Title	Grinding efficiency of abutment tooth with both dentin and core composite resin on axial plane
Author(s)	Miho, O; Sato, T; Matsukubo, T
Journal	Bulletin of Tokyo Dental College, 56(1): 9-23
URL	http://hdl.handle.net/10130/5660
Right	
Description	

Bull Tokyo Dent Coll (2015) 56(1): 9–23

Original Article

Grinding Efficiency of Abutment Tooth with Both Dentin and Core Composite Resin on Axial Plane

Otoaki Miho[1], Toru Sato[1] and Takashi Matsukubo[2]

[1] *Department of Crown and Bridge Prosthodontics, Tokyo Dental College, 2-9-18 Misaki-cho, Chiyoda-ku, Tokyo 101-0061, Japan*
[2] *Department of Epidemiology and Community Dentistry, Tokyo Dental College, 2-9-18 Misaki-cho, Chiyoda-ku, Tokyo 101-0061, Japan*

Received 24 March, 2014/Accepted for publication 23 October, 2014

Abstract

The purpose of this study was to evaluate grinding efficiency in abutment teeth comprising both dentin and core composite resin in the axial plane. Grinding was performed over 5 runs at two loads (0.5 or 0.25 N) and two feed rates (1 or 2 mm/sec). The grinding surface was observed with a 3-D laser microscope. Tomographic images of the grinding surfaces captured perpendicular to the feed direction were also analyzed. Using a non-ground surface as a reference, areas comprising only dentin, both dentin and core composite resin, or only core composite resin were analyzed to determine the angle of the grinding surface. Composite resins were subjected to the Vickers hardness test and scanning electron microscopy. Data were statistically analyzed using a one-way analysis of variance and multiple comparison tests. Multiple regression analysis was performed for load, feed rate, and Vickers hardness of the build-up material depending on number of runs. When grinding was performed at a constant load and feed rate, a greater grinding angle was observed in areas comprising both dentin and composite resin or only composite resin than in areas consisting of dentin alone. A correlation was found between machinability and load or feed rate in areas comprising both dentin and composite resin or composite resin alone, with a particularly high correlation being observed between machinability and load. These results suggest that great caution should be exercised in a clinical setting when the boundary between the dentin and composite resin is to be ground, as the angle of the grinding surface changes when the rotating diamond point begins grinding the composite resin.

Key words: Core build-up — Composite resin — Grinding efficiency — Grinding surfaces — Multiple regression analysis

Introduction

Esthetic considerations have increased demand for metal-free dental repair. As a result, metal is being replaced by composite resin in core build-up[2,10,17], and particularly so

This paper was originally a thesis submitted to the Graduate School of Tokyo Dental College in March 2014 by Otoaki Miho.

when the direct core build-up method is used, with dual-cure composite resins commonly being used in combination with fiber posts. In such cases, preparation of the abutment tooth aims at a smooth, angle-free, gently curved finish[20]. In clinical practice, both composite resin and dentin are often present on the same axial plane in the abutment tooth, resulting in a change in the angle at the boundary with the build-up material when the abutment tooth is prepared. Suggested causes for this roughness include differences in the mechanical properties of the composite resin and dentin and the manner in which the grinding tools are used. Most reports on the grinding efficiency of core build-up material[11,12,15,21] and on grinding tools[9] have evaluated resin cutting depth or grinding duration under constant loads. One study, which featured adjustments to the load on an air turbine hand-piece and feed rate[4], reported on the relationship between load and machinability and between machinability and number of runs using a bur. However, in that study, the dentin and composite resin were evaluated separately. In a clinical setting, the feed rate and load may vary. Consideration must be given to continuous grinding of the core build-up material surface and the surface of the abutment tooth. The present study was conducted assuming the preparation of a commonly clinically encountered abutment tooth with both dentin and core composite resin in its axial plane. Differences in the amount of material on the dentin formation and build-up material surfaces were assumed to be a function of the formation rate and the load applied to the diamond point.

The goal of the present study was to investigate grinding efficiency in abutment teeth consisting of both dentin and core composite resin in the axial plane.

Materials and Methods

1. Materials used in test

The following 3 makes of dual-cure, automix-type core-build composite resin were used: "BeautiCore Paste" (Shofu: LOT101005, referred to as "A-Core," below); "CLEARFIL DC CORE AUTOMIX ONE" (Kuraray Noritake Dental: LOT0035AA, referred to as "B-Core," below); and "UNIFIL CORE EM" (GC: LOT101007, referred to as "C-Core," below).

2. Preparation of test piece

A bovine mandibular anterior tooth crown was used as the residual tooth substance to be built up. The tooth was fixed in an epoxy ring 23 mm in internal diameter and 25.4 mm in height using epoxy resin (Scandiplex; Fritsch Japan Co., Ltd., Yokohama, Japan). The dentin surface was exposed with #120 SiC paper under running tap water using an automated grinder-polisher (AutoMet 2 & EcoMet 3; Buehler, IL, USA). Cavities 10 mm long, 7 mm wide, and 3 mm deep were formed on the dentin surface. Each cavity was filled with one of the 3 types of composite resin. The resins were then cured in accordance with the manufacturer's instructions (Table 1).

