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

KZR-CAD HR 3
GAMMATHETA

KZR-CAD HR BLOCK 3 GAMMATHETA
Product Report

A CAD/CAM BLOCK for Molars:
Carving out the Future of Dental Treatment

Edited by YAMAKIN Ph.D. Group

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Product Report

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1. Introduction

To support the digitalization of dental treatment, which has been progressing rapidly in recent years, YAMAKIN has researched and developed CAD/CAM milling materials such as “KZR-CAD Hybrid Resin BLOCK” and “KZR-CAD HR BLOCK 2” (BLOCK 2 for short). These products are applicable for each part of the oral cavity. In addition, YAMAKIN has completed the development of “KZR-CAD HR BLOCK 3 GAMMATHETA” (BLOCK 3 for short) by building on and improving the technology for BLOCK 2. “BLOCK 3” is a product which reflects YAMAKIN’s policy of “creating value” by closely coordinating products, technology, information, and services and providing value to all customers in the market. Also, it exhibits both high strength for hybrid resin blocks for CAD/CAM milling material and sustained fluoride release property, even though these have been considered difficult to achieve up to now.

On this occasion, we are issuing this product report to introduce the detailed product information and characteristics of BLOCK 3.
YAMAKIN will continuously collect information, accumulate clinical and examination records, and then we will proactively share the know-how gained through inspections, so as to offer patients enhanced dental treatment.
We hope this report will help dental professionals use Hybrid Resin BLOCK with confidence, and that it will contribute to the evolution of the dental field, however modestly.

Note: “Hybrid resin” in this report means “hybrid composite resin” which contains inorganic fillers (ceramics).
It is indicated as “hybrid ceramics” in our catalog and it is also called “composite resin” or “hybrid composite”.

2. What is the new product, KZR-CAD HR BLOCK 3 GAMMATHETA?

2.1 Product Concept

The product concepts of BLOCK 3 are: high flexural strength, excellent processability and polishability, the retention of BLOCK 2’s sustained fluoride release property, and the evolution of the technology. It has a tendency that the smaller the particle size is, the higher the strength becomes [1]. While BLOCK 2 contains fillers of approx. 4 µm, BLOCK 3 is intended to achieve higher strength by containing fillers of approx. 1 µm. (Figure 2)
Also, increasing the number of inorganic fillers improves the hardness, elastic modulus, compressive strength and flexural strength of resin materials which contain inorganic fillers as reinforcing material [2-4] . Long-Chain Spacer Silane Coupling Agent, with outstanding water resistance against filler surfaces, is used for the surface treatment of the inorganic fillers for BLOCK 3. This helps fillers stay highly filled and enhances integration with the resin matrix. (Figure 3) As a result, a greatly improved strength has been achieved for BLOCK 3, enough to allow it to be used on molars.

Figure 1. BLOCK 3 and Package

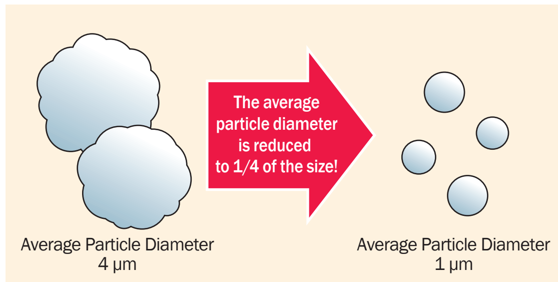


Figure 2. Average Particle Diameter

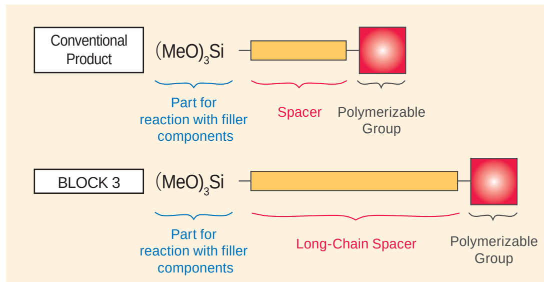


Figure 3. Silane Coupling Agent

Before Treatment

Forming an Abutment tooth

Cleaning the Abutment tooth
(Multi-Etchant: YAMAKIN)

Setting with Adhesive Resin Cement

After Setting BLOCK 3 #1

After Setting BLOCK 3 #2

Figure 4. Clinical Case: The Mandibular First Molar
(Onlay⟶ Jacket Crown: KZR-CAD HR BLOCK 3 GAMMATHETA)
(Contributed by: YAMAKITA DENTAL OFFICE (Kochi, Japan); Dr. Jun Kunito)

How BLOCK 3, GAMMATHETA Got Its Name

GAMMATHETA is named after "GAMMA," which means the number 3, and after "THETA (θ)," which is a symbol of various angles. We used these two words for the name, to mean "YAMAKIN's 3rd Hybrid Ceramics BLOCK for CAD/CAM milling machine, developed from various angles." The product was developed by examinations from various angles during basic research on replacing gold and palladium alloys with hybrid resin material.

2.2 Flexural Strength

The flexural strength was evaluated by three-point flexural testing in accordance with JDMAS 245: 2017 [5]. A test specimen of a size 4.0 mm×1.2 mm×14.0 mm was cut out from the hybrid resin block with a precision cutting machine (Accutom-50: Marumoto Struers K.K.) and the surface was finished with the water-resistant sandpaper P2000. The specimen was immersed in water at 37°C for 7 days, then, a three-point flexural test was carried out using a compact table-top tester, with a span of 12 mm and cross-head speed of 1 mm/min (EZ-Graph: SHIMADZU Corporation). For comparison, a specimen which was not immersed was also tested.

As Figure 6 shows, the flexural strength of BLOCK 3 was higher than BLOCK 2 by approx. 70 MPa (in increase of approx. 1.3 times) in both cases, with and without water immersion. The improved strength was confirmed in comparison with BLOCK 2. A high value of flexural strength, 270 MPa, was maintained even after 7 days of immersion in water; as a result, it sufficiently achieved 240 MPa, the requirement for use as a CAD/CAM crown on molars by JDMAS 245:2017.

Note: CAD/CAM crown means a crown which is fabricated by being milled from a hybrid resin block.
Note: JDMAS 245 : 2017 is a standard of hybrid resin blocks for dental milling and machining to fabricate CAD/CAM crowns for premolars and molars, established by Japan Dental Trade Association.

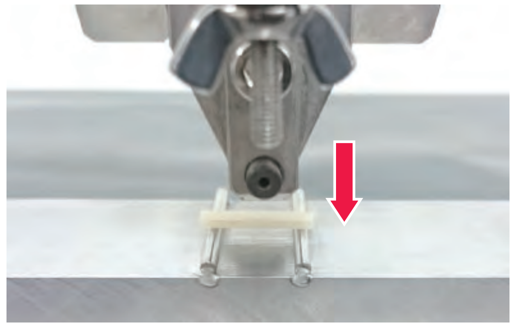
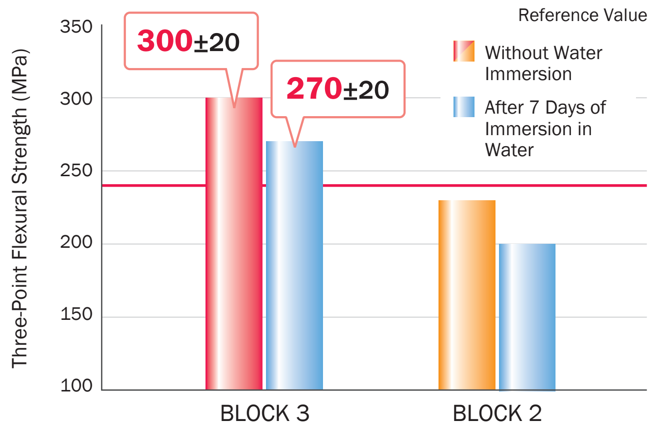


Figure 5. Three-Point Flexural Test



*JDMAS 245: 2017, Resin Material for CAD/CAM Crowns by Milling and Machining

Figure 6. Three-Point Flexural Strength

2.3 Breaking Strength

In considering the high load on CAD/CAM material for the molars, the highest load will be the maximum occlusal force. Occlusal force on the molars is reported in Table 1.

It is reported that the flexural strength of the hybrid resin block material decreased due to immersion in water, but that the decrease stabilized within one month[6]. When the safety of using CAD/CAM crowns for the molars is considered, a strength which withstands the 1,280 N of load given in Table 1 as the maximum occlusal force will be required.

CAD/CAM crowns were fabricated and a breaking test was carried out to confirm the strength of BLOCK 3 when it was used for the molars in practice, and to confirm changes in strength due to the thickness of CAD/CAM crown.

