind with P120 SiC 2)Sandblast (50um of Al_2O_3)
	3M	LAVA Zirconia (LZ)	—	
	Kuraray Noritake Dental	KATANA Zirconia (KZ)	—	

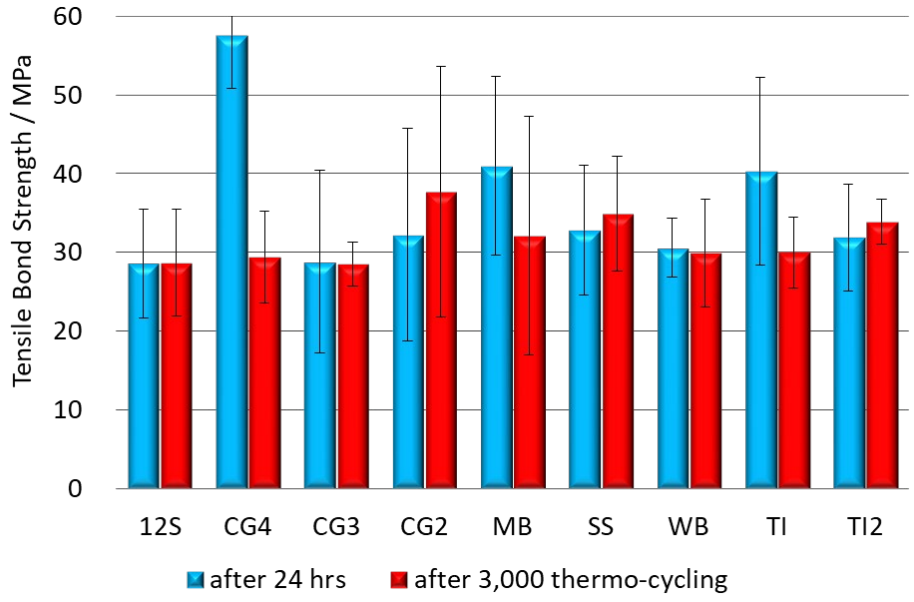


Fig.37 Tensile bond strength of Tokuyama Universal Bond II on metal

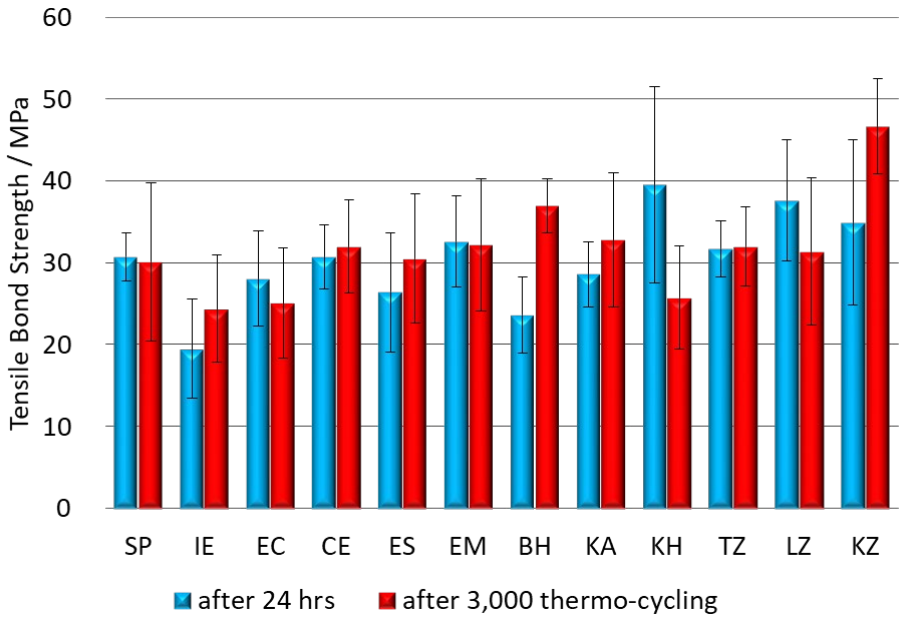


Fig.38 Tensile bond strength of Tokuyama Universal Bond II on ceramics, indirect resin, CAD/CAM block and zirconia

The bond strength of Tokuyama Universal Bond II was compared with that of competitors' prosthetic primers. Prosthetic primers used for comparison are listed in *Table 10, 11*, while the evaluation result is shown in *Fig. 39–43*.