Using the Alpha Light II (effective wavelength, 400 to 600 nm) to provide irradiation, the A-Core and C-Core were both irradiated for 300 sec and the B-Core for 180 sec in line with the manufacturer's specifications.

After curing, each sample was polished with #600 waterproof abrasive paper using the automated polishing machine until a uniform surface was obtained. A 4-mm-wide cut was then made perpendicular to the surface in the tooth axis to obtain a test piece 4 mm wide and approximately 23 mm long with a dentin-composite resin boundary perpendicular to the polished horizontal surface and at right angles with respect to the long side. The sample was stored in distilled water at 37°C for 48 hr (Fig. 1).

3. Grinding efficiency tester settings

The grinding efficiency tester consisted of an air turbine hand-piece (Osadatron TDL Head 4H; Osada Electric Co., Ltd., Tokyo, Japan), a parallelometer (Bachmann Parallelometer Model 82; Inoue Attachment Co., Ltd., Tokyo, Japan) for attaching to the turbine,

Table 1 Grinding efficiency test samples

Products (Shade)	Polymerization conditions	Major components	Bonding agents	Manufacturer	Abbreviation
BeautiCore Paste (Dentin)	Dual cure + light exposure*[1]	Bis GMA TEGDMA PRG filler	BeautiDual Bond	Shofu Inc.	A-Core
CLEARFIL DC CORE AUTOMIX ONE (Dentin)	Dual cure + light exposure*[2]	Bis GMA TEGDMA Methacrylate monomer Surface-treated glass powder Surface-treated silica microfiller Aluminum microfiller Silica microfiller	CLEARFIL Bond SE ONE	Kuraray Noritake Dental	B-Core
UNIFIL CORE EM (Universal)	Dual cure + light exposure*[1]	Urethane dimethacrylate Fluoroaluminosilicate glass	Self-etching bond	GC Corporation	C-Core

Light exposure: Alpha-Light II (effective wavelength = 400 to 600 nm)
*[1]: 300 sec, *[2]: 180 sec
The active ingredients are listed as announced by respective manufacturers.

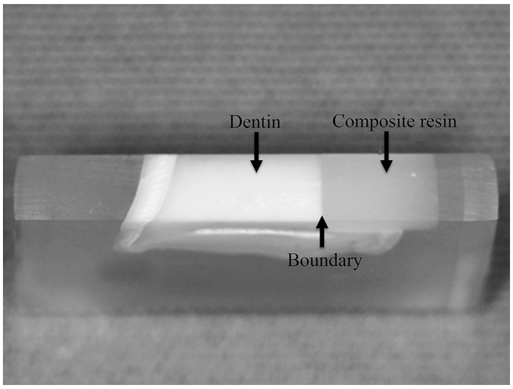

Fig. 1 Test piece 4 mm wide and approximately 23 mm long with dentin-composite resin boundary perpendicular to polished horizontal surface and at right angles with respect to long sides

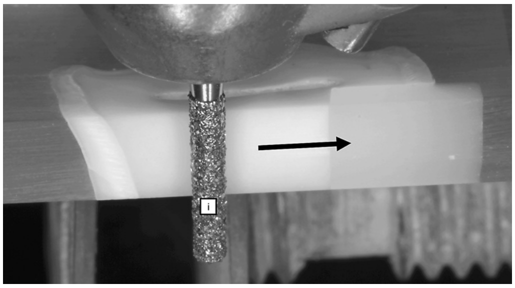

Fig. 2 Magnified view of grinding area
i) Straight cylinder type diamond point (FG Regular 211, 1.4 mm diameter)

and a push-pull gauge (Analog Push-Pull Gauge; Japan Instrumentation System Co., Ltd., Nara, Japan) for defining load. The air turbine handpiece was attached to the parallelometer and positioned to work with a horizontal movement to enable the push-pull gauge to be pressurized perpendicular to the polished surface. An automatic linear motion stage (Suruga Seiki Co., Ltd., Shizuoka, Japan) was used to fix and move the test piece at a constant speed.

The rotation shaft of a straight cylinder-shaped diamond-pointed bur 1.4 mm in diameter (FG Regular 211, Shofu Inc., Kyoto, Japan), which was attached to the air turbine, was placed parallel to the dentin-resin boundary line on the polished surface of the test piece.

