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YAMAKIN

From Production Skills to Scientific Knowledge,
and Onward to Fusion with Medical Science

TMR-AQUA BOND 0 Product Report

～An adhesive that has realized rapid treatment under moist conditions～

Edited by YAMAKIN Ph.D. Group

Index

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What is the YAMAKIN Ph.D. Group?
This is a group of experts in various specialized fields who combine their knowledge, experience and technical expertise to act as a prime mover in the continuous generation of innovation.

TMR-AQUA BOND 0 Product Report

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1. Introduction

It can be said that dental adhesives have grown along with the evolution of composite resin (CR) restoration.

In particular, CR restoration has spread rapidly as a highly effective treatment method of repair for dental caries [1] due to the MI (Minimal Intervention) approach to treatment. MI was proposed in 2000 as a way to minimize the area of intervention in the infected tooth, and to leave as much sound tooth as possible in place.

The CR which fills in the minimum cavity has almost no adhesion to the tooth substance. Therefore, a specialized adhesive between CR and tooth is required. When such an adhesive first appeared, it was of a 3-liquid type, in line with the adhesion process adopted (priming, permeating and bonding to the tooth). Subsequently, the adhesive was simplified to a 2-liquid or 1-liquid type by the introduction of a functional compounds such as adhesive monomers, which are effective for organic chemistry and high-polymer chemistry. Also, sufficient a strength and durability have been realized even with 1 liquid type adhesive by this technique. Furthermore, as an interesting example, CRs that do not require adhesives are beginning to be developed, but it can be said that there is still room for further study on their physical properties.

In view of the above circumstances, the development of adhesives in the future will proceed primarily by simplifying the method of adhesion and expanding the adherend.

"Simplifying the method of adhesion" includes reducing or shortening of the steps required for adhesion; for example, the wait time (decalcifying time) until the surface is etched after application of the adhesive to the tooth substance, or shortening the time required for visible light irradiation (light irradiation time) in the subsequent curing.

"An adhesive with an expanded range of adherends" refers to a product that can be used not only for dentin but also for materials such as precious metals, non-precious metals and ceramics. Adhesives that can adhere to these materials without primers have already been put on the market.

In the development of such technology, strength and bonding durability to the above materials have become issues; efforts to resolve these issues have been made, but there is remaining room for improvement.

TMR-AQUA BOND 0

YAMAKIN developed an adhesive designed for convenience of use and ability to adhere to materials other than tooth substance. "TMR-AQUA BOND 0" (AQUA BOND) was successfully developed by applying the comprehensively usable "Multi Primer" [2, 3] technology derived from YAMAKIN's basic research and "iGOS BOND" [4] technology, which has high adhesive strength and adhesion resistant to the moist conditions in the oral cavity.

"AQUA BOND" is an adhesive which has both adequate strength and bonding durability to each adherend, even when demineralization time and photoirradiation time are shortened. This is a combination which had been difficult to realize before.

In this report, we will discuss the performance of "AQUA BOND" as along with its actual verification results. We hope that you will be interested in "AQUA BOND" as a highly reproducible adhesive that can meet the demand of clinical treatment by achieving adhesion that can tolerate a wide range of adhesion conditions, and as a product that can reduce complications and treatment time.

2. Development background

"AQUA BOND" is created from accumulation of YAMAKIN's unique adhesive technology. We will explain the technical background of its creation.

2.1 Adhesive focusing on moisture

We develop adhesives, focusing on the moisture involved in dental adhesion.
"The moisture involved in adhesion" refers to a wide range of phenomena, such as moisture entering during cavity formation, tissue fluid that seeps out of the dentinal tubule of dentin, to capillary action and osmotic pressure on the adhesive interface, water vapor contained in exhalation, and the water introduced when removing the adhesive material solvent by air-blowing [5].

For adhesion, a minimum amount of moisture is necessary for wettability and permeability to the adhesive interface; however, such a minimum amount of moisture will cause disproportionation and dilution of the adhesive composition and lead to adhesion failure. Also, since the latter inhibiting factor greatly affects the outcome in clinical cases, adhesion is done with attention paid to moisture-proofing measures.

However, in clinical cases of moisture-proofing, it is difficult to prevent moisture penetrating from various routes.

For example, in adhesion of dentin, when an adhesive is applied to treated dentin surface, it is thought that osmotic pressure causes the interstitial fluid to leak from the dentinal tubule to the interface. It is very difficult to prevent moisture from penetrating into this adhesive, and there are many uncertainties as to how much moisture permeates an area of cavity and to what extent it becomes a hindrance to adhesion [6].

Since components of adhesive include hydrophobic organic compounds such as crosslinking monomers, it is thought that water enters from outside and water is localized in the phase separation of the composition or in the vicinity of the interface between the adhesive and the tooth. In such a situation, moisture gathers in the vicinity of the interface, and an adhesive layer which is fragile with respect to adhesion is formed. Furthermore, water drops in the vicinity of the interface may wash out monomers from the adhesive layer. Especially in the case of acidic monomers, they will continue to scrape the tooth surfaces even after curing; as a result, the weakened adhesive interface may cause detachment from the adherend[6].

In order to prevent the possibility of deterioration of adhesion due to such phase separation, it is possible to prevent phase separation of the composition with a surfactant or the like. However, since ordinary surfactants have no polymerizability, they essentially do not take part in a curing reaction by photopolymerization, but rather they cause a reduction in strength when they are applied in large amounts; therefore, it is necessary to pay attention to the formulation.

Therefore, YAMAKIN has planned the development of an adhesive from a new perspective.
In other words, from the idea of "making moisture work for us," we have devised an adhesive in such a way that adhesion is not susceptible to being affected by moisture which cannot be excluded clinically (Figure 1).

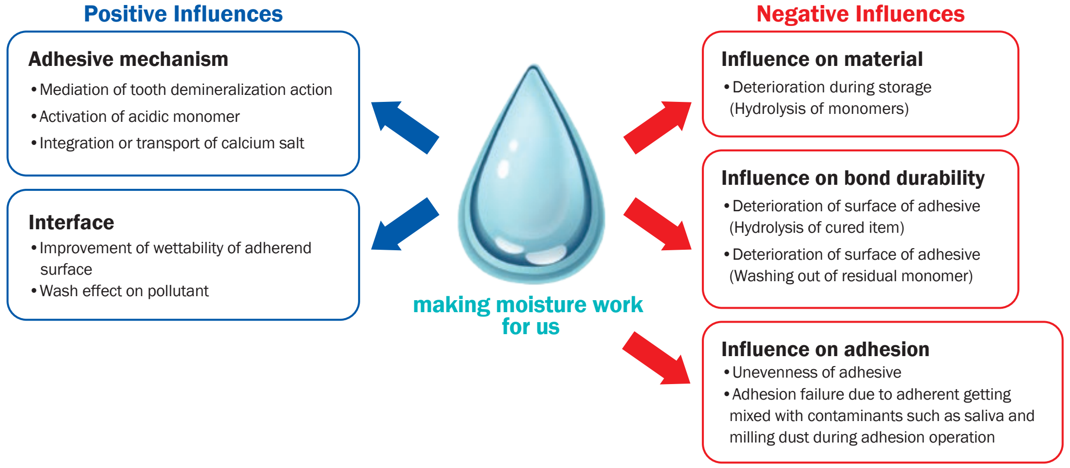


Figure 1 Positive and negative influences on "making moisture work for us" in adhesion

First, in the composition of an adhesive, we focused on adhesive monomers and developed an original adhesive. In this process, we succeeded in developing M-TEG-P® phosphate monomer and introducing it into the composition of dental adhesive "iGOS BOND" ("our conventional product"). Thanks to M-TEG-P, we have succeeded in developing an adhesive whose components will not exhibit phase separation during the solvent volatilization that occur after application, and whose adhesion will not be susceptible to influence by the amount of moisture mixed into the adhesive layer.

