Abstract: The purpose of this study was to evaluate the surface properties and gloss of CAD/CAM composites after toothbrush abrasion testing. Four CAD/CAM composites for molars (Cerasmart 300, Estelite P block, Katana Avencia P block, and KZR-CAD HR3 Gammatheta), one CAD/CAM composite for premolars (Shofu Block HC Hard), and one feldspathic ceramics (Vitablocs Mark II) were assessed. Knoop hardness number, gloss, and surface roughness (Ra, Rz, and Sa) were measured before and after toothbrush abrasion testing. Knoop hardness number values were in the order Vitablocs Mark II > Katana Avencia P block > Estelite P Block > Shofu Block HC Hard > Cerasmart 300 > KZR-CAD HR3 Gammatheta. After testing, the gloss of Estelite P block and KZR-CAD HR3 Gammatheta was greatly decreased and surface roughness was greatly increased. Periodic recall and re-polishing may thus be necessary when these products are used clinically.

Keywords: CAD/CAM materials; composite; gloss; mechanical property; surface roughness; toothbrush abrasion.

Introduction

Computer-aided design and computer-aided manufacturing (CAD/CAM) technology was first used in dentistry in the late 1970s, and advances in digital impression technology and manufacturing processes have made it essential in modern clinical dentistry (1-8). Dental CAD/CAM enables implementation of traceability in production lines, stable production of dental prostheses by means of consistent machining of homogeneous materials, decreased production times, and repeated production. CAD/CAM materials used in restorations include ceramics and resin composites. Metal-free restorative procedures using such materials are in great demand in applications that accommodate the aesthetic requirements of patients, in reducing the use of increasingly expensive precious metals, and as an alternative option for patients with metal allergies (9).

Otto and Mormann reported satisfactory clinical durability for CAD/CAM ceramic crowns (10), but few reports have evaluated the clinical behavior of CAD/CAM composite crowns. CAD/CAM composite is polymerized and formed into a block shape in advance at the factory, which results in less monomer residue...
and enables a higher filler content, thereby improving strength (11-14). Materials used in dental prostheses should be nontoxic but strong enough to avoid abrasion in the oral cavity. They must also minimize plaque adhesion and be physically and chemically stable, to prevent decomposition and discoloration. Finally, they must satisfy patient aesthetic requirements. The criteria for gloss and surface roughness of composites were previously reported (15-17).

New CAD/CAM composites for molars have recently been developed. However, few studies have assessed the physical properties of CAD/CAM composites in molars. In addition, gloss and surface roughness of these composites after toothbrush abrasion have not been adequately investigated. This study evaluated gloss and surface roughness of CAD/CAM composites for molars, before and after toothbrush abrasion testing.

**Materials and Methods**

**Specimen preparation**

Four CAD/CAM composite blocks for molars, one CAD/CAM composite block for premolars, and one CAD/CAM feldspathic ceramic were used in this study. The product names, manufacturers, abbreviations, and compositions are shown in Table 1. A diamond disk (IsoMet, Buehler, Lake Bluff, IL, USA) was used to create seven plate-shaped specimens (thickness, 2.5 mm) from each block. All specimens were wet-ground with a series of silicon carbide papers, after which they underwent mirror finishing with a diamond suspension (3 μm and 1 μm, MetaDi, Buehler) and wet felt cloth (TexMet 1500, Buehler). After polishing, specimens underwent ultrasonic cleaning for 10 min in distilled water and were stored at 37°C in water for 24 h.

**Knoop hardness number**

Before the toothbrush abrasion test, a microhardness tester (HMV-1, Shimadzu Corp., Kyoto, Japan) was used to measure Knoop hardness number (KHN) during a period of 5 s at a load of 490.3 mN. Seven specimens were tested for each CAD/CAM block.

**Toothbrush abrasion test**

After measuring KHN, the toothbrush abrasion test was performed in accordance with the method of Koizumi et al. (18). A Stroke-type abrasion tester was used to perform the test with a vertical load of 3.4 N at approximately 2.5 Hz for 20,000 strokes. Seven plate-shaped specimens from each CAD/CAM block were tested.