The air turbine was operated at a rotation speed of 340,000 rpm in up-cut mode and load applied to the turbine head at a right angle with respect to the polished surface using the push-pull gauge. The surface was then ground while water was injected at an air pressure of 0.25 MPa and flow rate of 50 ml/min. The automatic linear motion stage

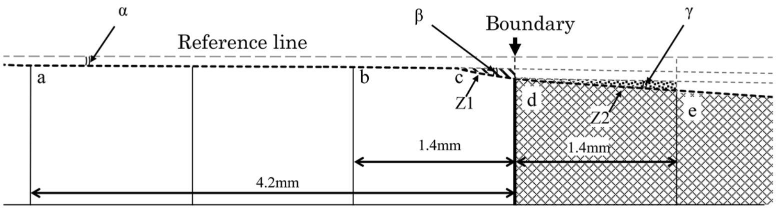

Fig. 3 Measurement reference values on transverse section

was moved 10 mm parallel to the polished surface. Grinding was commenced on the dentin side and covered 5 mm of the dentin and boundary. Approximately 5 mm of the composite resin was ground (Fig. 2).

4. Grinding conditions

Load was set at 0.5 or 0.25 N perpendicular to the polished surface by the push-pull gauge and feed rate was set at 1 or 2 mm/sec. Grinding efficiency tests were performed over 5 runs for each set of conditions, with the diamond point replaced every 5 runs.

5. Examination and measurement of grinding surfaces

The grinding surfaces were examined and measured using a 3-D measuring laser microscope (LEXT OLS400; Olympus Corporation, Tokyo, Japan). In addition, we analyzed tomographic images of the grinding surfaces of the test pieces captured perpendicular to the feed direction.

6. Analysis of grinding results

1) Evaluation of number of runs using diamond point

The profile of the dentin grinding surface was examined for each of the first 5 runs using the diamond point. In profile determination, the angle of the grinding surface was determined with the non-ground surface as the reference line (Fig. 3).

- Point “a”: Point 4.2 mm from the dentin-build-up material boundary toward the dentin on the grinding line.
- Point “b”: Point 1.4 mm from the dentin-build-up material boundary toward the dentin on the grinding line.
- Angle α: Angle between the reference line and the straight line passing through points “a” and “b”.

2) Evaluation of dentin and core composite resin

For profile determination, the angle of the grinding surface was determined with the non-ground surface as the reference line, with each area being used as an index of machinability (Fig. 3).

- Point “c”: Point at which an angle change occurs on the grinding line.
- Point “d”: Point in the dentin-build-up material boundary on the grinding line.
- Point “e”: Point 1.4 mm from the dentin-build-up material boundary toward the build-up material on the grinding line.
- Angle β: Angle between the straight line passing through points “a” and “b” and the straight line passing through points “c” and “d”.
- Angle γ: Angle between the straight line passing through points “a” and “b” and the straight line passing through points “d” and “e”.
- Area Z1: Area surrounded by the grinding line between points “c” and “d,” the line passing through point “c” and parallel to the straight line passing through points “a” and “b,” and the line passing through point “d” and perpendicular to the reference line.
- Area Z2: Area surrounded by the grinding line between points “d” and “e,” the line passing through point “d” and parallel to the straight line passing through points “a” and “b,” and the line passing through point “e” and perpendicular to the reference line.

Evaluation of the angle of the grinding surface depending on the number of runs

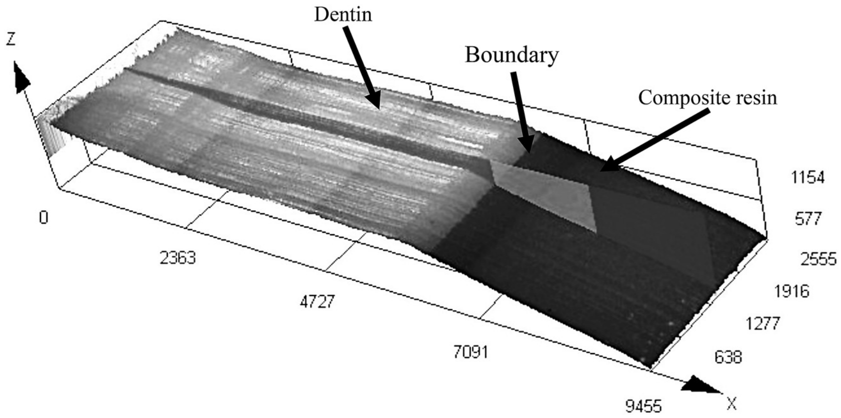

Fig. 4 Example 3-D laser image of ground surface

using the diamond point found that grinding was stable on the 3rd, 4th, and 5th runs. For this reason, areas incorporating both bovine dentin and composite resin and those comprising composite resin alone were distinguished based on the results of the 3rd, 4th, and 5th runs.