M-TEG-P is a registered trademark of YAMAKIN CO., LTD.

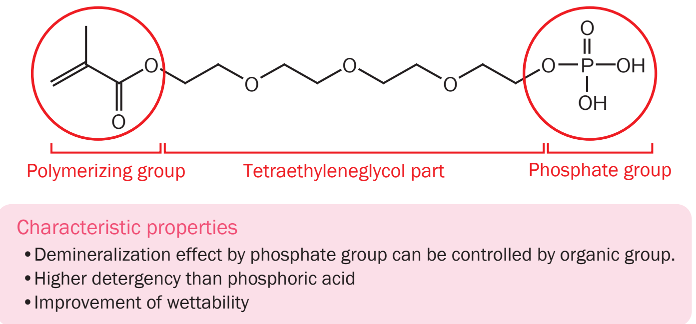


Figure 2 Chemical structure and characteristics of M-TEG-P

By "making moisture work for us," we were able to create a product that is tolerant to conditions such as a moist adherend environment, to air-blowing conditions after application, or leaving time (under light-shielded) after removing it from the container and which can adhere with good reproducibility.

2.2 Challenges for the development of TMR-AQUA BOND 0

In this way, we were able to develop an adhesive with good reproducibility in adhesion under a moist conditions. However, against a background of increasingly simplified processes and shortened treatment times in dental adhesion, there was growing demand for products which did not require leaving time (demineralization time) after application, and which could adhere not only to dentin but also to prosthetic appliances. Our conventional product adhered to dentin with good reproducibility, but it did not allow for shortening of demineralization time or adhesion to prosthesis without primer.

The development challenges for "AQUA BOND" were shortening demineralization time and light irradiation time (polymerization time), increasing the number of adherends, and maintaining high adhesive strength and durability so that we could provide a product to users who wanted to simplify adhesion processes and shorten treatment time. Therefore, M-TEG-P was essential as a functional monomer to realize "AQUA BOND".

2.3 Functions of "TMR-AQUA BOND 0" as realized

"AQUA BOND" can adhere to various adherends without a primer, as given in the following table. With "Multi Primer LIQUID" (Multi Primer), it can adhere to porcelain and resin materials containing inorganic fillers (resin material). AQUA BOND was designed to be used in combination with resin material and porcelain in combination with primer. This is because we determined that the maintenance of storage stability and adhesion durability could be compromised if silane coupling agent (which imparts adhesiveness to both materials) is concentrated with strongly acidic monomer into one liquid. Therefore, the need for primer has not been completely eliminated.

Table 1 Adherends of AQUA BOND (With/without combined use of primer)

Product name		TMR-AQUA BOND 0	TMR-AQUA BOND 0 + Multi Primer LIQUID
Adherend	Tooth substance	✓	−
	Zirconia	✓	−
	Titanium	✓	−
	Gold alloy	✓	−
	Silver alloy	✓	−
	Gold-silver-palladium alloy	✓	−
	Resin (inorganic fillers)	−	✓
	Porcelain	−	✓

For shortening treatment time, AQUA-BOND enables the next step of the process to be performed during the decalcifying time: solvent removal by air-blow immediately after an adhesive is applied on an adherend, including tooth substance. During light irradiation time, as long as the LED lamp has a light amount of 1000 mW/cm^2 or more, AQUA-BOND can be cured and adhere well with good reproducibility with irradiation of 10 seconds or more without any particular additional requirements. Furthermore, in the case of LED lamps with a light amount of 2400 mW/cm^2 or more, adhesion by irradiation for 3 seconds or longer can be reliably achieved.

Figure 3 shows a list of initial adhesive strengths of each material. For resin material and porcelain material, adhesion with combined use of "Multi Primer" together is evaluated. Detailed evaluation methods of adhesion will be described later.

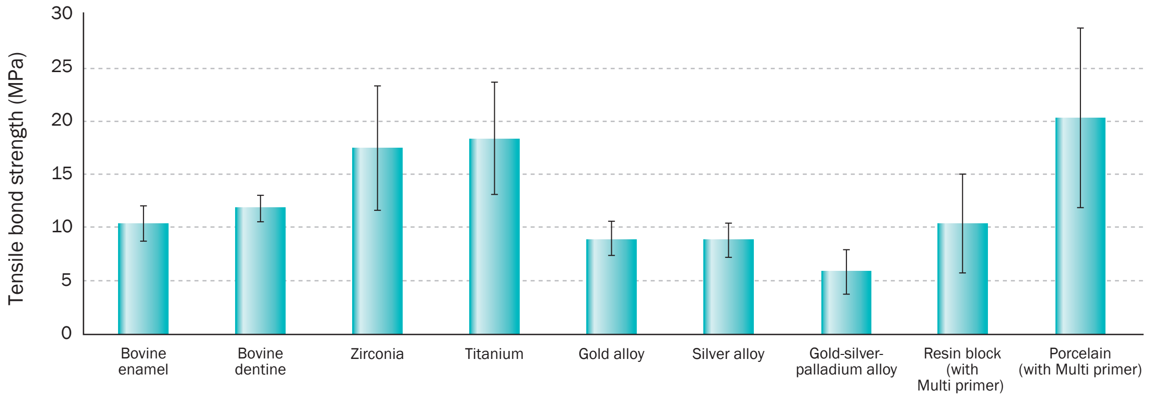


Figure 3 Initial adhesive strength to tooth substance and to each of the other materials above

3. Adhesion to tooth substance

The evaluation of adhesion of "AQUA BOND" was carried out as follows. The relationship between demineralization time and adhesion of "AQUA BOND" was evaluated, as was adhesion in a moist model.

3.1 Evaluation of the initial adhesive strength to tooth substance

Adhesion to tooth substance of "AQUA BOND" is evaluated with bovine teeth. Evaluation was carried out with the test method shown in Figure 4.

The following outline is of a test of modeling composite restoration in the oral cavity. Masking tape with a 3-mm diameter hole was affixed on each polished flat surface of bovine enamel and bovine dentine to limit the adhesive surface. After the adherend surface was dried by air-blowing, "AQUA BOND" was applied. Five seconds after application (demineralization time), the applied surface was dried by air-blowing and polymerized by light. After that, the composite resin for dental filling was filled and cured. A stainless steel rod was fixed to this cured surface using resin cement to prepare a test specimen. The specimen was stored in water at 37 °C for one day and then subjected to a test to pull the stainless steel rod perpendicularly to the adherend surface at a speed of 1 mm/min, and the tensile bond strength was obtained from stress at breaking.