Table 1. Occlusal Force of Molars

Researcher (Publication year)	Subjects	Occlusal force of molars	
		Average value	Maximum value
Waltimo A, *et al.* [7] (1993)	15 males, 22 - 35 years old	847 N	870 N
Waltimo A, *et al.* [8] (1994)	7 males who grind their teeth at night (average age of 45 years)	911 N	1,150 N
Braun S, *et al.* [9] (1995)	80 males, 26-41 years old	814 N	1,280 N

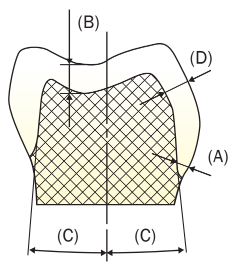
2. 3. 1 Breaking Test

2. 3. 1. 1 Conditions of Test

The distribution of the occlusal force loaded on each posterior tooth is shown in Table 2. The mandibular first molar on which the maximum occlusal force was loaded was tested as the subject. Titanium Gr.5 (KZR-CAD Titanium Disc Gr.5: YAMAKIN) for the abutment teeth and BLOCK 2 and BLOCK 3 for CAD/CAM crowns were used to fabricate three kinds of crowns based on the conditions for preparing abutment teeth as given in Figure 7. After setting on the abutment teeth, CAD/CAM crowns were left exposed to air for 24 hours or immersed in distilled water at 37 °C for one month. Both were tested as test specimens. (n=5)

Table 2. Occlusal Force of each Posterior Tooth [10]

		1st Premolar	2nd Premolar	1st Molar	2nd Molar
Upper	Average bilateral occlusal force (Kg)	41.08	49.24	65.43	60.85
Lower	Average bilateral occlusal force (Kg)	44.32	55.36	74.49	70.44



Specifications	Model #1	Model #2	Model #3
Thickness of Margin: (A)	1.0 mm and over	1.0 mm and over	1.5 mm and over
Thickness of Occlusal Surface: (B)	1.5 mm and over	2.0 mm and over	1.5 mm and over
Taper Degree of Axial Surface: (C)	6 Degrees		
Axial Surface: (D)	Multifaceted formation in order to achieve surface thickness of 1.5 mm and over		
Corners	R0.5 and over		
Margin Area	The whole circumference with R1.0 Chamfer		

Figure 7. Preparing the Abutment Teeth

2. 3. 1. 2 Preparing Abutment teeth for the Test

The model teeth of the mandibular first molar on the left for standard practice (A5-500: Nisshin) were processed in accordance with Figure 7; the models were scanned and 3D-modelled by C-pro Dental System D700-3SP (Panasonic Health Care), and then CAD models for processing were fabricated by PowerShape: AUTODESK. Abutment teeth for the test were fabricated with a dental machining center, V-22-5XB (MAKINO MILLING MACHINE CO., LTD.)

2. 3. 1. 3 Fabricating CAD/CAM Crowns for Tests

Crown CAD models were fabricated by double scanning of the model teeth of the mandibular first molar on the left for standard practice and abutment teeth were processed. Spaces for cement were 20 μm in the range of 2 mm from marginal line, 40 μm in the range of 2-3 mm, and 40 μm in the range of 3 mm and over. Crowns for tests were fabricated by a dental CAD/CAM milling machine (DWX-50: Roland DG Corporation).

2. 3. 1. 4 Setting CAD/CAM Crown

The abutment teeth and the surface of CAD/CAM crowns for adhesion were sand-blasted at pressures of 0.4 MPa and 0.2 MPa using alumina particles (50 μm).Then an ultrasonic cleaner was used to wash them, and they were then dried. A primer, Super Bond PZ Primer (Sun Medical Co., Ltd.) was applied on the inner surface of the CAD/CAM crowns as pretreatment for adhesion. After the application, abutment teeth and CAD/CAM crowns were set with an adhesive resin cement, Super BOND Bulk-mix (Sun Medical Co., Ltd.). Then 1 Kg of load was applied for 10 min as a test specimen. Excess cement was removed during the loading.

Test Method

The test specimen was set on a compact table-top tester (EZ-Graph: SHIMADZU Corporation) and a steel ball (ϕ8.0 mm) was set near a jig for loading and the center of the occlusal surface of the crown. (Figure 8) Load was applied at a cross-head speed of 0.5 mm/min in the direction of the tooth axis until the crown fractured. Maximum load at break was calculated and the value was regarded as the breaking strength. A transparent polyethylene sheet of 40 μm thick was inserted between the steel ball and the crown to spread the contact stresses uniformly.

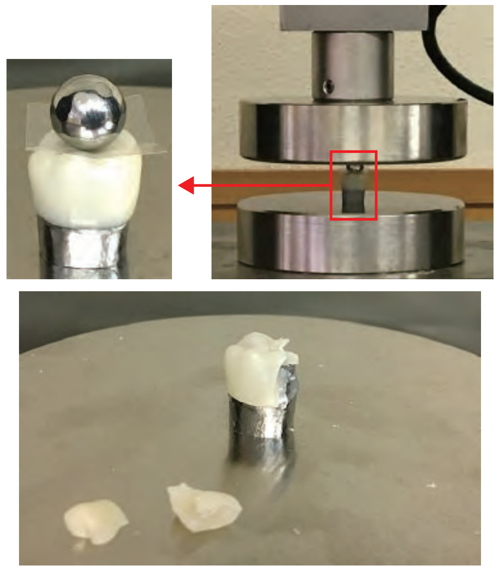


Figure 8. Breaking-Strength Test

2. 3. 2 Results and Discussion

The result of the breaking test is given in Figure 9. Model #1-3 of BLOCK 3 demonstrated a breaking strength approx. 1.6 times higher than BLOCK 2 on average. It is thought that the result was affected by differences of mechanical properties such as elastic modulus, bending strength and breaking energy, shown at material properties in 2.12. Breaking strength over 1,280 N was confirmed in each case of model #1, #2 and #3 with different condition of forming abutment tooth. This means that there is no strength problem in using BLOCK 3 for the molars.

To verify the effects on durability of materials by thickness of occlusal surface, the results of model #1 (1.5 mm) and model #2 (2.0 mm) were compared. In the case where BLOCK 3 was used, model #2 has a higher breaking strength($p<0.05$). In the case where BLOCK 2 was used, a significant difference ($p<0.05$) was not confirmed; however, the breaking strength had a tendency to be high. Therefore, it was confirmed that the thicker the occlusal surface crown, the higher the durability.

There was no significant difference between model #1 with 1.0 mm of margin and model #3 with 1.5 mm of margin. It is thought that the influence of difference of marginal thickness is minimal.

Models which 24 hours after setting and models after 30 days of immersion in water were compared and there was no significant difference in each condition of forming abutment tooth; as a result, it is confirmed that BLOCK 3 was a material which has high durability and less deterioration even in the condition of being kept in water.

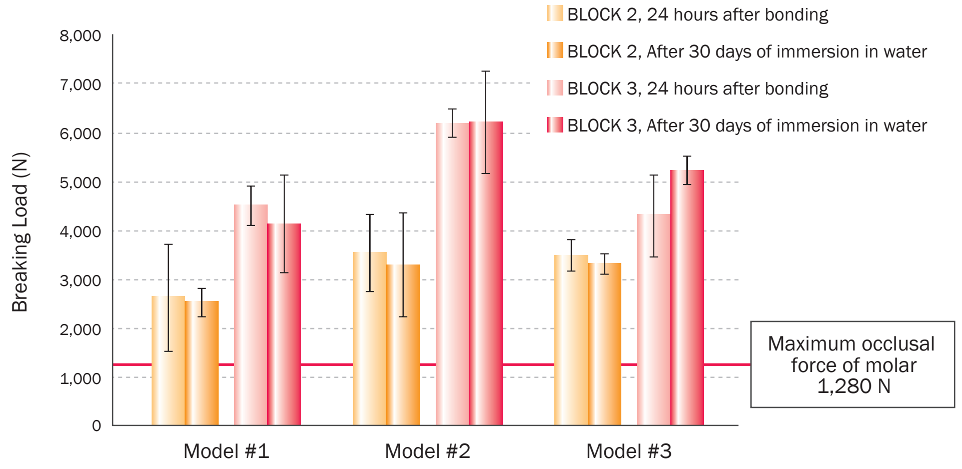
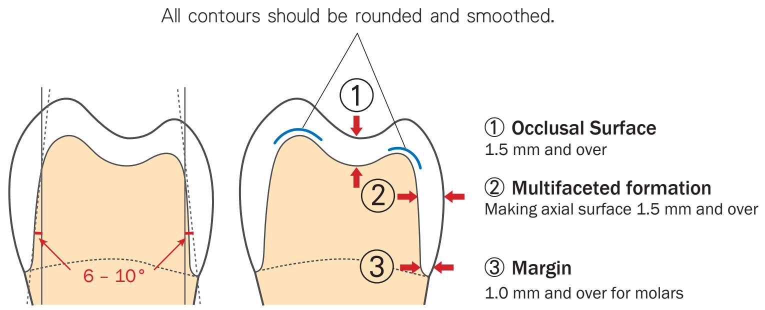


Figure 9. Result of Breaking-Strength Test

2. 3. 3 Forming an Abutment Tooth for Using a CAD/CAM Crown on Molars

The following conditions are recommended to form an abutment tooth for molars on the basis of the results of the breaking test on the altered CAD/CAM crown materials and models.



Note: Form with sufficient thickness depending on the case.

Figure 10. Cautions for Forming an Abutment Tooth for Molars

2. 3. 4 Summary

It was confirmed from the test results that the value of the breaking strength of both BLOCK 2 and BLOCK 3 was over 1,280 N under all conditions, and their use for molars will present no difficulties. Also, it was confirmed that BLOCK 3 has higher breaking strength than BLOCK 2 under all conditions.

2. 4 Bonding Strength

Hybrid resin blocks for CAD/CAM crowns are polymerized at a high temperature and high pressure; therefore, almost no monomer components for bonding remain. By contrast, YAMAKIN has reported that the more inorganic filler was filled in, the higher the tensile bonding strength of the hybrid resin block becomes [11]. The following steps are necessary to combine an inorganic filler part and adhesive resin cement:

Sand-blast the adhesion surface and expose inorganic fillers to increase adhesion area. Then, to combine adhesive resin cement and inorganic filler chemically, apply primer containing phosphoric acid monomer or silane coupling agent on the surface of the inorganic filler and change it into resin.