7. Evaluation of Vickers hardness and SEM images

Vickers hardness was determined under loading conditions of 3 N at 15 sec in each composite resin sample and polished dentin surface using a hardness testing machine (MVK-1; Shimadzu Corporation, Kyoto, Japan). Five measurements were made in each test sample, with the mean value considered to indicate hardness; 6 test samples were allocated for each type of composite resin. The mirror-polished surfaces of the 3 core composite resins were examined using images obtained with the Electron Beam Three-Dimensional Surface Roughness Analyzer: ERA-8900FE (ELIONIX INC., Tokyo, Japan). A mirror polish was achieved in the composite resin with the REFINE POLISHER (Copyright© Refine Tec Ltd., Kanagawa, Japan), with alumina solutions being applied to the felt buff in steps in the order of 1.0, 0.3, and 0.05 microns.

8. Statistical analyses

Data on load and feed rate were statistically analyzed using a one-way analysis of variance, with multiple comparisons also performed for each build-up material and each number of runs. The Scheffé test as carried out using SAS Version 9.2 for Windows (SAS Institute, Cary, NC, USA). A p-value of less than 0.05 was considered statistically significant. Multiple regression analysis was conducted for load, feed rate, and build-up material sample Vickers hardness value for each number of runs.

Results

1. Examination of grinding surfaces using a 3-D laser microscope

The portion of the dentin to be ground has a declining surface until a given load is exerted. In the present study, this decline gradually increased in depth in some cases, becoming almost horizontal in others after load was stabilized. When the diamond point reached the composite resin, the angle of the surface changed, increasing depth. Angle change occurred on the grinding line at 0.7 mm (the radius of the diamond-pointed bur) within the dentin side of the boundary. The diamond point then ground only the composite resin, resulting in a grinding surface that had a nearly constant declination (Fig. 4).

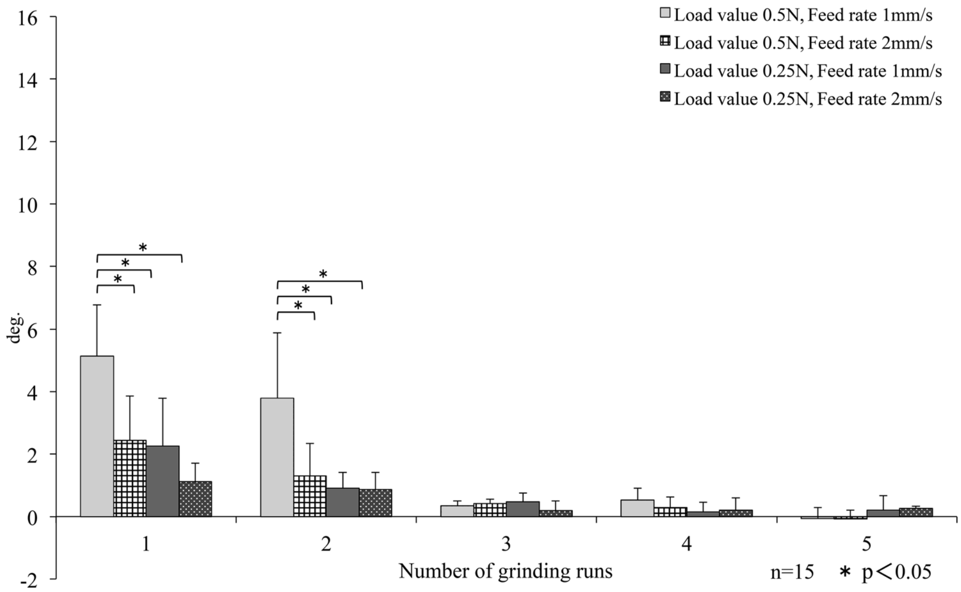

Fig. 5 Angle of slope (α) when only dentin was ground depending on number of runs

2. Evaluation of grinding efficiency by number of runs using diamond point

The effect of number of runs using the diamond point was evaluated at declination (α) in areas comprising dentin alone. The value of α changed drastically between the 1st and 2nd runs, shifting from approximately 1° on the 1st run to 5° on the 2nd, with a significant difference from the other grinding conditions observed at a load of 0.5 N and a feed rate of 1 mm/sec. In contrast, on the 3rd, 4th, and 5th runs, the value of α exhibited a converging tendency within the range of 0.5° to −0.1° on average, with no significant differences in α observed among grinding conditions (Fig. 5).

3. Evaluation of portion of dentin and core composite resin subjected to continuous grinding

1) Declination (β) in areas comprising both dentin and composite resin and declination (γ) in areas comprising composite resin alone

A significant difference in β was noted among grinding conditions in C-Core only. The β value tended to decrease from the 3rd through the 5th runs in A- and B-Core (Fig. 6). A high γ value was obtained at a load of 0.5 N and feed rate of 1 mm/sec on the 3rd run in all samples, with significant differences observed among the various grinding conditions. On the 4th and 5th runs, however, C-Core alone exhibited a large γ value at a load of 0.5 N and feed rate of 1 mm/sec, with significant differences found among the various grinding conditions (Fig. 7).