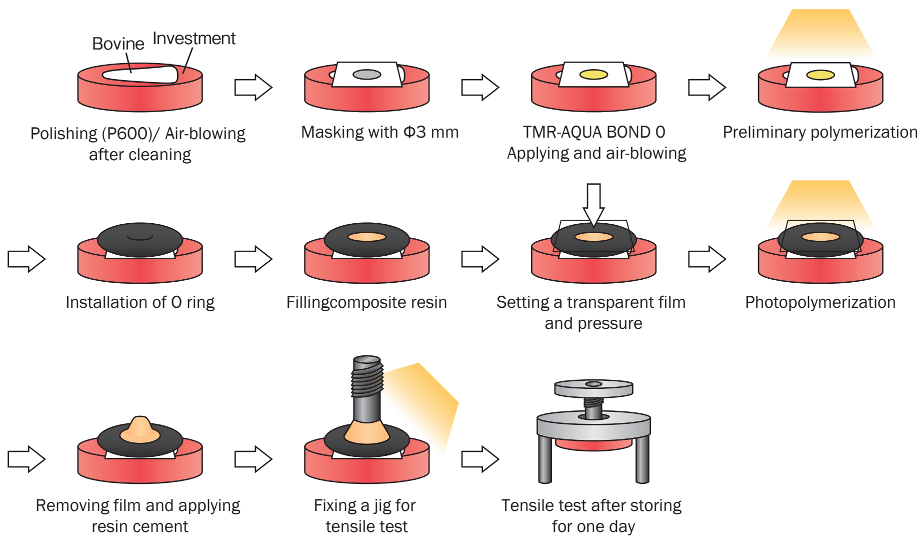


Figure 4 Method of adhesion to tooth substance

3.2 Evaluation of adhesion under moist conditions

The oral cavity is a high-humidity environment, and there are circumstances where dry the tooth surface cannot be dried sufficiently during cavity formation, or where moisture cannot be prevented even if due care is taken. Therefore, adhesion of "AQUA BOND" in a moist condition was evaluated. In this evaluation method, after adherend surface was dried, the tooth surface was moistened uniformly so as to be covered with a thin film of water, and then the adhesive strength was examined as a model evaluation.

Test specimens for adhesion test in a dry condition and a moist condition are shown in Figure 5.

dry condition moist condition

Figure 5 Test specimens for adhesion test (dry condition and moist condition)

In a moist conditions, "AQUA BOND" is applied and bonding is carried out in a state where a film of water of about 100 µm covers the tooth surface. The results are shown in Figure 6.

"AQUA BOND" showed effective adhesion to both enamel and dentin even when it was adhered under moist conditions. It is thought that due to the effect of M-TEG-P, wettability to the tooth surface of the whole composition is effective under both dry and moist conditions and the maintenance of adherence uniformity realizes highly reproducible adhesion under both dry and moist conditions.

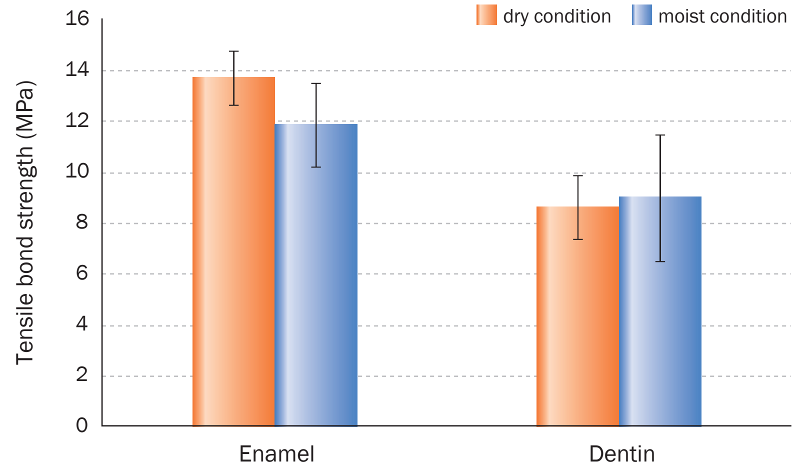


Figure 6 Adhesion to tooth substance (dry conditions, moist conditions)

3.3 Adhesion per demineralization time

"AQUA BOND" is designed to maintain high adhesion even if the demineralization time and light irradiation time after application are shortened in order to reduce the burden on the patient. The demineralization time after application and the adhesion of "AQUA BOND" were confirmed. It was then confirmed whether there was a cause-and-effect relation between them depending on the time. The adhesion to the tooth substance at different demineralization times is given in Figure 7.

"AQUA BOND" did not desorb enamel or dentin even under any of the demineralization time conditions, and in comparison with our conventional product, stronger adhesion was confirmed, especially under shorter demineralization time conditions for enamel. By contrast, for dentin, it can be seen that there is no notable decrease of adhesion even with relatively long demineralization for 20 seconds. This shows that the reaction between M-TEG-P and hydroxyapatite on the surface of the tooth is moderately controlled. That is, M-TEG-P efficiently removes the smear layer on the surface of the enamel and dentin, or the calcium component as the smear plug, and forms a preferable surface for adhesion. Therefore, "AQUA BOND" can adhere immediately after application; adhesiveness gently increases with time due to controlled demineralization, and it has been demonstrated dhesion will not decrease due to excessive demineralization etc. in dentin.

In other words, "AQUA BOND" can be said to be tolerant to demineralization time rather than not requiring demineralization time.

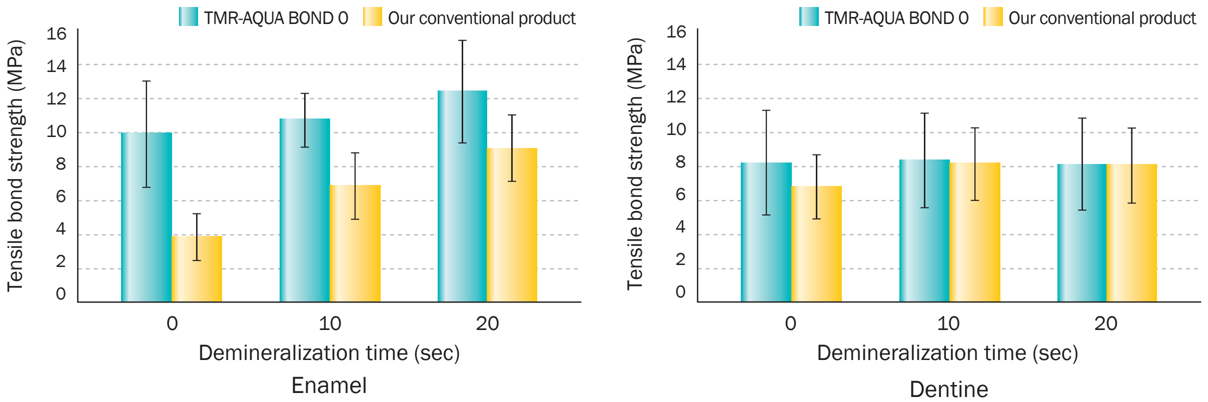


Figure 7 Adhesion per demineralization time (Enamel and dentine)

4. Adhesion to materials other than tooth substance

Materials other than tooth substance, zirconia, titanium and precious alloys can be adhered without primer. Especially of interest is the adhesion to zirconia.
Here, we will discuss adhesion to materials other than tooth substance. The materials used as adherends are as given in Table 2.

Table 2 Materials used as adherends

Material	Product name
Zirconia	KZR-CAD Zr SHT
Titanium	KZR-CAD Ti
Gold alloy	YP GOLD TYPE I
Silver alloy	UNI 1-n
Gold-silver-palladium alloy	PALLAZ 12-n
Resin block	KZR-CAD HR Block 3 GAMMATHETA
Porcelain	ZEO CE LIGHT

4.1 Adhesion to zirconia

Regarding adhesion characteristic to zirconia, adhesive strength was evaluated with "KZR-CAD Zirconia SHT" ceramics for dental machining. The evaluation was carried out by the test method given in Figure 8. The outline of the test method is as follows and is a modeling test assuming repair in the oral cavity.
Masking tape with a hole of 3 mm diameter was attached to the polished flat surface of zirconia, to limit the adhesive surface. After drying the adherend surface by air-blow, "AQUA BOND" was applied. Five seconds after application (leaving time), the applied surface was dried by air-blow and polymerized by irradiation of light. After that, the composite resin for dental filling was filled and cured.
A stainless steel rod was fixed on this cured surface using resin cement to prepare test specimens. The specimens were stored in water at 37 °C for 1 day and then subjected to a test to pull the stainless steel rod perpendicularly to the adherend surface at a speed of 1 mm/min, and the tensile bond strength was obtained from stress at breaking.