**Surface roughness and gloss measurements**

Gloss and surface roughness were measured before and after the toothbrush abrasion test, in accordance with the method of Koizumi et al. (18). The angle of reflection of the gloss meter was 60 degrees (16-18). In addition, a laser microscope (1LM21W, Lasertec Corp., Yokohama, Japan) was used to determine Sa, a measure of surface roughness.

**Scanning electron microscopic observation**

After the toothbrush abrasion test, the surfaces of specimens were sputter coated with gold and observed with a scanning electron microscope (S-4500, Hitachi High-Technologies, Tokyo, Japan) at an accelerating voltage of 15 kV and 1,000× magnification.

**Statistical analysis**

Results that showed a normal distribution on the Kolmogorov-Smirnov test (SPSS Ver. 19, IBM, Somers, NY, USA) were analyzed for homoscedasticity with

### Table 1 Materials assessed

| Material/Trade name                  | Abbr. | Manufacturer      | Lot number | Composition                                                                 |
|--------------------------------------|-------|-------------------|------------|-----------------------------------------------------------------------------|
| CAD/CAM ceramic block (control)      |       |                   |            | Monochromatic feldspathic ceramics                                           |
| Vitablocs Mark II A3C                | VMII  | VITA Zahnfabrik   | 62670      | UDMA, barium glass                                                          |
| CAD/CAM composites block for molars  |       |                   |            | UDMA, barium glass, silica-zirconia filler, pigments, others                |
| Cerasmart 300 A3-LT                  | CS3   | GC Corp.          | 1710161    | UDMA, NPGDMA, silica, barium glass                                          |
| Estelite P Block A3-LT               | ESP   | Tokuyama Dental Corp. | 001038     | UDMA, Bis-MPEPP, NPGDMA, silica, pigments, others                           |
| Katana Avencia P block A3-LT         | KAP   | Kuraray Noritake Dental Inc. | 000005 | UDMA, barium glass                                                        |
| KZR-CAD HR3 Gammatheta A3            | KZR   | YAMAKIN Co., LTD. | 01021814   | UDMA, DEDGMA, SiO2-Al2O3-ZrO2 SiO2                                          |
| CAD/CAM composites block for premolars | SHH  | Shofu Inc.         | 817676     | UDMA, urethane diacrylate, zirconium silicate, silicate particles, pigments, others |

UDMA: urethane dimethacrylate; Bis-MPEPP: 2,2-Bis(4-methacryloyloxypropoxyphenyl)propane; NPGDMA: neopentyl glycol dimethacrylate; DEGDMA: diethylene glycol dimethacrylate. *J J Dent Mater 37, 131-146, 2018.; **Adhes Dent 36, 36-38, 2018.
When results in one or more categories did not show homoscedasticity, they were analyzed with the nonparametric Kruskal-Wallis test. The Steel-Dwass test for multiple comparisons (Kyplot 5.0, KyensLab Inc., Tokyo, Japan) was used in accordance with the results of the Kruskal-Wallis test. In addition, the Mann-Whitney U test (Kyplot 5.0) was used to evaluate differences between values before and after the toothbrush abrasion test. A $P$ value of less than 0.05 was considered to indicate statistical significance.

**Results**

Table 2 shows the results of KHN measurements. Median KHN ranged from 76.8 to 599.8. The results of multiple comparisons showed a significant difference between all specimens. Among resin composites, KAP had the highest KHN, 127.0.

The results of gloss measurements, in gloss units (GU), are summarized in Table 3. Median GU ranged from 88.8 to 95.0 before and from 35.3 to 81.0 after testing. Before testing, multiple comparisons revealed that the GU value for VMII was significantly higher than those for the other materials; however, there were no significant differences among VMII, KAP, and SHH after testing (category d). The median GU values for ESP and KZR were lower than 70 (category f) and were significantly lower than the values for the other materials. GU values for all materials were significantly lower after testing.