2) Area (Z1) in portions comprising both dentin and composite resin and area (Z2) in portions comprising composite resin alone

Significant differences in Z1 were found on the 3rd grinding run between a 0.5 N load and 1 mm/sec feed rate and a 0.25 N load and 2 mm/sec feed rate in C-Core. On the 4th and 5th grinding runs, significant differences from the other grinding conditions were found at a load of 0.5 N and feed rate of 1 mm/sec.

Significant differences were also found in A-Core on the 4th grinding run between a 0.5 N load and 1 mm/sec feed rate and a

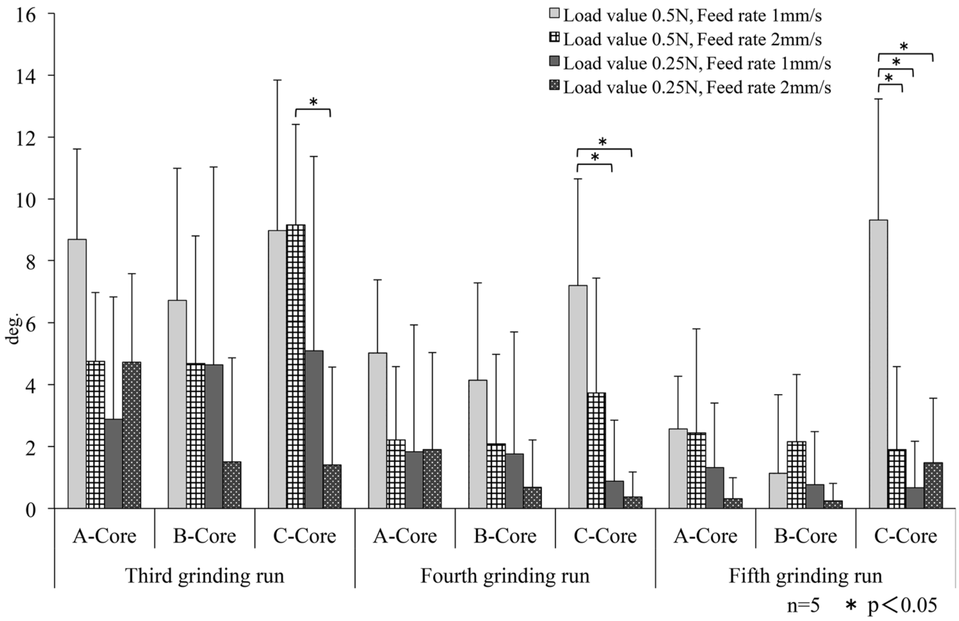

Fig. 6 Angle of slope (β) of area where dentin and composite resin were ground simultaneously 3, 4, or 5 times

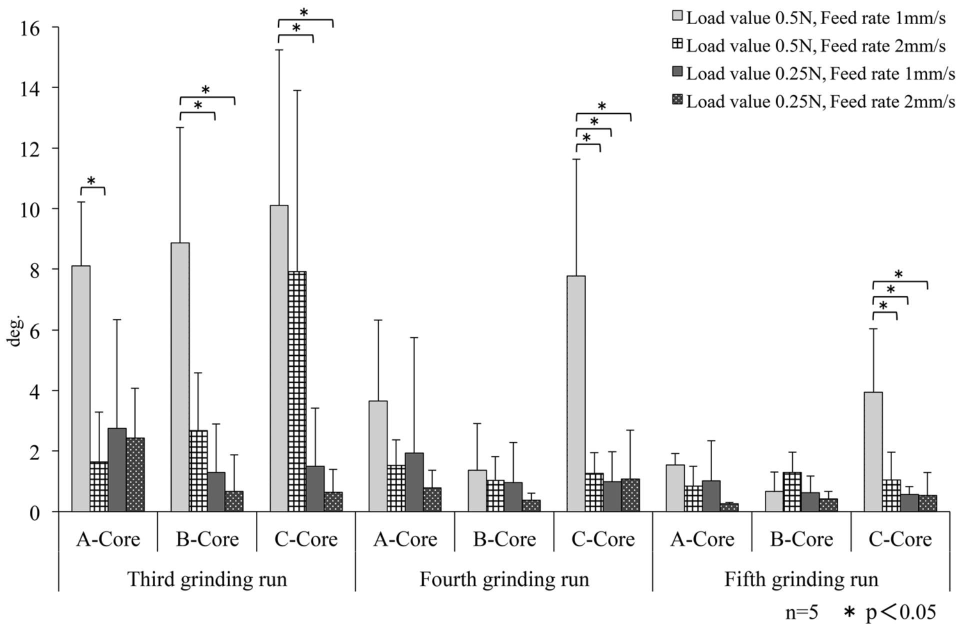

Fig. 7 Angle of slope (γ) of area where only composite resin was ground 3, 4, or 5 times