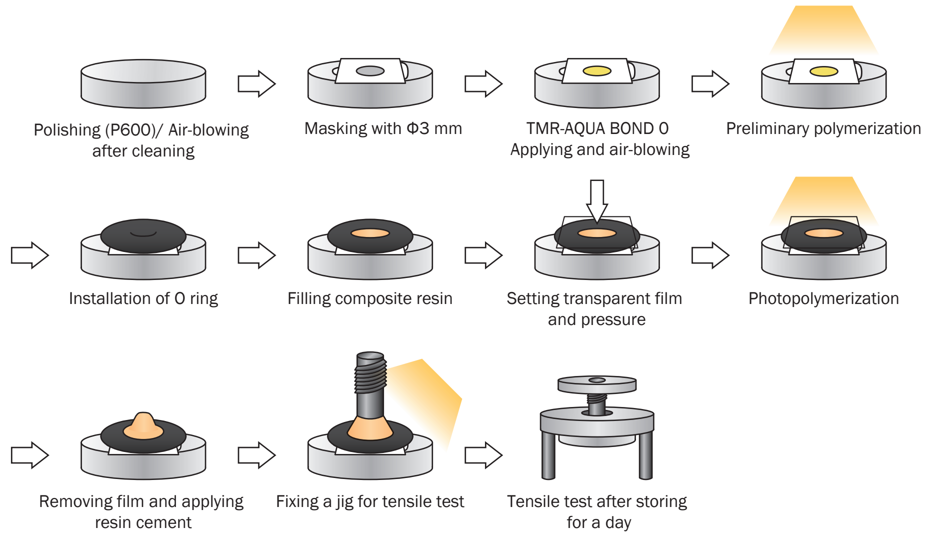


Figure 8 Method of adhesion to zirconia

Adhesion of "AQUA BOND" to zirconia is shown in Figure 9. Even without the use of primer, "AQUA BOND" showed stronger adhesion to zirconia than our conventional product, which is used in combination with "Multi Primer." It is known that phosphate monomer is excellent in reactivity with zirconia [7-9]; therefore, the phosphate group of M-TEG-P contained in "AQUA BOND" works effectively for adhesion to zirconia. While M-TEG-P has been used as an adhesive monomer in our conventional product, we have succeeded in preparing the composition so as to make M-TEG-P exhibit more functional efficiently in "AQUA BOND." Therefore, high adhesion not only to tooth substance but also to zirconia has been obtained.

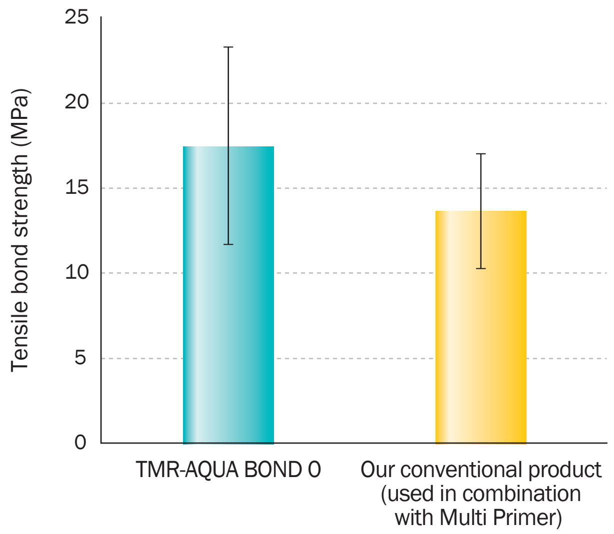


Figure 9 Adhesion to zirconia

4.2 Adherends other than zirconia not requiring primer

In addition to zirconia, adherends that can be adhered without primer are titanium, precious alloys, and the like. Adhesiveness of titanium, gold alloy, silver alloy and gold-silver-palladium alloy were evaluated using the same method as in Figure 8, and the results are shown in Figures 10 to 13.

In the case of adhesion to titanium which is in the same Group 4 as zirconia, our conventional product also contains M-TEG-P, so that titanium can be adhered to without a primer; however, as with the above-mentioned titanium and with zirconia, by adjusting the composition, an improvement in adhesiveness whereby M-TEG-P and titanium surface can interact more efficiently is observed.

Our conventional product can adhere to precious alloys by using "Multi Primer LIQUID" in combination with it as a primer. "AQUA BOND" has components with adhesiveness to precious metals, so it can adhere to them without primer.

For adhesives containing a primer component, proximity to the adherend is hindered by the other components, and the efficiency of the interaction between the primer component and the adherend is less than that of adhesives which require the separate use of a primer. Apart from its primer component, "AQUA BOND" is composed of similar main ingredients, including methacrylate and dimethacrylate, as our conventional product. If we compare the two, it should be expected that the adhesion of "AQUA BOND," which contains a primer component, will be inferior.

However, "AQUA BOND" is characterized by exhibiting higher adhesion to any precious alloy than our conventional product used with primer.

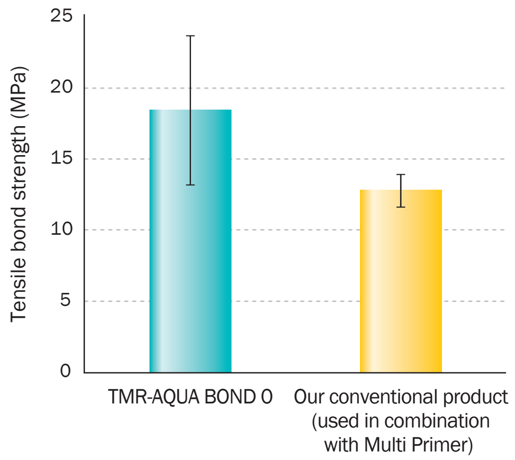


Figure 10 Adhesion to titanium

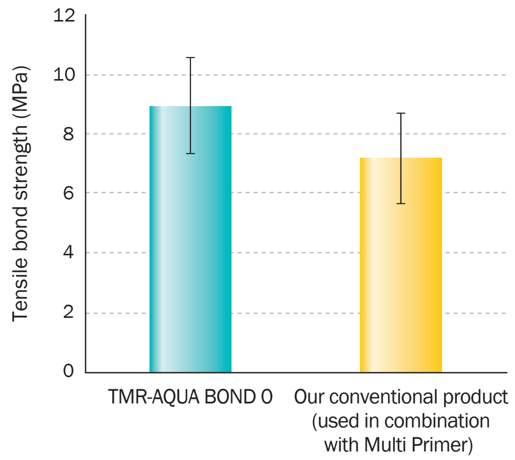


Figure 11 Adhesion to gold alloy

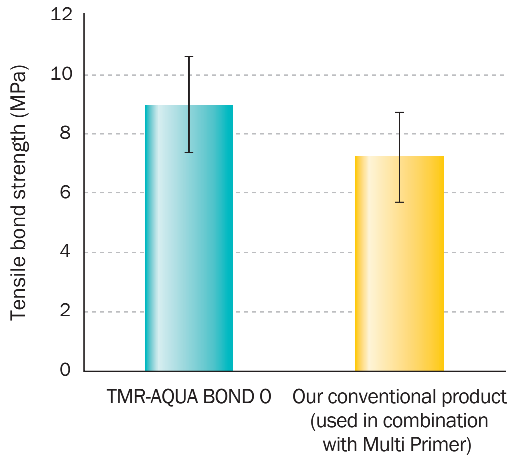


Figure 12 Adhesion to silver alloy

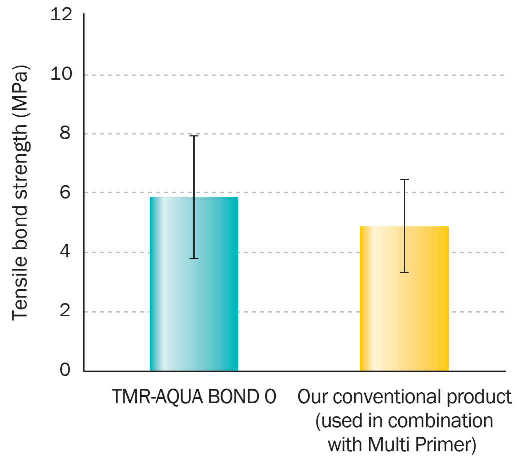


Figure 13 Adhesion to gold-silver-palladium alloy

4.3 Adherend requiring the combined use of primer

"AQUA BOND" is designed so that it can adhere to resin material and porcelain etc. by primer treatment with "Multi Primer LIQUID." There are two reasons for this— the problem of the efficiency of chemical interaction between the primer component and the adherend, and the problem of the storage stability of the adhesive itself.