To verify the bonding strength of BLOCK 3, the tensile bonding strength was measured after bonding with resin cement on the market. (Table 3) Test specimens were prepared by cutting a hybrid resin block into 2-mm-thick slices, sanding the adhesive surface with sand-paper P1000, sand-blasting (0.2 MPa) with alumina particles (50 μm) for 6 sec., immersing it in alcohol solution, and cleaning with an ultrasonic cleaner. After that, surface treatment was performed in accordance with the instructions for each resin cement. To standardize the area to be adhered, masking tape with a hole of 3 mm in diameter was attached. Resin cement was applied on the adhesion area, and then a stainless steel rod was fixed. Diagram of the bonding test are given in Figure 11. Test specimens of BLOCK 2 were used for comparison.

Table 3. Adhesive Resin Cement for Ceramics Block

Brand	Sun Medical Co., Ltd.	3M Japan Limited	GC Corporation		Tokuyama Dental Corporation	SHOFU INC.	KURARAY NORITAKE DENTAL INC.
Adhesive Resin Cement	Super-Bond	RelyX™ Ultimate Adhesive Resin Cement	G-CEM LinkForce	G-CEM ONE	ESTECEM II	Block HC Cem	SA Routing® Plus
Primer, Bonding Agent	PZ PRIMER	Scotchbond™ Universal Adhesive	G-Multi PRIMER		BONDMER Lightless	Block HC Cem Primer	CLEARFIL™ Universal Bond Quick

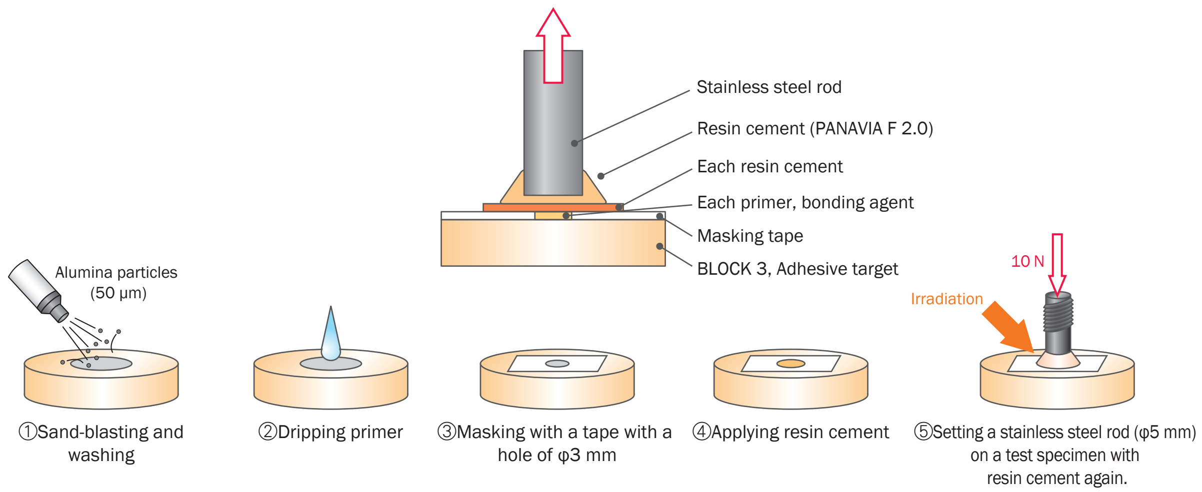


Figure 11. Diagram of the Bonding Test Method

The tensile test was conducted with cross-head speed of 0.5 mm/min using a compact table-top tester (EZ-Graph: SHIMADZU Corporation).

The tensile bond strength differed widely depending on the bonding system, as shown in Figure 12. Both BLOCK 2 and BLOCK 3 displayed this tendency. Since long-chain spacer silane coupling agent is used for the surface treatment of the inorganic fillers for BLOCK 3, fillers were filled at a higher rate than BLOCK 2; however, there was no influence on the adhesive property and the tensile bond strength of BLOCK 2 and BLOCK 3 were equal.

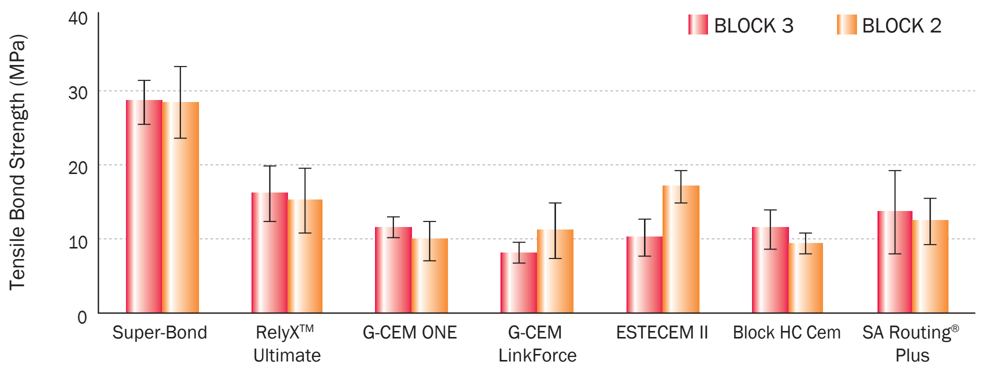


Figure 12. The Tensile Bond Strength of Resin Cement with BLOCK 2 and BLOCK 3

Desorption may occur not only at the interface between CAD/CAM crown and resin cement but also at the interface between abutment teeth and resin cement. Abutment teeth for CAD/CAM crowns will be formed by silver alloy or a natural tooth. As shown in Figure 13, the tensile bond strength between resin cement and silver alloy was confirmed at an average of 15 MPa and over, which is comparatively high, for all resin cements. By contrast, it was confirmed that the tensile bond strength with dentine was lower than silver alloy and the tensile bonding strength was about 16 MPa even for the resin cement with highest adhesive property as shown in Figure 14.

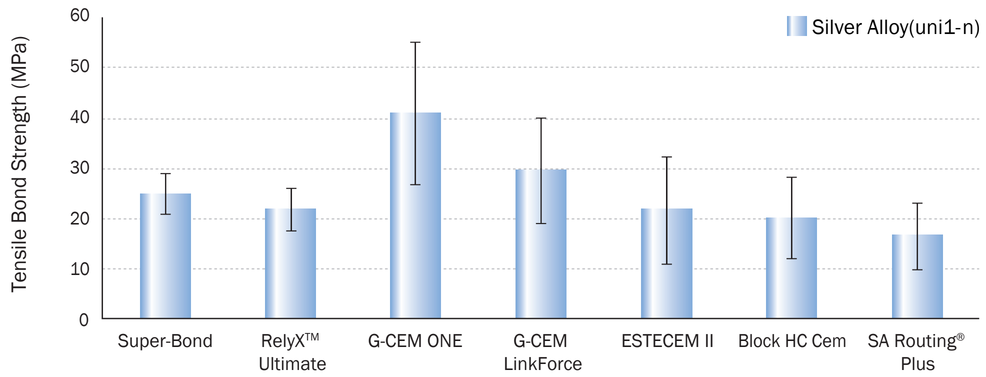


Figure 13. The Tensile Bond Strength of Resin Cement with Silver Alloy

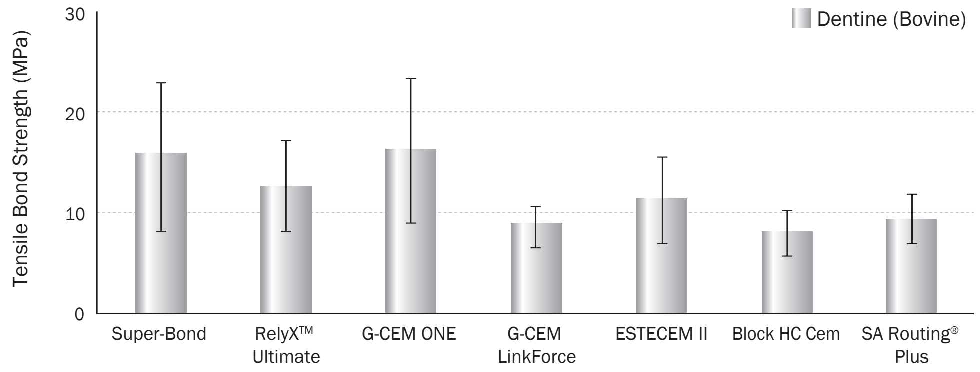


Figure 14. The Tensile Bond Strength of Resin Cement with Dentine

From the above results, it is considered that it is necessary to select resin cement taking into consideration not only the CAD/CAM crown but also the bonding strength with the abutment tooth.

The tensile bond strength of Super-Bond showed 15 MPa and over, and RelyXTM Ultimate, G-CEM ONE and ESTECEM II showed 10 MPa and over.

2. 5 Staining Resistance

In cases where the uncured layer is on the surface of the resin material, it tends to become stained and worn down [12]. As described above, BLOCK 3 is polymerized to a high degree at a high temperature and a high pressure; therefore, the uncured layer of BLOCK 3 is lesser than in light-cured resins such as indirect hybrid resin, and this will help to prevent the layer being stained by foods and drinks such as coffee, tea, wine, and curry. Stain resistance in BLOCK 3 was verified.