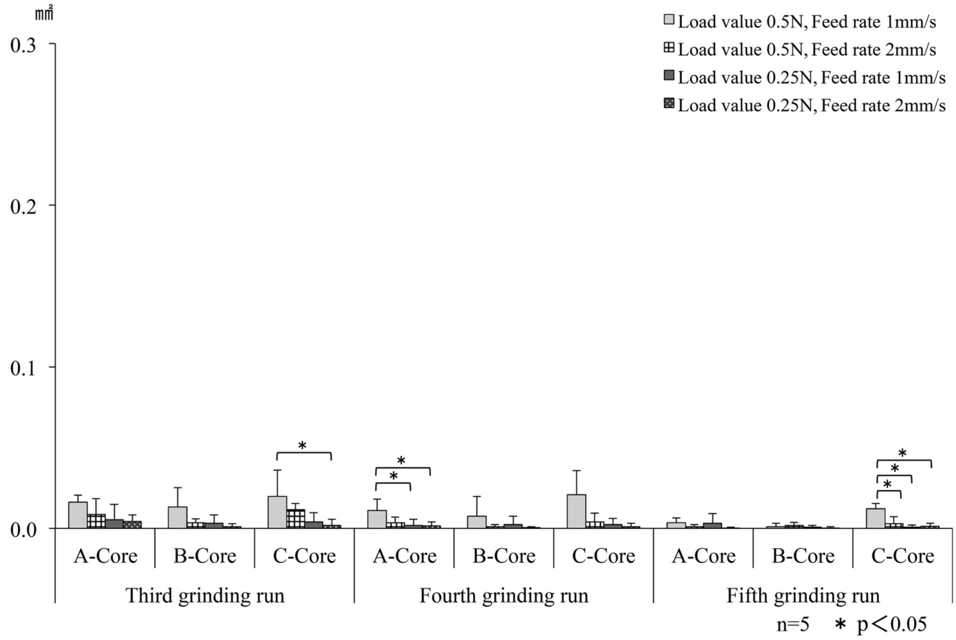

Fig. 8 Surface (Z1) of area where both dentin and composite resin were ground 3, 4, or 5 times

0.25 N load and 1 or 2 mm/sec feed rate. The entire Z1 was approximately 0.05 mm^2 or less on average, which was markedly smaller than Z2 described below (Fig. 8).

In all samples, Z2 was high at a load of 0.5 N and a feed rate of 1 mm/sec on the 3rd run. Significant differences in machinability were found among different loads and feed rates in A-Core, whereas this was only noted among different loads in B-Core. C-Core also exhibited a high machinability value at a load of 0.5 N and feed rate of 2 mm/sec, with significant differences noted in load and feed rate.

On the 4th and 5th grinding runs, a high machinability value was obtained with C-Core at a load of 0.5 N and feed rate of 1 mm/sec. On the 3rd, 4th, and 5th grinding runs, the grinding surface area decreased as the number of runs increased. At a load of 0.25 N and feed rate of 2 mm/sec, small grinding surface areas were obtained under all conditions except for with A-Core on the 3rd run (Fig. 9).

4. Vickers hardness of composite resins

The hardness (HV) of each build-up material was determined to be 71.4±8.5, 57.4±4.8, and 67.0±5.0 for A-, B-, and C-Core, respectively. The hardness (HV) of dentin was 77.4±2.6.

5. SEM imaging of composite resins

SEM imaging of the sample composite resins revealed a larger number of irregularly shaped filler particles approximately 20 μm in diameter with A-Core and a lower density of such particles than with other composite resins. The B-Core filler particles, which were more spherical than those of A-Core, had a diameter of approximately 10 μm. With C-Core, many irregularly shaped filler particles less than approximately 10 μm in diameter and many even finer particles less than 0.2 μm in diameter were observed (Fig. 10).

6. Multiple regression analysis

With load, feed rate, and Vickers hardness as explanatory variables, multiple regression analysis of the machinability of Z1 and Z2