The above problems can be solved depending on the primer component used, and as described in the previous section, "AQUA BOND" has demonstrated adhesion to a precious metal when used in combination with adhesive components. By contrast, a silane coupling agent is effective as a primer component for a resin material and porcelain, but since the silane coupling agent is chemically very unstable with respect to acid and water, in blending silane coupling agent into an adhesive, it is especially difficult to resolve the problem of water. From these circumstances, from the viewpoint of providing a stable adhesive, "AQUA BOND" was designed so as not to excessively simplify the adhesion system.

Figures 14 and 15 show the adhesion to a resin material (resin block was chosen in this report) and porcelain. In both cases, it can be seen that the adhesion system of "AQUA BOND" and "Multi Primer" exhibits high adhesion. It can be proposed as a combination of “Multi Primer” and “AQUA BOND 0” that can reliably adhere to new resin materials such as resin blocks, which have considerable issues in regard to adhesion.

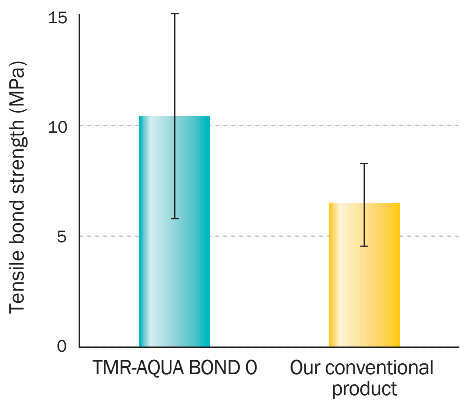


Figure 14 Adhesion to resin block
(used in combination with Multi Primer)

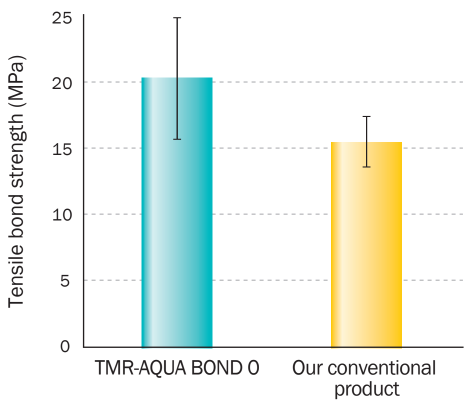
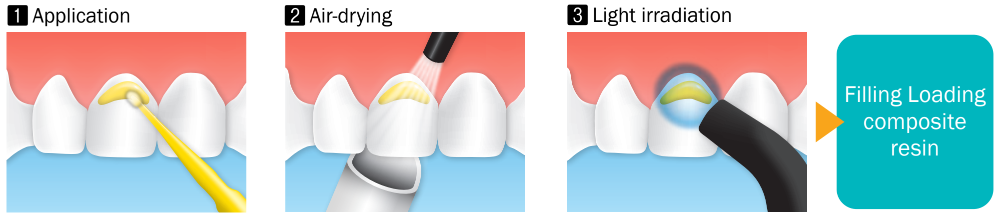


Figure 15 Adhesion to porcelain
(used in combination with Multi Primer)

5. Adhesion process

1 Application
2 Air-drying
3 Light irradiation



Apply AQUA BOND on entire dried cavity.
After application, air-drying can be performed even without waiting time.

Perform air-drying until the liquid surface will not be moved while performing suction with vacuum (for about 5 seconds or more with strong pressure).

Category	Light intensity	Irradiation time
LED light	2400 mw/cm²	3 seconds or more
	1200 mw/cm²	10 seconds or more
	300 mw/cm² or more	
Halogen Light	300 mw/cm² or more	

Figure 16 How to use AQUA BOND

“AQUA BOND” employs a simple adhesive process with 1 step and 1 liquid. The process consists of 1) applying, 2) Air-drying and 3) light curing, and then filling composite resin to complete (Figure 16).

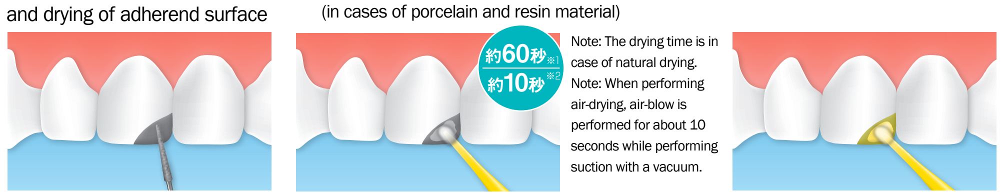
1. For some products, there is a need to agitate the adhesive on the applied tooth surface with an applicator brush or the like for a certain period of time during the application procedure, in order to promote demineralization and penetration. However, with "AQUA BOND," it is enough to simply apply the product gently on the tooth surface.

2. In the air-drying procedure, when the product is dried until the liquid surface does not move (5 seconds or longer at high pressure), a uniform thin film is formed due to the characteristics of "AQUA BOND."

3. In polymerization by light, if a thin film is uniformly formed, it will be cured by irradiation at a light intensity of 2400 mW/cm² for 3 seconds or longer with a light irradiator for dental polymerization.

When an adherend is a crown restoration (porcelain or resin material) for repairing in the oral cavity or the like, it is necessary to apply "Multi Primer" for surface treatment before "AQUA BOND" application (Figure 17). The subsequent procedure is the same as the procedure for adhering to tooth substance.

1 Surface roughening, cleaning and drying of adherend surface
2 Applying Multi Primer LIQUID and drying (in cases of porcelain and resin material)
3 Applying TMR-AQUA BOND



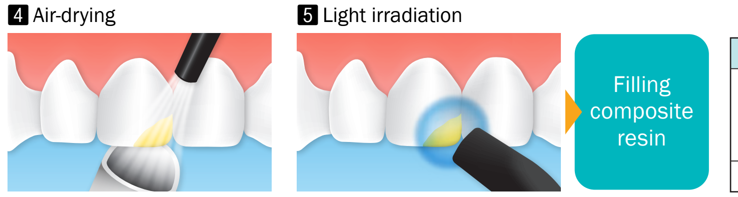
Note: The drying time is in case of natural drying.
Note: When performing air-drying, air-blow is performed for about 10 seconds while performing suction with a vacuum.

Perform surface roughening, cleaning and drying.

Apply Multi Primer LIQUID (optional item) on dried adherend surface and dry it for approx. 60 seconds.

Apply TMR-AQUA BOND 0 to the entire adherend surface. After application, air-drying can be performed even without waiting time.

4 Air-drying
5 Light irradiation



Air-drying until the liquid surface will not be moved while performing suction with a vacuum.
(for about 5 seconds or more with strong pressure)

Curing with a light irradiator for dental polymerization.