Pellets made of BLOCK 2 and BLOCK 3, with a diameter of 15 mm and a thickness of 1 mm, were prepared. Also, pellets made of bovine dentine and of bovine enamel, which were embedded in resin, were prepared. The exposed surfaces of the pellets were mirror-polished and used as test specimens. The test specimens were immersed in an aqueous solution of instant coffee or tea at 37 ºC and the colors were measured over time using a spectrophotometer (CM-3610d; KONICA MINOLTA JAPAN, INC.). The color differences (ΔE) were then calculated, and the colors were compared with those before the immersion. Before the measurement, each aqueous solution was rinsed off with distilled water.

As shown in Figure 15 and Figure 16, the color differences in bovine dentine and bovine enamel increased over time for both coffee and tea. By contrast, neither BLOCK 2 and BLOCK 3 changed significantly. Therefore, BLOCK 2 and BLOCK 3 have excellent staining resistance and do not tend to be stained. Long-term aesthetics are expected to be maintained.

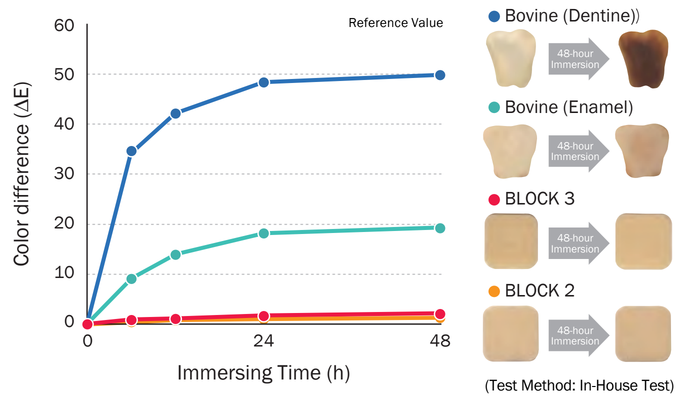


Figure 15. Evaluation of Staining Resistance by Coffee (5% Instant Coffee in Aqueous Solution [at 37 °C])

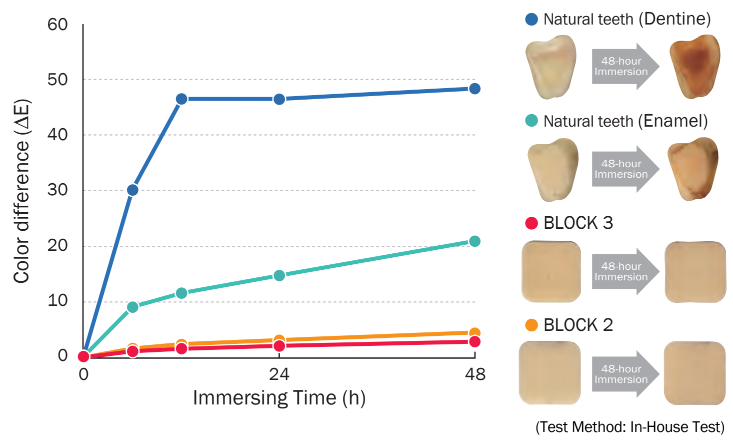


Figure 16. Evaluation of Staining Resistance by Tea (Tea [at 37 °C])

2. 6 Abrasion Resistance

Prostheses are worn away by occlusion: by repeatedly contacting the enamel of the opposite teeth, the balance of occlusion will be lost and occlusion may progressively worsen.[13] Therefore, the amount of wear from opposite teeth is an important element in application for the first molars, which have the greatest occlusal pressure in the oral cavity. An abrasion test of opposing tooth was conducted in order to evaluate abrasion resistance. As test specimens, BLOCK 3, and bovine enamel (320 HV)[15] – whose Vickers hardness is similar to natural tooth (300-350 HV)[14] – were used, along with indirect hybrid resin, porcelain and Zirconia. For this test, rod-shaped test specimens with hemispherical edges were made of each material and each specimen was tested by left-and-right slide (4 mm) at 1.7 times/sec., loading approx. 2 Kg of weight with an impact and abrasion tester (K655; TOKYO GIKEN, INC.). Before starting the test, the hemispherical edges were mirror-polished. The amount of wear of each test specimen and bovine enamel was measured with a surface-roughness measuring machine (SV-622; Mitutoyo Corporation) after 50,000 times sliding. As shown in Figure 17, it was found that BLOCK 3 was less likely to be worn away, to wear away the opposite teeth, and kept appropriate abrasion resistance in contrast to other materials which damage the opposite teeth; as a result, it is thought that the problems caused by losing occlusion balance are rendered less likely to occur.

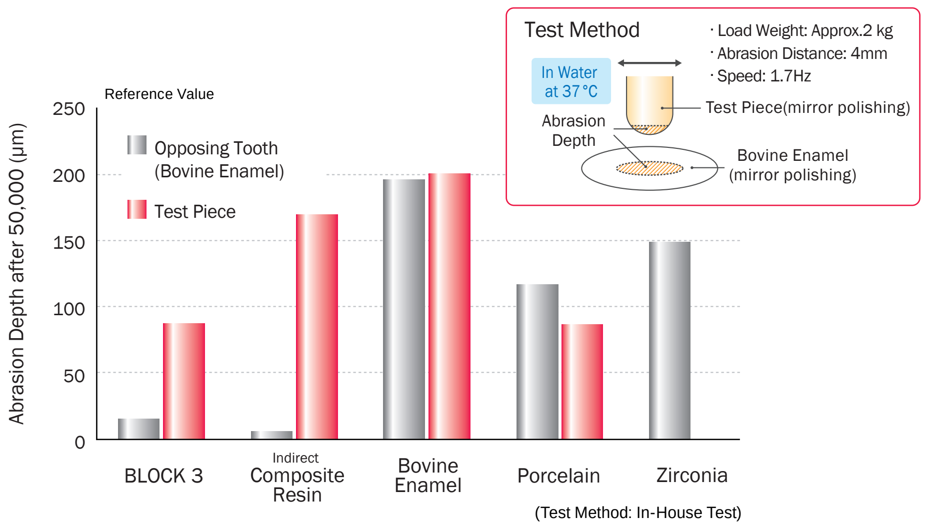


Figure 17. Abrasion Resistance

2. 7 Radiopacity and Fluorescence

In order to confirm the presence of second caries for follow-up after treatment, radiopacity is required. Therefore, the radiopacity was measured in accordance with JDMAS 245: 2017.

Test specimens with a thickness of 1 mm were cut out from a hybrid resin block (L size) with a precision cutting machine (Accutom–50; Marumoto Struers K.K.), and the surface was polished with P1000 waterproof abrasive paper. As shown in Figure 18, the test pieces were arranged alongside an aluminum step wedge which was equally spaced in steps of 0.5 mm in thickness, and placed in an X-ray film cassette on a lead sheet. The test specimens were irradiated with X-rays at a tube voltage of 65 kV with the distance between the X-ray film and the irradiated part being 400 mm. The irradiation time was set to be such that the optical density of the X-ray film in the vicinity of the test piece and step wedge after development was 1.5 to 2.0. After fixation of X-ray-film development, the optical density of each test specimen and of each step of the aluminum step wedge were measured using a photographic densitometer, and the thickness of aluminum in relation to the test specimens was calculated by the relation to the optical density.

The examination result of radiopacity is given in Figure19. The radiopacity of BLOCK 3 was equivalent to aluminum with a thickness of 2.2 mm and it showed higher radiopacity than BLOCK 2. This verification result matches the fact that inorganic fillers that have radiopacity are highly contained.

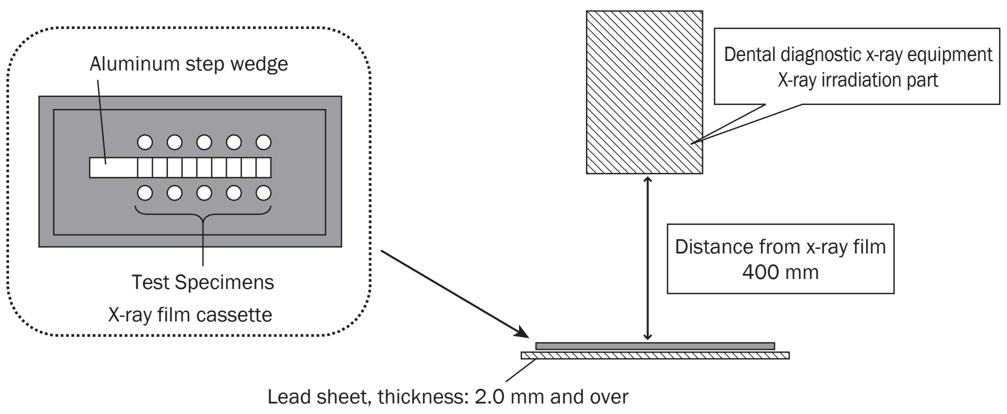


Figure 18. Diagram of Radiopacity Testing

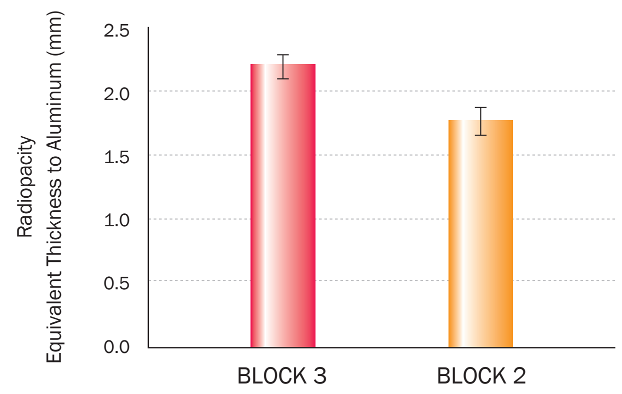


Figure 19. Radiopacity

CT scan picture for the mandibular first molar which were fabricated with hybrid resin blocks are shown in Figure 20. It is confirmed that BLOCK 3 has equivalent or more radiopacity than BLOCK 2. Also, pictures under irradiating black light are indicated in Figure 21. As BLOCK 3 has fluorescence which is similar to natural teeth in the same way as BLOCK 2, it has natural shade which will not be influenced by the light source.