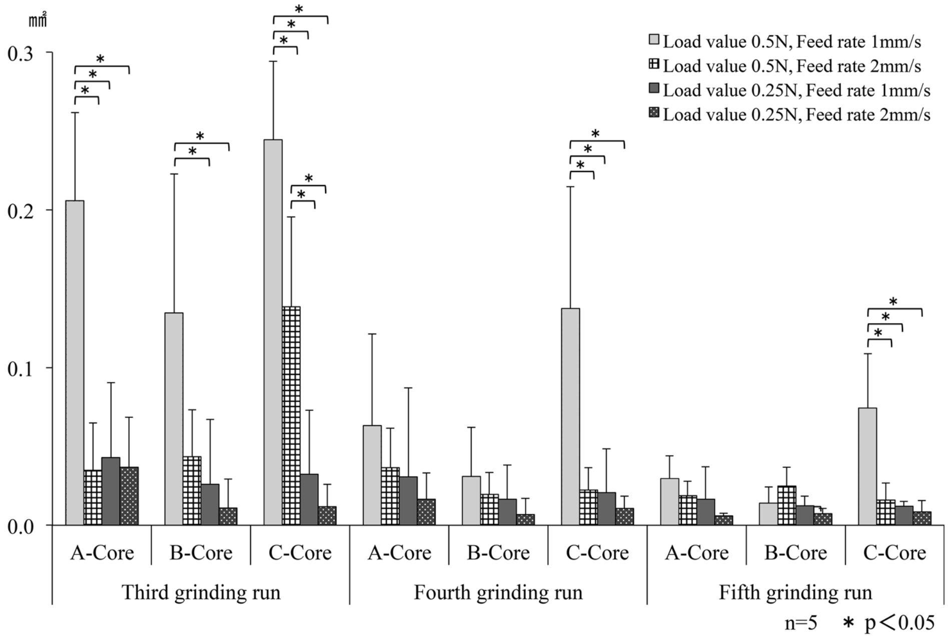

Fig. 9 Surface (Z2) of area where only composite resin was ground 3, 4, or 5 times

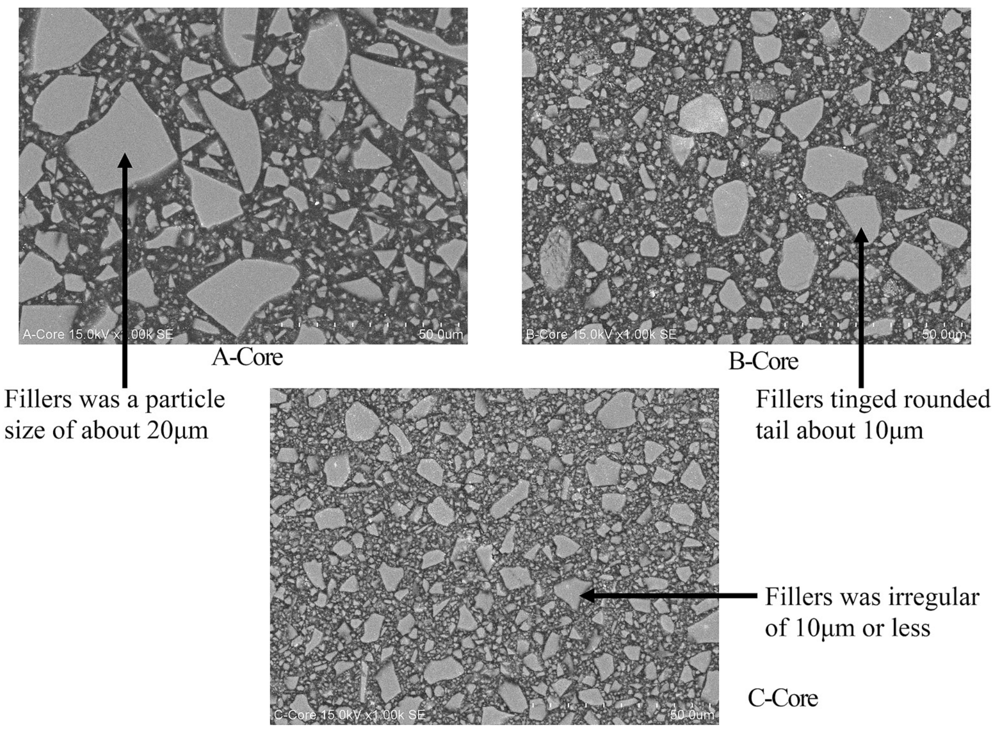

Fig. 10 SEM images of various core samples

Table 2 Results of multiple regression analysis

	Number of grinding runs	r^2	Load (N)	Speed (mm/s)	Hardness (HV)
Area Z1	3	0.3545	<.0001	0.0100	0.1055
	4	0.2846	0.0011	0.0033	0.2957
	5	0.2235	0.0052	0.0210	0.1591
Area Z2	3	0.5169	<.0001	0.0002	0.0647
	4	0.2801	0.0021	0.0054	0.0896
	5	0.2935	0.0003	0.0104	0.3356

revealed a correlation with load and feed rate, with a significance level of <0.05 on all runs examined (3rd, 4th, and 5th). Comparing the correlations of load and feed rate with machinability, load exhibited a correlation equivalent to or greater than that of feed rate. The coefficient of determination was higher on the 3rd than on the 4th or 5th runs, demonstrating greater interpretability. No correlation with Vickers hardness was found (Table 2).

Discussion

1. Test pieces

All the core composite resins used in the present study were of the automatic mixing type commonly used for crown dentin, and which is characterized by minimal bubbling during kneading. The resins had been polymerized using the dual-cure method, ensuring adequate setting even in the innermost portion and a more stable bending strength than that obtainable with the chemical polymerization method[13]. To eliminate the influence of polymerization depth and kneading, the test pieces were stored for 48 hr before use.