Table 4 summarizes Ra results before and after the toothbrush abrasion test. Median Ra ranged from 0.008 to 0.014 before testing and from 0.055 to 0.632 after testing. Before testing, multiple comparisons revealed that the GU value for VMII was significantly higher than those for the other materials; however, there were no significant differences among VMII, KAP, and SHH after testing (category d). The median GU values for ESP and KZR were lower than 70 (category f) and were significantly lower than the values for the other materials. GU values for all materials were significantly lower after testing.

Table 2  Knoop hardness number (KHN) test results

|          | Median | IQR  |
|----------|--------|------|
| Vitablocs Mark II | 599.8* | 10.5 |
| Katana Avencia P Block | 127.0* | 4.2  |
| Estelite P Block | 113.2* | 1.9  |
| Shofu Block HC Hard | 93.6* | 0.9  |
| Cerasmart 300 | 81.3* | 6.3  |
| KZR-CAD HR3 Gammatheta | 76.8* | 1.9  |

$n = 7$. IQR: interquartile range. Statistical category identical superscript capital letters indicate that values are not significantly different (Steel-Dwass test for multiple comparisons, $P > 0.05$).

Table 3  Gloss, in gloss units (GU), before and after toothbrush abrasion testing

| GU               | Before | After | M-W |
|------------------|--------|-------|-----|
|                  | Median | IQR  | Median | IQR  |
| Vitablocs Mark II | 95.0*  | 0.5   | 81.0*  | 2.0  |
| Katana Avencia P block | 89.5*  | 2.1   | 75.4*  | 7.5  |
| Shofu Block HC Hard | 91.4*  | 0.4   | 75.6*  | 3.0  |
| Cerasmart 300     | 90.7*  | 2.3   | 65.9*  | 14.6 |
| Estelite P Block  | 92.4*  | 1.6   | 34.7*  | 12.0 |
| KZR-CAD HR3 Gammatheta | 88.8*  | 0.9   | 35.3*  | 7.6  |

$n = 7$. IQR: interquartile range. Statistical category identical superscript letters indicate that values are not significantly different (Steel-Dwass test for multiple comparisons, $P > 0.05$). M-W, “S” indicates a significant difference between values before and after toothbrush abrasion testing (Mann-Whitney U test; $P < 0.05$).

Table 4  Ra before and after toothbrush abrasion testing

| Ra (μm)          | Before | After | M-W |
|------------------|--------|-------|-----|
|                  | Median | IQR  | Median | IQR  |
| Vitablocs Mark II | 0.008* | 0.001 | 0.055* | 0.007 | S |
| Shofu Block HC Hard | 0.009* | 0.001 | 0.117* | 0.072 | S |
| Katana Avencia P block | 0.014* | 0.001 | 0.235* | 0.138 | S |
| Estelite P Block  | 0.014* | 0.001 | 0.276* | 0.068 | S |
| Cerasmart 300     | 0.009* | 0.001 | 0.322* | 0.292 | S |
| KZR-CAD HR3 Gammatheta | 0.009* | 0.001 | 0.632* | 0.219 | S |

$n = 7$. IQR: interquartile range. Statistical category identical superscript letters indicate that values are not significantly different (Steel-Dwass test for multiple comparisons, $P > 0.05$). M-W, “S” indicates a significant difference between values before and after toothbrush abrasion testing (Mann-Whitney U test; $P < 0.05$).
significantly higher for CS3 and KZR than for VMII (categories d and f). Ra was significantly higher for all materials after testing.

Rz results before and after the toothbrush abrasion test are shown in Table 5. Median Rz varied from 0.094 to 0.105 before testing and from 0.882 to 2.087 after testing. As with Ra, the results of multiple comparisons showed no significant differences among VMII, CS3, and KZR before testing (category a). After testing, SHH and VMII were not significantly different (category d), but Rz was higher for CS3 and KZR than for VMII (categories d and f). Rz was significantly higher for all materials after testing.

Table 6 shows Sa values before and after the toothbrush abrasion test. Median Sa before testing was between 0.210 and 0.268. The results of multiple comparisons showed no significant differences among the materials (category a). In contrast, after testing, Sa values were significantly higher for all materials other than KAP than for VMII (categories e and f). Only the Sa for VMII did not significantly change after testing.