Category	Light intensity	Irradiation time
LED light	2400 mw/cm²	3 seconds or more
	1200 mw/cm²	10 seconds or more
	300 mw/cm² or more	
Halogen Light	300 mw/cm² or more	

Figure 17 Procedures for repairing dental restorations
(zirconia, metal, porcelain and resin material) in the oral cavity

6. Retention of uniformity

Since M-TEG-P has stable characteristics both in water and oil, it also has the effect of maintaining a homogeneous state without separation of the lipophilic monomer and water.

Therefore, as given in Figure 18, "AQUA BOND" has been confirmed to be usable without phase separation until about 30 minutes after removal from the container under light-shielded conditions. A comparison of the adhesive strength of "AQUA BOND" immediately after removal with that 30 minutes after removal is given in Figure 19. Although the adhesive strength of "AQUA BOND" to enamel decreased by having "AQUA BOND" let sit, sufficient adhesive strength is maintained. Also, with respect to dentin, there was hardly any change in adhesive strength. This is attributable to the fact that even when the solvent component contained in "AQUA BOND" volatilizes, it does not separate, and maintains uniformity; as a result, it shows high reproducibility of adhesion.

Figure 18 State immediately after removal, 10 min later and 30 min later

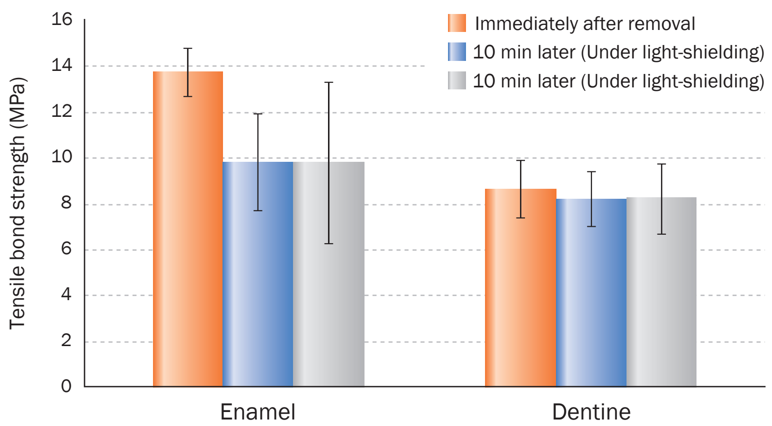


Figure 19 Adhesive strength immediately after removal from container, 10 min later and 30 min later

7. Adhesive interface

In general, minute irregularities caused by machining exist on the tooth surface in a cavity. For this reason, adhesive needs to fill the minute irregularities and provide a smooth surface of adhesive layer to enable composite resin to adhere to the cavity surface without gaps. By contrast, in order to sufficiently exert the physical strength of the filled composite resin, it is desirable that the thickness of the adhesive layer, which is inferior in strength, is as thin as possible.

The adhesive interfaces between dentin and AQUA BOND and composite resin are shown in Figure 20. It was confirmed that the interface between the adhesive layer and the composite resin was smooth, without being affected by the unevenness of the tooth surface, and that "AQUA BOND" was able to form a smooth surface of adhesive layer. Furthermore, although the thickness of the adhesive layer depends on the irregularities of the tooth surface, it is 5 to 10 µm, and it was also confirmed that a homogeneous thin bond layer was realized.

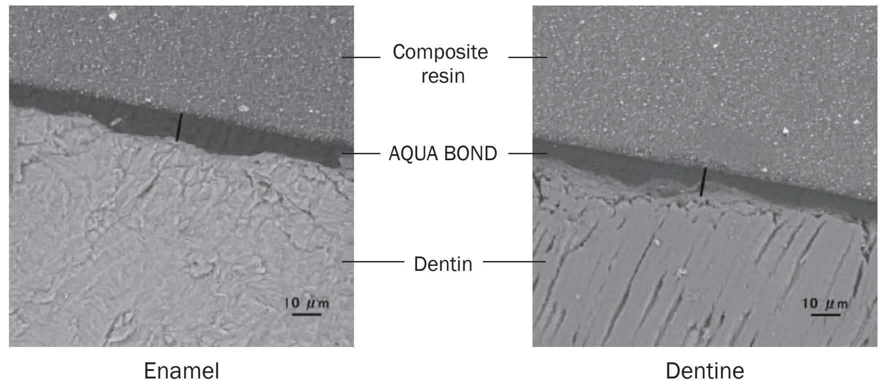


Figure 20 Adhesive interfaces

8. TMR series

In addition to "AQUA BOND", as of August 2018 the TMR series developed by YAMAKIN includes resin-based restorative material "TMR-Z Fill 10." (Z Fill) and the dental pulp-capping material "TMR-MTA cement Mielle" (MTA cement Mielle). This is a product series that serves the mission of "no extracting," " minimal grinding" and "preserving teeth," based on the MI concept.

Let us take pulp capping as an example. Pulp capping is an important procedure to protect the pulp and preserve the tooth. However, its success rate is low, and it is said that there are many cases in which extraction is chosen in order to avoid subsequent risk of infection. In order to solve such process gap to whatever extent possible, YAMAKIN has developed an innovative product that includes the functionality of the TMR series (Figure 21).

Thanks to their particular functions, the following products have a range of possibilities which we intend to pursue in the future: "MTA cement Mielle" has good sealing properties, exhibits excellent stability after setting, and promotes hard tissue formation, as recognized in experiments and in the academic literature, "AQUA BOND" adheres to "MTA cement Mielle" and allows CR filling immediately after the dental pulp protection achieved by "MTA cement Mielle" (the adhesion concept will be described later);, and "Z Fill" releases fluoride ions, and can be expected to strengthen tooth substance and inhibit bacteria adhesion.
We will conduct clinical verification in the future, and we plan to report our findings at academic conferences and in reports.

Figure 21 Innovation through the TMR Series

<Adhesion concept of "MTA cement Mielle" and AQUA BOND">
"MTA cement Mielle" is made into a paste by being mixed with water, and thus contains moisture. As a result, it is not a good match for hydrophobic bonding materials. However, "AQUA BOND" is hydrophilic, and it includes M-TEG-P (which displays amphiphilic properties) as an adhesive component. It is thus a good match, even though "MTA cement Mielle" contains water, and it is thought that it will closely adhere to irregularities of the cement surface (Figure 22).

It is known that phosphoric acid monomer is excellent in reactivity with zirconia[7-9], so it is thought that combining the zirconia contained as a radiographic agent in "MTA cement Mielle" and the phosphate group of M-TEG-P contained in "AQUA BOND" will work effectively for adhesion (Figure 23).

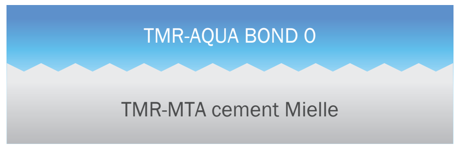


Figure 22 Image of interface

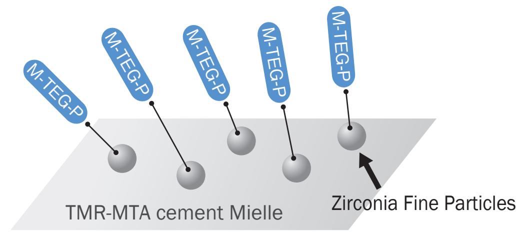


Figure 23 Combining M-TEG-P and Zirconia

Figure 24 shows the evaluation results for the adhesive strength of the system (TMR series) that adheres "Z Fill" to MTA Cement using "AQUA BOND". After being mixed with water, the paste is filled into a silicone mold, and air-dried (up to 30 seconds) 5 minutes after mixing; "AQUA BOND" is applied thereon, followed by air-drying and irradiation with light. "Z Fill (Flow)" is applied and irradiated with light; a stainless steel rod is fixed with resin cement as a test piece, and the tensile bond strength is measured one day later. As shown in Figure 24, a defined range of adhesive strengths has been confirmed by utilizing the TMR series, and it can be said that these are new values discovered in this combination.