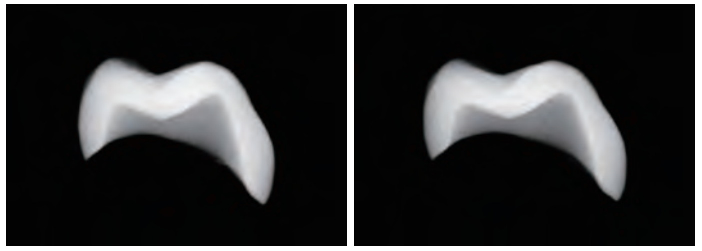


Figure 20. Radiopacity (Left: BLOCK 3, Right: BLOCK 2)

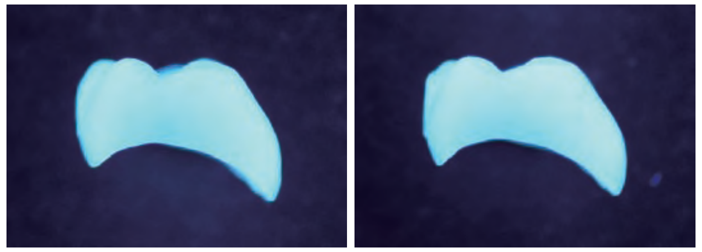


Figure 21. Fluorescence (Left: BLOCK 3, Right: BLOCK 2)

2. 8 Inhibition of Bacterial Adhesion

Fluoride has various effective functions to prevent caries such as antibacterial property [16], improvement of acid resistance of teeth [17], and remineralization action [18], and it is applied to various dental materials such as toothpaste.

We have reported that BLOCK 2, which has sustained fluoride ion release property, prevents adhesion of *Streptococcus mutans* (referred to below as "bacteria") We have also reported the role played by the sustained release of fluoride ions [19]. In this section, inhibition of bacterial adhesion on BLOCK 3, which has the similar fluoride ion sustained release property as BLOCK 2, and the involvement of fluoride ion in the inhibition of bacterial adhesion, were verified.

2. 8. 1 Test of Inhibition of Bacterial Adhesion

BLOCK 2, BLOCK 3, and commercial non fluoride releasing indirect hybrid resin (as reference material) were used in this experiment. Bacteria suspended in the sucrose-containing BHI culture medium were seeded to specimens and were cultured for 24 hours under aerobic conditions. After washing with PBS (-), WST-8 (colorimetric indicator for bacterial cell detection) [20, 21] was added and left for 2 hours; then the absorbance at 450 nm of WST formazan which was generated based on the metabolic activities of the bacteria remaining on the specimens was measured (Figure 22). In this test, the absorbance of antimicrobial material is decreased since the number of remaining bacteria after washing becomes lower; that is, the amount of generated WST formazan is decreased.

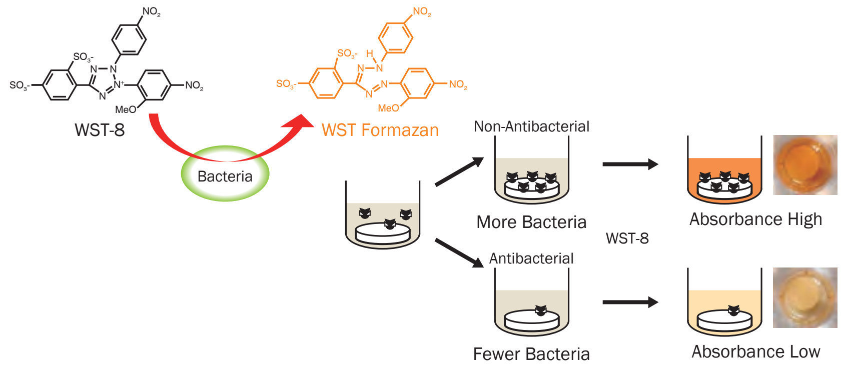


Figure 22. Measuring Remaining Bacteria with WST-8

Bacteria were cultured on each specimen and provided for this test. The absorbance of both BLOCK 2 and BLOCK 3 were significantly lower than that of indirect hybrid resin. (Figure 23) Significant differences in the absorbance between BLOCK 2 and BLOCK 3 were not confirmed. Thus, it was found that the bacterial adhesion-inhibition of BLOCK3 is equivalent to that of BLOCK 2.

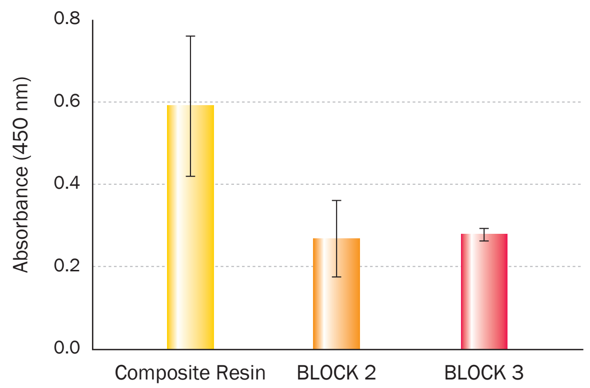


Figure 23. Inhibition of Bacterial Adhesion

2. 8. 2 The Relation between Concentration of Fluoride Ion and Inhibition of Bacterial Adhesion

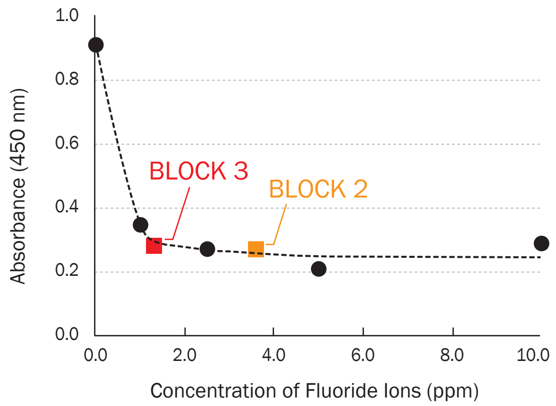


Figure 24. Concentration of Fluoride Ions (ppm)

After immersing each specimen in distilled water for 24 hours, fluoride ions concentration in the collected distilled water was measured with the ion meter (F-55; Horiba, Ltd.) (Figure 24). As a result, it was inferred that fluoride ions were released at 3.6 ppm from BLOCK 2 and at 1.3 ppm from BLOCK 3. Bacterial suspensions containing various concentrations of fluoride (0-10 ppm) were seeded on indirect hybrid resin to verify the influence of fluoride ions on the adhesion of bacteria to composite resin; a marked decrease in absorbance at a fluoride ion concentration of 1 ppm was then confirmed. In concentration ranges of 1 ppm and over, a slight decrease of absorbance was confirmed; however, it then plateaued and a trend was confirmed that inhibition of bacterial adhesion for BLOCK 2 and BLOCK 3 were equivalent, even though the amount of sustained fluoride ion release was less in BLOCK 3 than in BLOCK 2.

As elution of components from a material can lead to deterioration in the strength, it is desirable for the material design to keep sustained release of the component to the minimum and to exhibit antimicrobial activity to the maximum. BLOCK 2 has sustained fluoride ion release property and high strength. BLOCK 3 has inhibition of bacterial adhesion equivalent to BLOCK 2 and achieves higher durability and strength than BLOCK 2 by keeping elution of components under control.

2. 9 Processability

BLOCK 3 for the first molars has higher mechanical strength than BLOCK 2 for premolars. In this article, the effects of enhanced mechanical strength on processability were verified.

2. 9. 1 Evaluation of Processability by Penetration Test

1) Verification Contents

A hole was drilled with a constant load using a drilling machine, and the time required for penetration was measured.

2) Equipment and Materials

Drilling Machine: DP-250, TAKAGI

Drill: Straight drill SDD0200, Mitsubishi Materials Corporation

For milling hybrid resin blocks, instruments made of ultra-hard materials, with a higher degree of hardness than high-speed steel and coated by diamond, are often used. However, despite their hardness, ultra-hard materials tend to fracture when shocked or when excessive stress is applied. The drilling machine can be used for plastics or mild steel plates; however, a flexible instrument made of high-speed steel was chosen for use in this case, as the hardness of the block to be milled was high.

3) Verification Method

Penetration processing was conducted with a constant weight (130 g) weight attached to the handle of the drilling machine. The required time for penetration was measured and compared. 4 holes were drilled in each block in the order of A to D. This process was conducted with 3 blocks as 1 set. The drill was replaced at every set and the verification was done for a total of 3 sets.