Figure 1 shows SEM images of the surfaces of specimens after the toothbrush abrasion test. The surface of VMII was smooth and glossy (Fig. 1A), but the surfaces of CS3, ESP, and KZR showed loose fillers and scratch marks (Fig. 1D-F); SHH showed spherical fillers (Fig. 1C).

Discussion

This study evaluated one type of CAD/CAM composite block for premolars and four types of CAD/CAM composite blocks for molars. The April 2014 revision of medical fees in Japan made CAD/CAM-fabricated composite crowns for premolars eligible for insurance coverage, while the April 2016 revision made CAD/CAM-fabricated composite crowns for molars eligible for insurance coverage for patients with metal allergies caused by metals in dental crowns. In December 2017, insurance coverage was extended to CAD/CAM-fabricated composite crowns for mandibular first molars in patients with four second molars and occlusal support. To be eligible for insurance coverage, CAD/CAM composite blocks used for premolars must have at least 60% total inorganic fillers, while those used for molars must have at least 70% total inorganic fillers. In addition, they must have a Vickers microhardness value of 75 HV 0.2 and a strength of 240 MPa in a three-point bend test, and water absorption of less than 20 ng/mm³, after being soaked in 37°C water for 7 days. The present CAD/CAM composite blocks for premolars and molars satisfied these conditions.

KHN values were in the order VMII > KAP > ESP > SHH > CS3 > KZR (Table 2), but inorganic filler content was in the order KAP > ESP > CS3, KZR, SHH (Table 1). The order of KHN values did not correspond to the
order of inorganic filler content. Unlike the other CAD/CAM composites, SHH includes spherical filler (Fig. 1F), which was reported to improve the mechanical properties of composite resin (19). KHN is believed to be affected both by the inorganic filler content and the shape of the filler.

The gloss of all specimens was greater than 70 GU before the toothbrush abrasion test (Table 3). However, the GU values for CS3, ESP, and KZR were lower than 70 after testing. Previous studies reported that the optimal value for composites is greater than 70 (16,17). Therefore, materials with a value lower than 70 are regarded as aesthetically inferior.

Although Ra is commonly used for quantitatively evaluating roughness, it cannot be used to assess an entire specimen. Therefore, Sa was measured to evaluate surface roughness and Rz to assess deep scratches. Yap et al. reported that composites require re-polishing because Ra values exceed the critical threshold of surface roughness for bacteria (0.2 μm) (20). Another study reported that Ra values of 0.5 μm or higher could be distinguished by the patient’s tongue (15). The present Ra values for KAP, ESP, and CS3 exceeded 0.2 μm and that for KZR exceeded 0.5 μm after the toothbrush abrasion test (Table 4). Uppal et al. reported that roughness values of a composite could be decreased by hygiene maintenance procedures (21). Furthermore, they concluded that restorations required routine recall polishing. Gloss depends on the surface roughness of materials. Therefore, routine recall might help recover gloss and surface roughness of composite materials, e.g. KZR, in CAD/CAM composite crowns.

Analysis of surface roughness (Ra, Rz, and Sa) before the toothbrush abrasion test showed that CS3 and KZR did not significantly differ from VMII, probably because CS3 and KZR have good grindability and are softer than other materials. The high Sa values of CS3 and KZR (category f) are primarily responsible for the presence of

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**Fig. 1** SEM images of surfaces of specimens after toothbrush abrasion testing; Vitablocs Mark II (A), Katana Avencia P block (B), Shofu Block HC Hard (C), Cerasmart 300 (D), Estelite P Block (E), and KZR-CAD HR3 Gammatheta (F).
In conclusion, the surface properties and gloss of CAD/CAM composites varied among the investigated products. Products that show greatly decreased gloss and increased surface roughness after toothbrush abrasion testing should be used with care.

Acknowledgments
This work was supported in part by a grant from the Dental Research Center, Nihon University School of Dentistry (2017).

Conflict of interest
None declared.

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