Tokuyama Universal Bond II showed stable initial bond strength and durability when bonded to various materials and they were also excellent when compared with competitors' products.

Table 10 Tested prosthetic materials and pre-treatment method

	Manufacturer	Product name	Composition	Pre-treatment
Precious metal	Towagiken	CASTMASTER12S (12S)	Au12/Pd20/Ag54/ Cu12/other2	1)Grind with P1500 SiC 2)Sandblast (50um of Al_2O_3)
Non-precious metal	i-CAST	Wirobond(WB)	Co60.2/Cr25/W6.2 /Mo4.8	1)Grind with P1500 SiC 2)Sandblast (50um of Al_2O_3)
Ceramics (Silica-base ceramics)	Kuraray Noritake Dental	Super Porcelain AAA	—	1)Grind with P800 SiC
Indirect composite	Tokuyama Dental	ESTELITE BLOCK II	—	1)Grind with P1500 SiC 2)Sandblast (50um of Al_2O_3)
Zirconia	TOSO	TZ-3Y-E	Yttria stabilized Zirconia (Yttria 3%)	1)Grind with P120 SiC 2)Sandblast (50um of Al_2O_3)

Table 11 Tested primers for prosthetic materials

Manufacturer		Tokuyama Dental	3M	Ivoclar Vivadent	Kuraray Noritake Dental	Kerr	Dentsply	BISCO
Resin Cement		ESTECEMII PLUS	RelyX Universal	Multilink Automix	Panavia V5	NX3	Calibra Ceram	Duo-Link Universal
Prosthesis	Precious metal	Tokuyama Universal Bond II(UB)	Scotchbond Universal Plus Adhesive(SU)	Monobond Plus (MP)	Clearfil Ceramic Primer Plus (CC)	OptiBond Universal (OU)	Prime&Bond Active (PB)	All-Bond Universal (AB)
	Non-precious metal							
	Ceramics						Calibra Silane Coupling Agent (CS)	
	Indirect composite						Prime&Bond Active (PB)	
	Zirconia / Alumina							

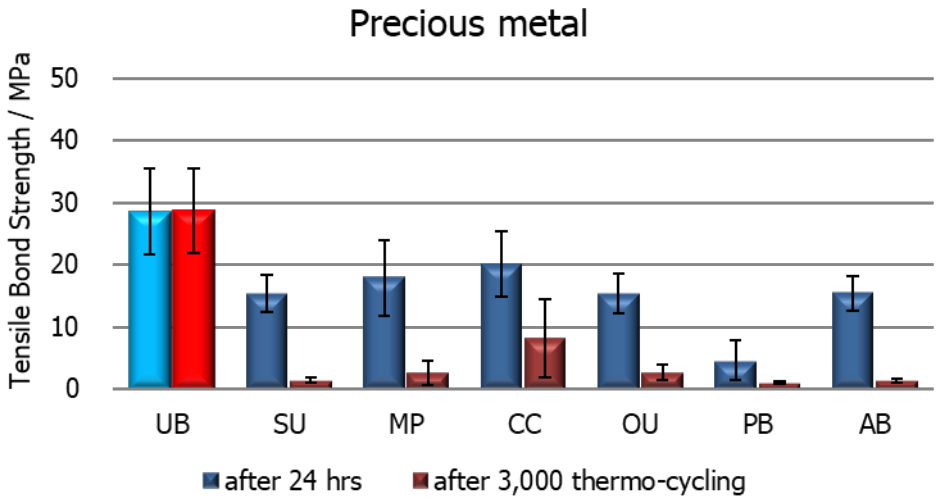


Fig.39 Tensile bond strength of Tokuyama Universal Bond II and primers on precious metal