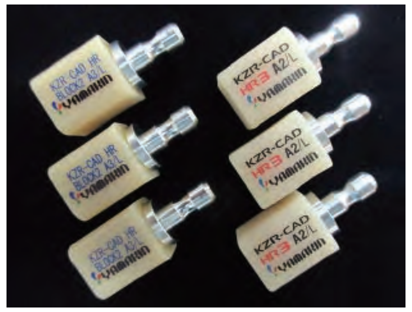


Figure 25. BLOCK 3 and BLOCK 2 for Verification

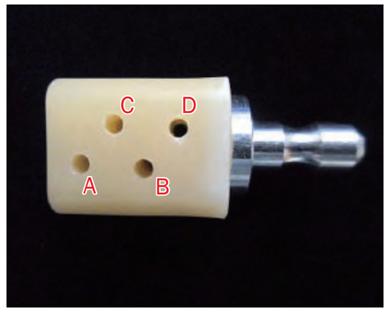


Figure 26. BLOCK 3 After Penetration Process

1. Set a block on the drilling machine (DP-250).

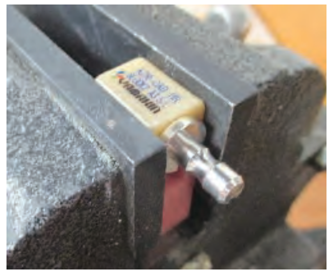


Figure 27. Block Set on the Drilling Machine

2. Place the static drill on the Block, then apply load with a weight attached to the handle.

Figure 28. Load on the Handle

Figure 29. The Block Being Drilled

3. Rotate the drill and mill the block. Since load is applied with the weight, when rotation starts, the handle goes down and milling process starts at the same time. The circumstances of penetration from start of drill rotation until the tip penetrated the block were recorded, and the required time was measured frame by frame.

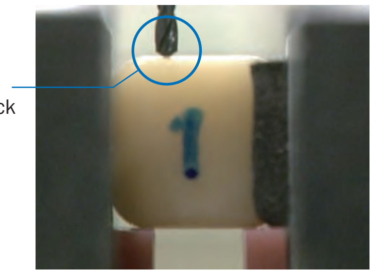


Figure 30. Condition Before Being Milled

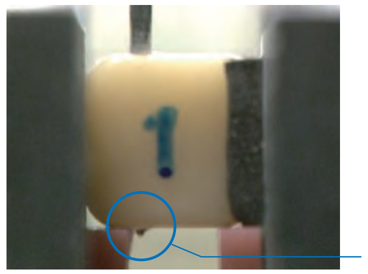


Figure 31. Condition After Penetration

4. Result

The time required to penetrate into each BLOCK is given in Table 4.

Table 4. Result of Required Time to Penetrate

Unit : Second

		BLOCK 3			BLOCK 2		
		1st Set	2nd Set	3rd set	1st Set	2nd Set	3rd set
1st Block	A	5.9	5.4	6.2	Fractured during test	Fractured during test	21.69
	B	26.3	12.5	11.8	Fractured during test	Fractured during test	23.23
	C	9.2	7.2	6.4	Fractured during test	Fractured during test	Fractured during test
	D	5.8	5.2	5.0	Fractured during test	Fractured during test	Fractured during test
2nd Block	A	6.0	6.4	5.4	Fractured during test	Fractured during test	29.20
	B	5.0	4.8	4.7	Fractured during test	Fractured during test	19.36
	C	5.5	5.1	4.9	Fractured during test	Fractured during test	Fractured during test
	D	5.1	5.1	4.7	Fractured during test	Fractured during test	Fractured during test
3rd Block	A	5.7	6.7	5.1	Fractured during test	Fractured during test	20.20
	B	4.9	4.8	4.4	Fractured during test	Fractured during test	18.86
	C	4.6	4.2	4.2	Fractured during test	Fractured during test	19.92
	D	4.2	3.9	4.1	Fractured during test	Fractured during test	23.07
Average		7.3	5.9	5.6	–	–	21.94

Note: The average value for BLOCK 2 was calculated using completed penetration times only.

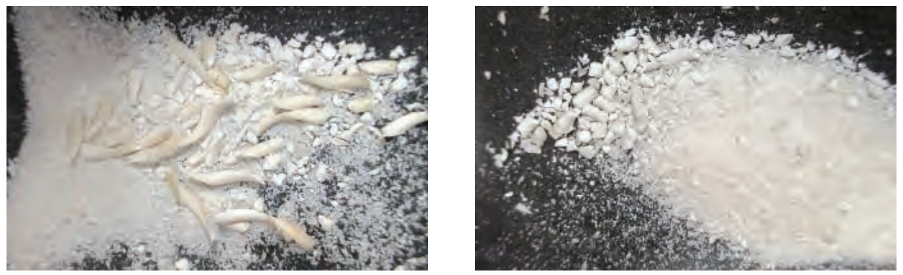
5. Discussion

The average time required to penetrate BLOCK 3 was around 6 sec.; 7.3 sec. for the 1st set, 5.9 sec. for the 2nd set, and 5.6 sec. for the 3rd set. Each of the 3 sets showed the same tendency in the progression of time required for penetration.

A longer time was required at point B of the 1st block in each set. The specific reason for this is not known, but it can be assumed that this was caused by a characteristic of initial wear of the new drill. In 12 times of penetration processing using a new drill, there was no confirmed increase in penetration time due to drill abrasion.

By contrast, in the penetration process of BLOCK 2, 8 out of 9 blocks fractured and measuring stopped during the process. The main cause of the high success rate of the 3rd set is not clear, but it can be assumed to be variations in the precision of the drill or the setting of the drill.

To investigate the reason of the fracture of BLOCK 2, a comparison was made with the circumstances of penetration of BLOCK 3. The initial speed of approach of the drill towards BLOCK 3 was fast and the speed slowed down just before penetration. By contrast, the initial speed of approach of the drill towards BLOCK 2 was fast; however, the speed became extremely slow after the drill entered into the block to some degree, and the drill sometimes did not penetrate further. Also, during the penetration process, large spiral chips and powder emerged successively from BLOCK 3. By contrast, chips of BLOCK 2 which were small and spiral, or powder came out only a little. (Figure 32)



BLOCK 3

Spiral chips were generated along the grooves of the drill and were discharged in response to the rotation.

BLOCK 2

There were spiral chips, but broke without shaping spirally. Fine powder was a lot, too.

Figure 32. Differences between Chips during Penetration Process

Because of this, chips of BLOCK 2 tend to accumulate in the grooves of the drill.
It can be assumed that the powder which could not be discharged, and which remained around the tip of the drill prevented cutting. This meant that the penetration process did not go ahead smoothly. Also, frictional heat was generated by keeping the blocks rotating at the same position, and it can be assumed that the blocks could not withstand the load, and fractured as a result.
It tends to be difficult for chips to be discharged in a penetration process by just lowering the drill vertically, as in this case, since there is no discharge outlet. However, in the actual processing of the block into the shape of a prosthetic appliance (such as the pocket processing, like the inner surface of the prosthesis), it is milled shallowly and widely instead of being machined deeply in a single operation. This means that chips are ejected more easily. Also, since chips are air-blown off at the tip of the milling bur, that the block will not be broken by chips during the milling process unless there is an extremely thin and deep point.
As a result, the processability of BLOCK 2 and BLOCK 3 could not be compared by the required time for penetration. However, as most chips of BLOCK 3 were spiral in shape, it is thought that BLOCK 3 has a characteristic which allows a cutting edge to be inserted easily, in contrast to BLOCK 2, whose chips do not tend to be spiral.

2. 9. 2 Comparison of Wear of Milling Burs in the Milling Process

1. Content of Verification
Milling was performed on BLOCK 2 and BLOCK 3 and the wear conditions of the milling bur was evaluated, along with the finished condition of the prostheses.

2. Equipment and Materials Used
Milling Machine: DWX-50 (Roland DG Corporation)
CAM Soft: WorkNC Dental (DataDesign Co., Ltd.)
Milling Bur: DG-LN-EBD R1×16 (OSG CORPORATION)
DG-LN-EBD R0.5×10 (OSG CORPORATION)
Material 1: BLOCK 3
Material 2: BLOCK 2
CCD Camera: 3D DigitalFine ScopeVC3000 (OMRON Corporation)

3. Verification Method
Eighty units each of BLOCK 2 and BLOCK 3 were milled and formed into single crowns using a new milling bur for each BLOCK. Two milling burs, DG-LN-EBD R1 (R1) and DG-LN-EBD R0.5 (R0.5) were used. To observe wear condition of the milling burs, new milling burs were used, and pictures of the milling burs were taken after every 10 millings. The single crown model used was maxillary right first premolar, and the finished condition was evaluated by observing the surfaces, and the fit with the model.

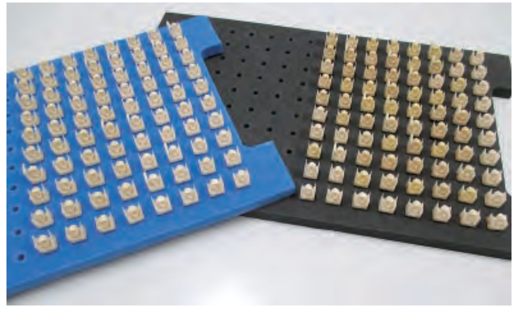


Figure 33. Milled BLOCKS

4. Verification Steps
1. Take a photo of milling bur before milling process with a CCD Camera.
2. Mill a block with DWX-50.
3. Take a photo of the milling bur every 10 millings of a block. Photos of the milling burs are taken a total of 9 times, starting from before the milling process to the 80th milling.
4. Evaluate condition of wear by observing the surface of the milling bur after photographing, and measuring the width of the cutting edge (Figure 34).