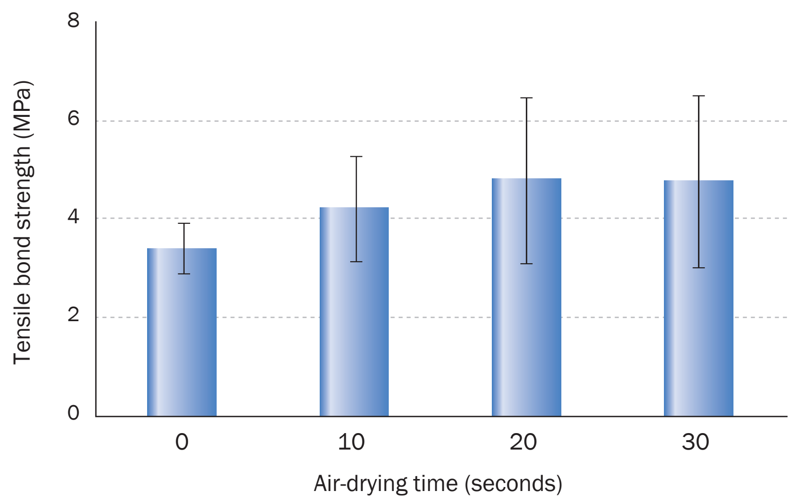


Figure 24 Adhesion by TMR series

9. Biological safety

The dental materials used in the oral cavity should be evaluated for any risk of adverse biological effect on the patient. This is called “biological safety evaluation”; it includes the evaluation of material risks for cytotoxicity, irritation, sensitization, genetic toxicity and so on. This section describes the cytotoxicity testing of "AQUA BOND" using the human monocytic leukemia cell line THP.1 cell (distributed by the Department of Oral and Maxillofacial Surgery, Kochi Medical School, Kochi University).

The test specimen was prepared as follows. "TWiNY" was filled into a mold with a diameter of 15 mm and a thickness of 1 mm, and then cured according to the manufacturer's instructions. Using "AQUA BOND" or our conventional product, we adhered two layers of "TWiNY" to prepare a test specimen. A reference material was prepared by overlapping two layers of "TWiNY" without adhesive (Figure 25).

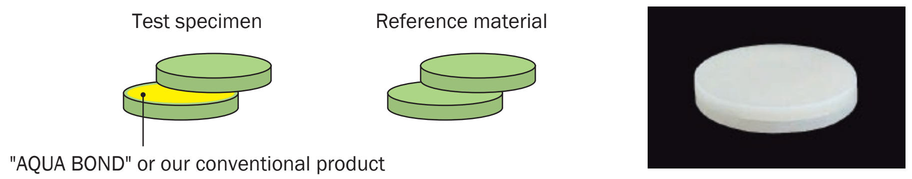
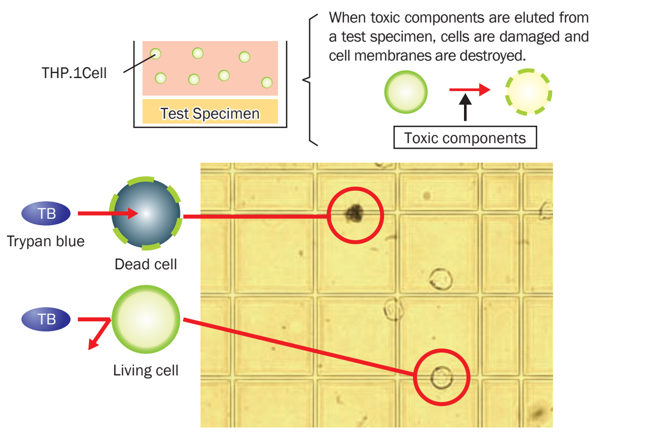


Figure 25 Test specimens for the cytotoxicity test

The test specimen was placed in a well of a 24-well plate. 100,000 THP.1 cells were seeded on the specimen, and cultured at 37 °C under 5% CO_2 for 3 days. The cultured cells were harvested and subjected to trypan blue dye exclusion test and WST - 8 cytotoxicity test.

Trypan blue-exclusion test [10]

As shown in Figure 26, when cells are cultured on material with cytotoxicity, the cytotoxic components destroy the cell membrane. Since cell membranes can exclude pigment compounds such as trypan blue, dead cells, whose membranes have been destroyed, are stained blue by trypan blue. On the other hand, living cells with cell membranes are not stained with this pigment. Therefore, counting the stained cells and non-stained cells can evaluate the effect of a test specimen on the viability of THP.1 cells.



Trypan blue is taken into the cell with destroyed cell membrane, and stains the cytoplasm.

Figure 26 Principle of Trypan blue exclusion test

Cells cultured on the test specimen were harvested, and then mixed with trypan blue. The number of living cells and dead cells in the mixture were counted with a hemocytometer. The cell viability was calculated from the proportion of living cells to total cells.

We have reported that the reference material "TWiNY" indicated excellent biocompatibility in this test [11]. Test specimens, which include "TWiNY" and dental adhesive ("AQUA BOND" or our conventional product), showed the equal cell viability to the reference material.

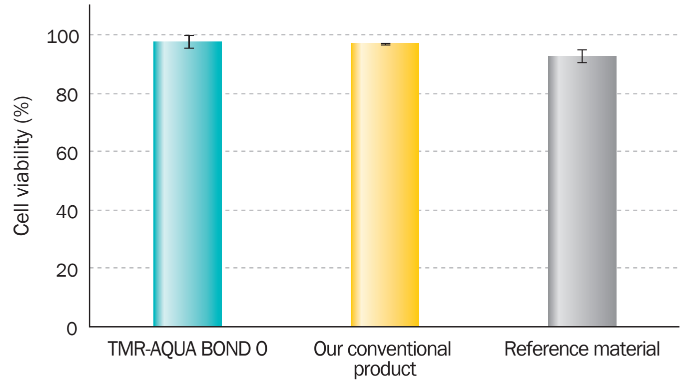


Figure 27 Influence of adhesive on viability of THP.1 cell

WST-8 Cytotoxicity test [12, 13]

In the WST-8 cytotoxicity test, the indicator WST-8 has been metabolized to orange-colored WST-8 formazan by living cells. Since absorbance of WST-8 formazan is determined at 450 nm, the influence of the test specimen on the metabolic activity of THP.1 cells can be evaluated by the measured absorbance.