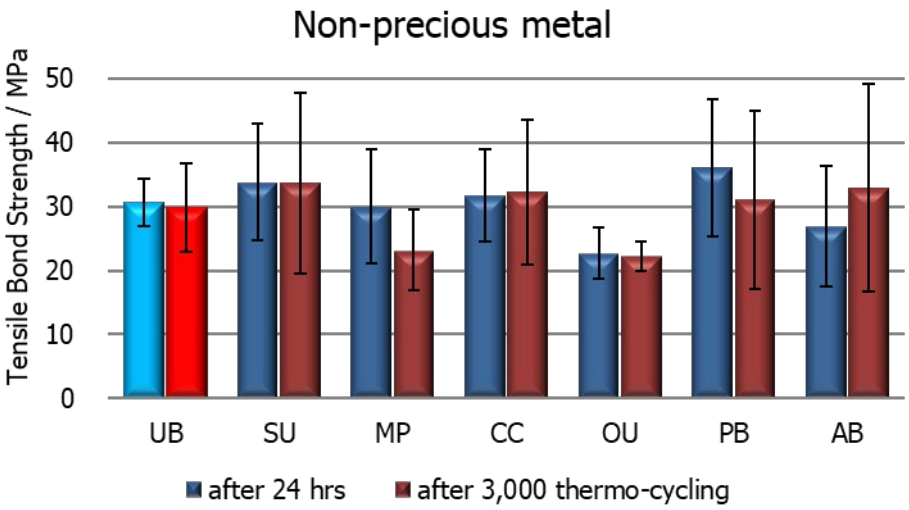
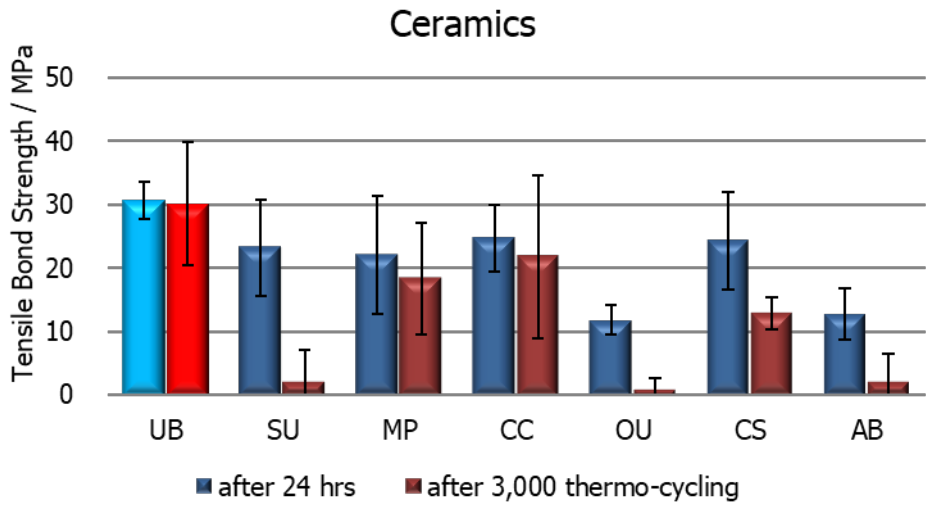


Fig.40 Tensile bond strength of Tokuyama Universal Bond II and primers on non-precious metal



※Not applicable

Fig.41 Tensile bond strength of Tokuyama Universal Bond II and primers on ceramics