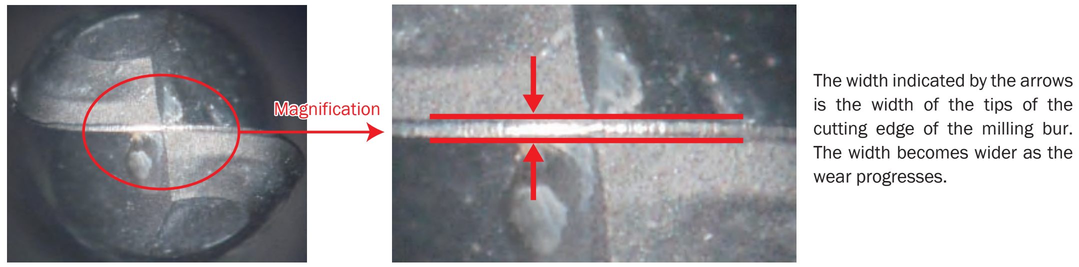


Figure 34. Evaluation Method of Wear of Milling Bur

5. Evaluate fitting condition between the prosthesis and the model, and the surface condition by photographing with a CCD camera under magnification (Figure 35).
Visually evaluate milling scars on the surface, and the gloss.
Set the prosthesis on the model and evaluate visually.

Visually evaluate milling scars on the surface, and the gloss. Set the prosthesis on the model and evaluate visually.

Figure 35. Evaluation Method of Prosthesis

5. Result

Results of milling process of each BLOCK are indicated in Figure 36 and 37.

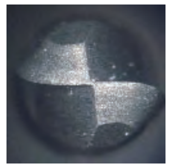
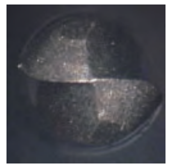
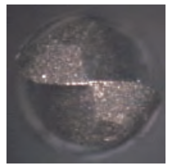
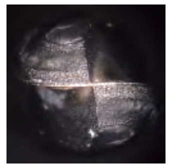
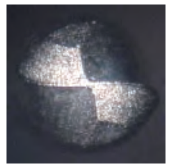
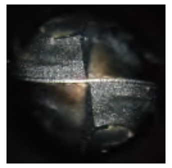
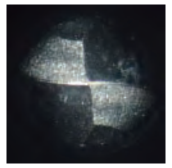
Material	BLOCK 3		BLOCK 2	
Milling Bur	R1	R0.5	R1	R0.5
Before Milling Process				
The width of Cutting Edge (µm)	9.6	9.6	11.5	10.4
The 40th Milling				
The width of Cutting Edge (µm)	16.3	11.5	18.1	12.4
The 80th Milling				
The width of Cutting Edge (µm)	21.1	12.4	20.5	12.4

Figure 36. Wearing Conditions of Milling Bur

Material	BLOCK 3		BLOCK 2	
Evaluation	Surface Condition	Fitting Condition	Surface Condition	Fitting Condition
1st Milling				
The 40th Milling				
The 80th Milling				

Figure 37. Conditions after Milling

6. Discussion

Wear of Milling Bur

The progress of wear of R1 was confirmed as the number of times of cutting increased for both BLOCK 2 and BLOCK 3. In the final comparison, the width of the cutting edge of the milling bur for BLOCK 3 became 11.5 μm wider than that of a new bur due to wear , while in the case of BLOCK 2, it became 9.0 μ m wider. The change to the cutting edge of R0.5 was smaller than that of R1 and there was little wear in either case. It is thought that this was because the milling program used on this occasion for R1 performed milling almost to the final shape, while R0.5 was used in its finished form, and thus required less work.

As a result, wearing of R1 was faster with BLOCK 3, but the wear of R0.5 was minimal for both BLOCKs . However, since the difference in the progress of wear was only 2.5 μm, it can be considered as a non-significant measurement variation; however, this could not be evaluated by a single verification. Also, the 81st process was carried out with the same R1 used for this verification and the chips were compared. Chips of BLOCK 2 were smaller and more powder was generated than for BLOCK 3, which produced bigger chips; thus, it is thought that the cutting edge cuts BLOCK 3 more appropriately.

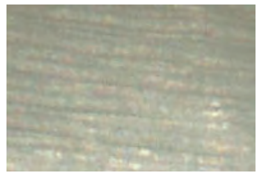
From these facts, even though the milling bur had slightly more wear with BLOCK 3, it is thought that the milling process for BLOCK 3 is carried out more appropriately. However, both milling burs are worn out normally, without diamond coating coming off , and they can be used continuously.

Condition of Prosthesis

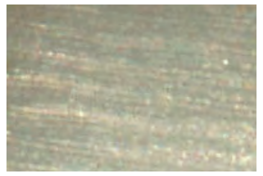
The 1st and the 40th BLOCK 3 pieces exhibited exceptionally good fit with the prosthetic appliances, but when the 80th was checked, scraping due to abrasion occurred and a small amount of clearance was confirmed near the margin tip on the buccal side. However, the scraping on the 80th can be easily fixed, and the fit is well within the required range. An almost identical tendency was confirmed for BLOCK 2 and there was no significant difference between the two.

Regarding the surface conditions of the prostheses, milling scars on the 1st BLOCK 3 piece could not be seen easily; however, scars with sharp edges on the 80th prosthesis could be seen easily. BLOCK 2 exhibited the same tendency. Also, milling scars made by R0.5, with almost uniform pitch and depth, were confirmed in the case of BLOCK 3. In the case of BLOCK 2, scraping made by R1 and milling scars made by R0.5 were confirmed. (Figure 38)

The first BLOCK 3



The 80th BLOCK 3



The 80th BLOCK 2

Figure 38. Comparing Milling Scars

Thus, when milling was conducted under the same conditions, a smoother surface and more uniform scars were confirmed for BLOCK 3. However, insofar as could be confirmed by a visual check, the finish was almost the same. Therefore, although there was a slight difference in the finish due to the difference in machinability caused by the characteristics of the BLOCKs, it can be said that BLOCK 3 can be used under the same conditions as those for BLOCK 2 in the processing of around 80 pcs.

2. 10 Polishability

The polishability of a ceramics block has a big influence on its work efficiency. A dental technician polished a model of the mandibular first molar, made of BLOCK 3, using polishing material containing alumina particles and polishing material containing diamond particles (C&B DIAMOND POLISHER and C&B NANO DIAMOND POLISHER). The required time to complete polishing was measured by visual evaluation.

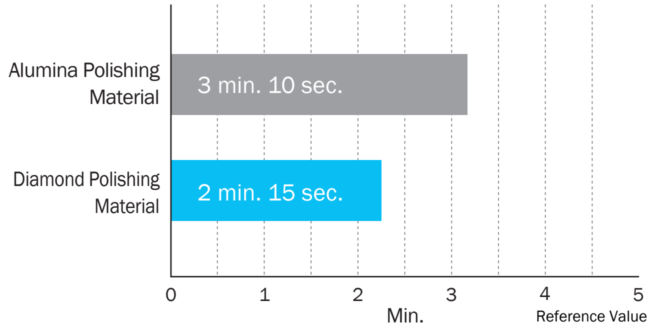


Figure 39. Time Required to Polish a Model of the Mandibular First Molar

Note: The data is from in-house testing and the values differ depending on the test conditions.
The surface is adjusted with a carborundum point and a silicon point after a milling process and the time required to complete polishing is measured.

As shown in Figure 39, BLOCK 3 can be polished with a polishing material containing alumina particles; however, smoother polishing is made possible by using polishing materials containing diamond particles (C&B DIAMOND POLISHER and C&B NANO DIAMOND POLISHER).

2. 11 Biological Safety

Various types of safety are required for dental materials, and evaluation of biological safety is required for any devices which come into contact with the human body even slightly. In the evaluation of biological safety, dental materials are categorized (as shown in Table 5) by the manner in which they come into contact with the body, such as surface contact, connecting the interior and exterior of the body, and being implanted in the body. They are also categorized by contact periods (e.g., 24 hours or less, 30 days or less, and over 30 days). The type of biological safety which should be considered for the evaluation of dental material is then determined by the categorization [22].

Table 5. Guidelines for Main Evaluation

Category	Nature of Body Contact	Duration of contact	Biological Test						
			Cytotoxicity	Sensitization	Irritation or Intracutaneous	Acute Systemic Toxicity	Sub-Acute (or Sub-Chronic) Systemic Toxicity	Genotoxicity	Implantation
Non-Contact Device		A: Limited (24 hours or less) B: Prolonged (over 24 hours to 30 days or less) C: Long-term (permanent) (Over 30 days)							
Surface Device	Skin	A	✓	✓	✓				
		B	✓	✓	✓				
		C	✓	✓	✓				
	Intraoral tissue (mucosa)	A	✓	✓	✓				
		B	✓	✓	✓				
		C	✓	✓	✓		✓	✓	
	Compromised surface	A	✓	✓	✓				
		B	✓	✓	✓				
		C	✓	✓	✓		✓	✓	
External communicating device	Tissue/Bone/ Teeth	A	✓	✓	✓				
		B	✓	✓	✓	✓	✓	✓	✓
		C	✓	✓	✓	✓	✓	✓	✓
Implant Device	Tissue/ Bone	A	✓	✓	✓				
		B	✓	✓	✓	✓	✓	✓	✓
		C	✓	✓	✓	✓	✓	✓	✓

Cytotoxicity has the potential to lead to toxicity in tissues and organs, and as a result, in individual organisms. Cytotoxicity test evaluates the biological safety of dental materials at the cell level, using cultured cells. If dental material will come into contact with the human body even slightly, the evaluation by cytotoxicity test must be taken into consideration. Various test methods are proposed in the international standard for *in vitro* cytotoxicity test of medical devices, ISO 10993-5: 2009 [23]. In Japan, colony-formation inhibition test using V79 cells (Chinese hamster lung-derived fibroblast) shown in Fig. 42 is recommended for its high sensitivity and abundance of comparative data. In this section, the evaluation of the cytotoxicity of BLOCK 3 by colony formation inhibition test are introduced.