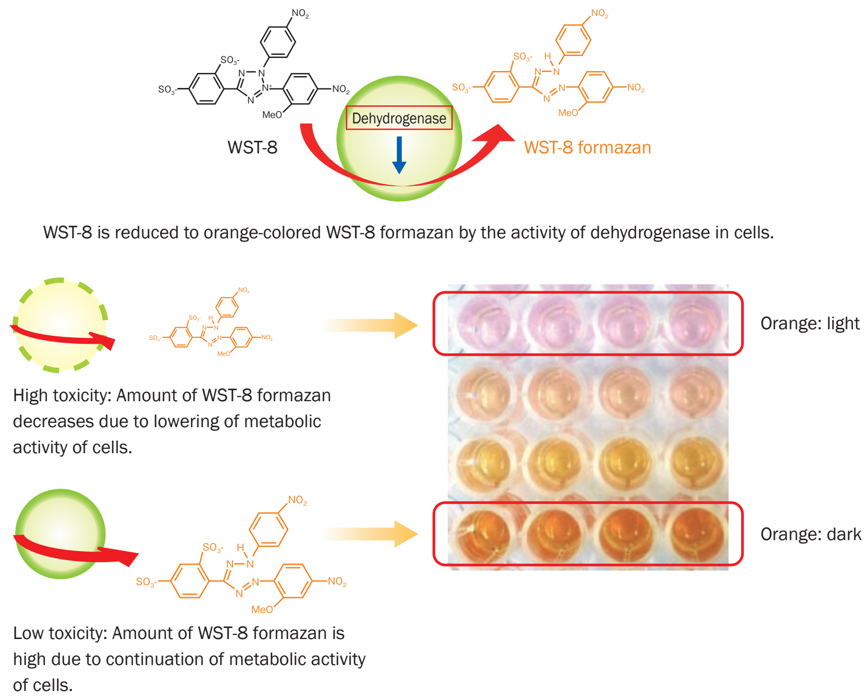


Figure 28 Principle of WST-8 Cytotoxicity test

Cells cultured on a test specimen were transferred to a well of a 96-well culture plate, and WST-8 reagent was then added to the well. After incubation at 37 °C for 2 hours, the absorbance of WST-8 formazan was measured at 450 nm. The metabolic activity of THP.1 cells cultured on the test specimen, which includes “AQUA BOND” or our conventional product, was equivalent to that of the reference material (Figure 29).

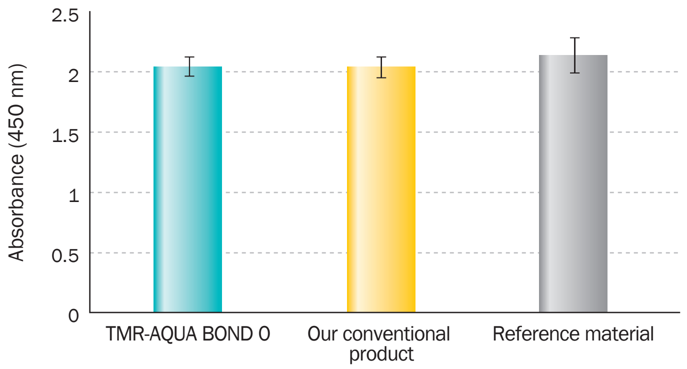


Figure 29 Influence of adhesive on metabolic activity of THP.1 cells

As mentioned above, the reference material "TWiNY" has excellent biocompatibility [11]. The addition of "AQUA BOND" or our conventional product to "TWiNY" showed no effect on the biocompatibility of "TWiNY" in the trypan blue dye exclusion test or the WST-8 cytotoxicity test. These results suggest that "AQUA BOND" is a safe product without non-acceptable cytotoxicity for biological tissue.

10. Conclusion

YAMAKIN focusses on water, which is indispensable in adhesion, and the relationship between water and adhesive, which greatly contributes to decrease in adhesion. We have developed an adhesive that can "make moisture work for us." The presence of the amphiphilic phosphate monomer M-TEG-P is the key, and by examining the composition that makes the best use of this monomer, we have succeeded in improving the functional efficiency of M-TEG-P. As a result, "AQUA BOND" exhibits higher adhesive strength to tooth substance than our conventional product, even though the demineralization time and polymerization time are shortened. For zirconia, titanium and various precious alloys, AQUA BOND can adhere even without primer, and in an adhesion system combined with Multi Primer, it can adhere with good reproducibility to resin material and porcelain.

As described above, "AQUA BOND" is a material that is easy to use and can be confidently proposed as a highly versatile adhesive. We would be pleased if you are interested in this report and use it in clinical cases.

The cytotoxicity test was carried out in collaborative research with the Department of Oral and Maxillofacial Surgery, Kochi Medical School, Kochi University.

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KZR-CAD Zr
Controlled Medical Device, Ziconia blank for dental milling and machining

KZR-CAD Ti
Controlled Medical Device, Dental titanium non-casting alloy

YP-GOLD TYPE 1-n
Controlled Medical Device, Dental casting gold alloy

UNI 1-n
Controlled Medical Device, Dental casting silver alloy

PALLAZ 12-n
Controlled Medical Device, Dental casting gold-silver-palladium alloy

KZR-CAD HR Block 3 GAMMATHETA
Controlled Medical Device, Resin material for dental milling and machining
CAD/CAM Crown material for molars

ZEO CE LIGHT
Controlled Medical Device, Metal ceramics for restorations

iGOS-BOND
Controlled Medical Device, Dental adhesive for coronal dentine
(Dental adhesive for dental ceramics) (Dental adhesive for dental metal)

Lineup

TMR AQUA BOND 0

Controlled medical device
- Dental Adhesive for Enamel and Dentine (Dental adhesive for ceramics) (Dental adhesive for metal)

Single Package TMR-AQUA BOND 0 (5 mL)

Set Package TMR-AQUA BOND 0 Set
・TMR-AQUA BOND 0 (5 mL) : 1pc.
・Disposable Applicator Brush : 50 pcs.
・Disposable Plate : 25 pcs.

Set Package 2 pcs Pack of TMR-AQUA BOND 0
・TMR-AQUA BOND 0 (5 mL) : 2pcs.

Accessory Disposable Applicator Brush : 50 pcs.
Disposable Plate : 50 pcs.

Related Products

TMR Z Fill 10.

Controlled medical device -Resin-based Dental Restorative Material

Single Package TMR-Z Fill10.
Universal 3.8g (2mL)

Single Package TMR-Z Fill10.
Flow 2.6g (1.5mL)
Accessory. Needle Tip: 10 pcs.

Single Package TMR-Z Fill10.
Low Flow 2.6g (1.5mL)
Accessory. Needle Tip: 10 pcs.

Set Package

Standard Pack (each 1 of A1, A2, A3, E)
・Universal
・Flow
・Low Flow
A1x1 / A2x1 / A3x1 / Enamelx1

2 pcs Pack (each 1 of A2, A3)
・Universal
・Flow
・Low Flow
A2x1 / A3x1

3 pcs of Same Shade Pack (Each 3pcs.of A2, A3, A3.5)
・Universal A2x3
・Flow A3x3
・Low Flow A3.5x3

Accessory Needle Tip: 20 pcs.

TMR MTA cement Mielle

Controlled medical device - Dental pulp capping material

Single Package
TMR-MTA cement Mielle (White, Light Ivory)
・Microtube Type (0.2g) : 3 pcs.

TMR-MTA cement Mielle (White, Light Ivory)
・Glass Container / Bottle Type (3g)
・Accessory: Spoon (1 pc.)

TMR-MTA cement Mielle (White, Light Ivory)
・Glass Container / Bottle Type (10g)
・Accessory: Spoon (1 pc.)

Multi Etchant

Controlled medical device
-Dental etching material (Adhesive material for dental ceramics)

Multi-use Etchant for
Various Types of Materials and Tooth

Single Package Multi Etchant (2mL)
Accessory : Needle tip 5 pcs.

Accessory Needle tips for Multi Etchant : 10 pcs.

Multi Primer LIQUID

Controlled medical device
- Bonding material for dental metal (dental ceramics, dental resin)

For intraoral repair of restorations
(metal, ceramics and resin)

Single Package Multi Primer LIQUID (7mL)

Manufactured by
YAMAKIN CO., LTD. 1090-3 Otani, Kamibun, Kagami-cho, Konan-shi, Kochi, 781-5451 Japan

The actual color of the product, model and package may differ from the photographs due to printing ink and shooting conditions.

We will continue to create value for the future.

Clean room in the YAMAKIN Kochi factory

All manufacturing processes are conducted in clean rooms and controlled extremely strictly.

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