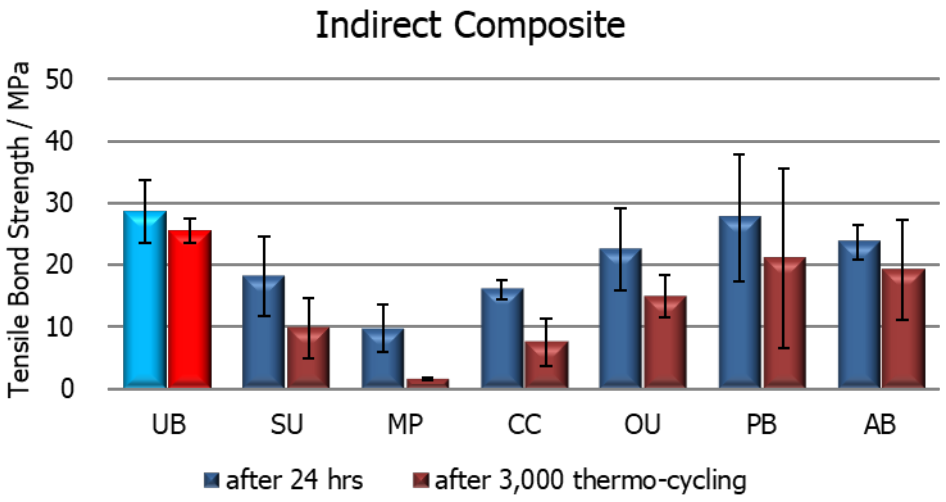


Fig.42 Tensile bond strength of Tokuyama Universal Bond II and primers on indirect composite

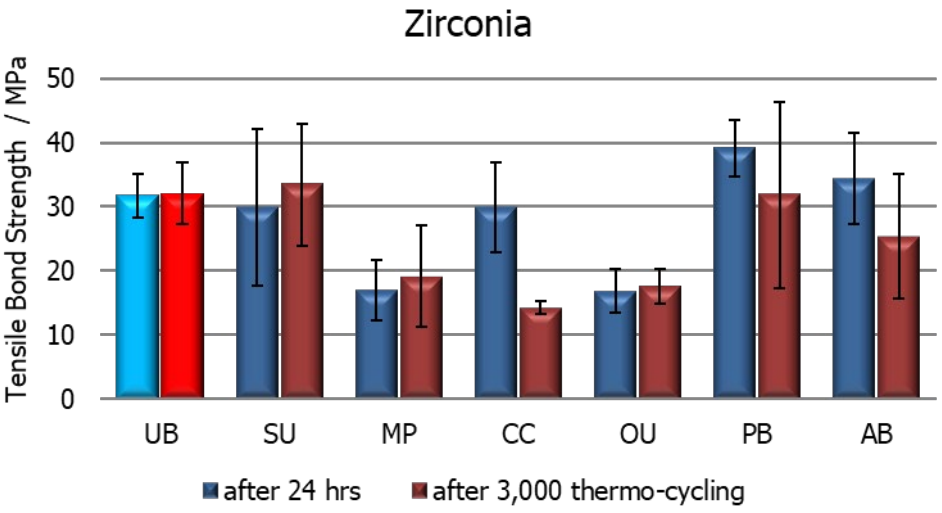


Fig.43 Tensile bond strength of Tokuyama Universal Bond II and primers on zirconia

Compatibility of Tokuyama Universal Bond II with competitors' resin cements was evaluated, when it was used as a pre-treatment agent for prosthetics.

Fig. 44 shows the evaluation result of bond strength on prosthetics using each competitor's resin cement. Resin cement was chemically cured.

Sufficient bond strength on various materials was obtained in combination with any of the cements.