Preparation of Test Solution

1.0 mL of cell culture medium (MO 5 medium) per 6 cm^2 of the surface area of the specimen was added and extraction was carried out at 37 °C for 24 hours. This extract was used as undiluted test solution (100%), and a dilution series of six concentrations in total, at 100, 50, 25, 12.5, 6.25, and 3.3%, was prepared using MO5 medium.

Colony formation inhibition test

50 cells (Figure. 40) were seeded in each well of 24-well culture plate and cultured in a CO_2 incubator for approximately 6 hours (5% CO_2 at 37 °C). After confirming the adhesion of the cells to the bottom of the wells, the cell culture medium was removed by aspiration and each test solution was added and cultured for 6 days. The 6-days cultured cells were fixed with a 10% formalin solution, stained with a 0.1% methylene blue solution, and colonies with 50 or more cells were counted. If cytotoxic components are not present, many cell colonies are formed, as shown in the diagram on the left of Figure 41. By contrast, if cytotoxic components are eluted from the dental material, the number of cell colonies decreases, as shown in the diagram on the right of Figure 41. The number of cell colonies when MO5 medium was used instead of the test solution was defined as the blank control and the number of cell colonies in the test solution was evaluated as the relative ratio to the blank control, that is, the colony formation ratio. Therefore, the lower the colony formation ratio from 100% (blank control) becomes, the higher the cytotoxicity of the sample.

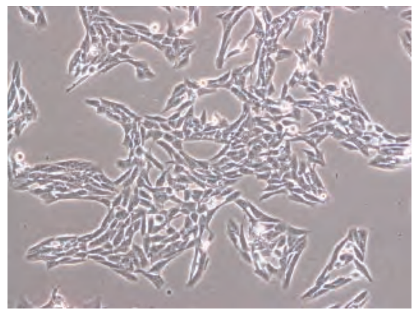


Figure 40. V79 cells

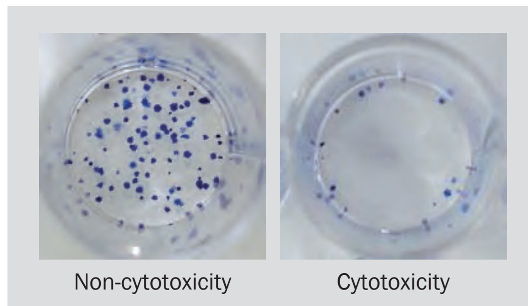


Figure 41. V79 cell colonies

In the colony formation inhibition test, all of the BLOCK 3-test solutions showed a cell colony formation ratio equivalent to that of the blank control; even in 100% concentration of the test stock solution, cell colony formation inhibition was not confirmed and it was revealed that BLOCK 3 did not have cytotoxicity. (Figure 42)

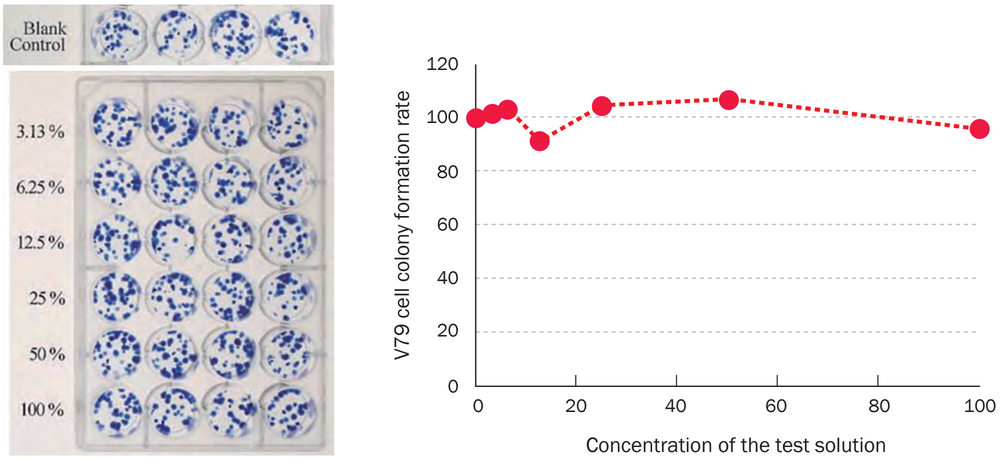


Figure 42. V79 cell colony formation of BLOCK 3

2. 12 Material Characteristics

The basic characteristics of BLOCK 2 and BLOCK 3 are shown in Table 6.

As described above, in particular the strength of BLOCK 3 was dramatically enhanced as compared with BLOCK 2. As mentioned in "2.1 Product Concept," this is largely attributable to the high filling rate of inorganic fillers by using the long-chain spacer silane coupling agent as the surface treatment agent for the inorganic fillers. Furthermore, water resistance (water absorption amount, dissolution amount) is also improved, and it is thought that it has high durability even in a humid environment such as in the oral cavity.

Table 6. Material Characteristics (Reference Values)

Item	Unit	BLOCK 3	BLOCK 2
Inorganic fillers containing rate	wt%	75	72
Vickers hardness*	HV0.2	90 ± 5	85 ± 5
Three-point flexural strength (Without water immersion)	MPa	300 ± 20	230 ± 10
Three-point flexural strength (After 7 days of immersion in water at 37°C)	MPa	270 ± 20	200 ± 10
Absorption amount	μg/mm³	17	25
Dissolution amount	μg/mm³	0.1	0.4
Sustained fluoride release	—	Yes	Yes
Radiopacity	—	Yes	Yes
Fluorescence	—	Yes	Yes
Polishing time (diamond polisher)	—	2min. 15sec.	1min. 45sec.
Alumina polisher	—	3min. 10sec.	2min. 15sec.

1) JDMAS 245: 2017 Resin Material for CAD/CAM Crown for Milling and Machining
The numerical values shown are reference values for prototypes and do not indicate product use.

3. Conclusion

It is thought that using CAD/CAM crowns for molars will remarkably enhance their aesthetics compared to traditional metal crowns. We hope that our newly developed product KZR-CAD HR BLOCK 3 GAMMATHETA will contribute to patients' QOL. KZR-CAD HR BLOCK 3 GAMMATHETA conforms to JDMAS 245: 2017 [5)]. Not only does it have high flexural strength, but it also has excellent processability and polishability, and in addition the sustained fluoride release property it has inherited from BLOCK 2 has evolved.

KZR-CAD HR BLOCK 3 GAMMATHETA is the fruit of our company's previous research and development, and it is a product which projects our corporate philosophy of "Creating Value by YAMAKIN." Although dental care is in the process of major change, we will continue to respond to such changes and strive more to develop products that customers find truly reliable, trustworthy and satisfying. We hope that we can help many dental care personnel and patients, regardless of where they may be, enjoy the benefits of various CAD/CAM materials, including hybrid resin block.

Supervision
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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.

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Technical Report on TWiNY (Jul. 2010)

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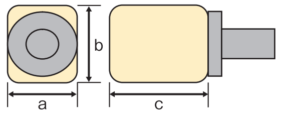
Hybrid Ceramics Block for CAD/CAM

Hybrid Ceramics Block for CAD/CAM

KZR-CAD HR 3 GAMMATHETA

Size



(a = Width, b = Depth, c = Height, Unit : mm)

Size		
S (a10, b12, c15)	M (a12, b14, c18)	L (a14.5, b14.5, c18)

Material Properties (Reference Value)

Three-Point Flexural Strength(MPa)		Vickers hardness* (HV0.2)	Radiopacity and Fluorescence	Sustained Fluoride Release
Without Water Immersion	After 7 Days of Immersion* in Water			
300 ± 20	270 ± 20	90 ± 5	✓	✓

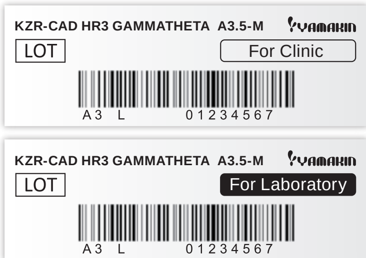
*JDMAS 245: 2017

Note: The figures given are for reference purposes and are not specifications.

Shade	QTY per box	Size		
		S	M	L
			1 notch	
A2	1 pc		✓	✓
A3				
A3.5				
A2	5 pcs		✓	✓
A3				
A3.5				

Traceability Sticker

Traceability stickers for each clinic and laboratory are enclosed with each block.
Lot number, shade, and size are indicated on the sticker.



The traceability sticker, actual size

Related Products

Polisher containing diamond particles

C&B DIAMOND POLISHER

NET. 8g

Polisher containing diamond particles

C&B NANO DIAMOND POLISHER

NET. 5g

Recommended for use of
KZR-CAD HR BLOCK 3, GAMMATHETA

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

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

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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