Primer: Tokuyama Universal Bond II

Curing condition of Resin cement: Self-cure (without light polymerization)

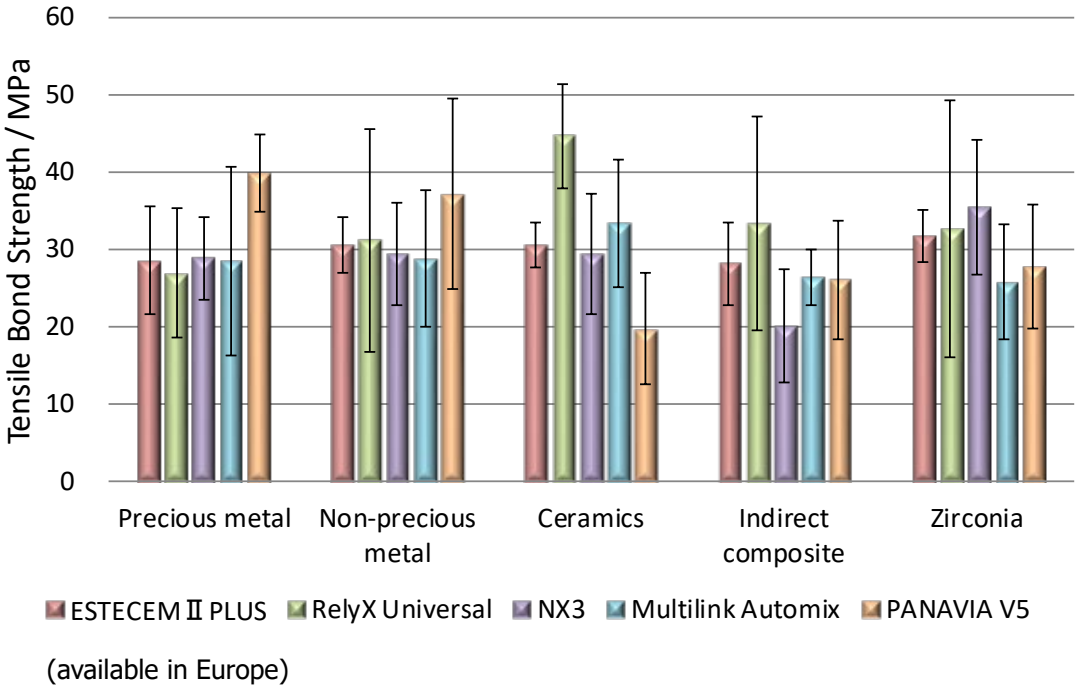


Fig.44 Bond strength on prosthetics using each competitor's resin cement.

6. Newly Added Features

Tokuyama Universal Bond II also has newly added features. Tokuyama Universal Bond II is easier to use due to visual confirmation that it is mixed by the color of the liquid and it can be stored at room temperature.

Before mixing, Bond A is yellow and Bond B is blue. The mixture is green once mixed. This feature allows you to visually confirm that Bond A and Bond B are mixed and you can use them with confidence.



Fig.45 The color change of Tokuyama Universal Bond II

TOKUYAMA UNIVERSAL BOND had to be stored refrigeration (0 to 10°C/32 to 50°F), but Tokuyama Universal Bond II can be stored at room temperature (0 to 25°C/32 to 77°F). This feature saves space in the refrigerator and saves you the trouble of putting it in and out of the refrigerator.

7. Conclusion

Tokuyama Universal Bond II is a new adhesive system for both direct and indirect restorations and is a useful material for the dental practice.

Features inherited from TOKUYAMA UNIVERSAL BOND

[Universal Use]

・Compatibility with self-etch, total-etch and selective-etch techniques

・Applicability to direct restoration and indirect restoration (limited to the primer treatment of the prosthetic restoration) with light-curing, dual-curing and self-curing composite materials without the use of a separate activator.

・Can be used as a primer for silica-based, zirconia based and metallic restorations.

[Simple Handing]

・No need to apply separately to tooth and restoratives

・No need to wait after bond application

・No need to light-cure

[Reliable]

・Stable bond strength

Newly added features

[Ease of mixing confirmation]

・Can be visually confirmed that it is mixed by color of the liquid

[Ease of Storage]

・Can be stored at room temperature

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