Bovine dentin was chosen as the experimental dentin for the assumed abutment tooth. The tensile strength of human and bovine dentin is influenced by the orientation of the dentinal tubules. Actual measurements have yielded values of from 34.5 to 64.5 MPa for human teeth, which is nearly the same as that for bovine teeth (38.9 to 67.6 MPa)[3].

2. Measuring ground area in each specimen

High-resolution 3-D laser microscopy in the direction of the specimen depth (0.01 μm) allowed topographical images to be obtained without having to prepare sections of ground portions of the test piece[14], which facilitated examination of the boundary between the dentin and composite resin. The area in which both dentin and composite resin were simultaneously ground was extremely small, making evaluation here much more difficult than in those areas comprising ground composite resin alone. Therefore, the continuity of the grinding surfaces was evaluated based on angle.

3. Load and feed rate

One earlier study evaluating cutting resistance determined a combined load of approximately 60 to 100 g for the three directions applied during grinding using a 3-D measuring load[18], while another report noted a mean cutting pressure in the vertical direction of 30.4 ± 12.9 g and a maximum cutting pressure of ≤ 100 g[22].

Other studies, however, have found that a reduction in air turbine rotation rate was proportional to increase in load[7] and that the air turbine sometimes became disabled due to stopping at grinding loads of 50 and 60 gf[4].

The loads used in this study, 0.5 N and 0.25 N, were selected in reference to these earlier reports. There was little likelihood of the diamond point cutting into the grinding surface when using a 1.4-mm diameter cylinder

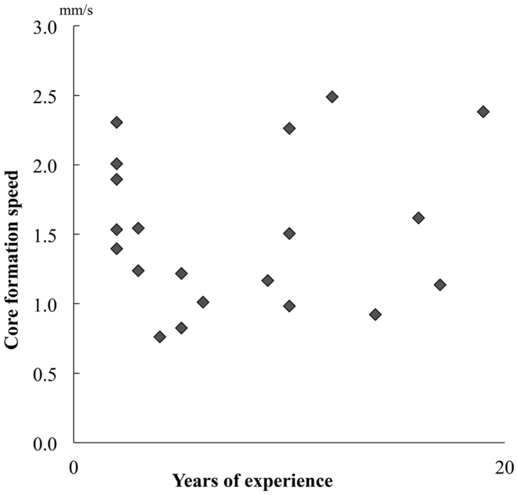

Fig. 11 Relationship between core preparation speed and number of years of experience of 19 dentists

type, with which load can be applied perpendicular to the grinding surface.

Regarding grinding settings, the rotating diamond point was first positioned, and then set on the test piece. Load was then specified using an analog push-pull gauge, and the air turbine positioned when the load conditions were reached.

In one previous study, the feed rate for the experimental system was set at between 0.04 and 2.10 mm/sec[4]. Another study measuring the grinding speeds of a number of samples[18] determined that the grinding tool feed rate ranged from 1.61 to 10 mm/sec. Accordingly, we asked 19 dentists with 2 to 19 years of experience in clinical practice each to form a mandibular first molar lingual surface in an epoxy model and measured their working speeds (Fig. 11), obtaining a mean of 1.51 mm/sec, a maximum of 2.49 mm/sec, and a minimum of 0.76 mm/sec. With these values in mind, we selected feed rates of 1 and 2 mm/sec for the present study.

4. Description of areas in which dentin alone was ground

Previous studies on machinability have reported that the machining performance of diamond points decreases due to abrasive grain wear, declining with increase in number of runs[8,9,19,21]. The findings on composite resin machinability have been controversial, especially with regard to whether or not to decrease the number of runs when using a diamond point. Opinion with regard to the machinability of dentin, however, remains relatively unchanged[4]. In the present study, the grinding surface had a mean angle of approximately 3.8° to 5.1° at a load of 0.5 N and a feed rate of 1 mm/sec during the 1st and 2nd runs of dentin grinding with a diamond point, suggesting an increase in grinding efficiency. At other loads and feed rates, the mean angle ranged from 0.8° to 2.4°, indicating a small declination in the grinding surface. In the 3rd, 4th, and 5th runs, the angle of the ground surface was observed to stabilize at all speeds and feed loads.

This may have been due to stabilization of the morphology of the diamond point abrasive grain and other factors following two grinding runs of 5 mm each in both the dentin and composite resin. Here, we analyzed the materials to determine how composite resin grinding efficiency altered under stable conditions.

5. Description of areas in which both dentin and composite resin were simultaneously ground

We believe that when the outer periphery of the diamond point comes into contact with the composite resin, a change in angle occurs immediately below the center of rotation of the diamond point. At the boundary between the dentin and composite resin, grinding occurs with the involvement of diamond point curvature and cutting depth. During this period, the diamond point grinds the dentin and composite resin at different ratios. The machinability of the target region was extremely small. With load, feed rate, and Vickers hardness as explanatory variables, multiple regression analysis of the machinability of Z1 revealed a correlation with load and feed rate in all the 3rd, 4th, and 5th grinding runs.

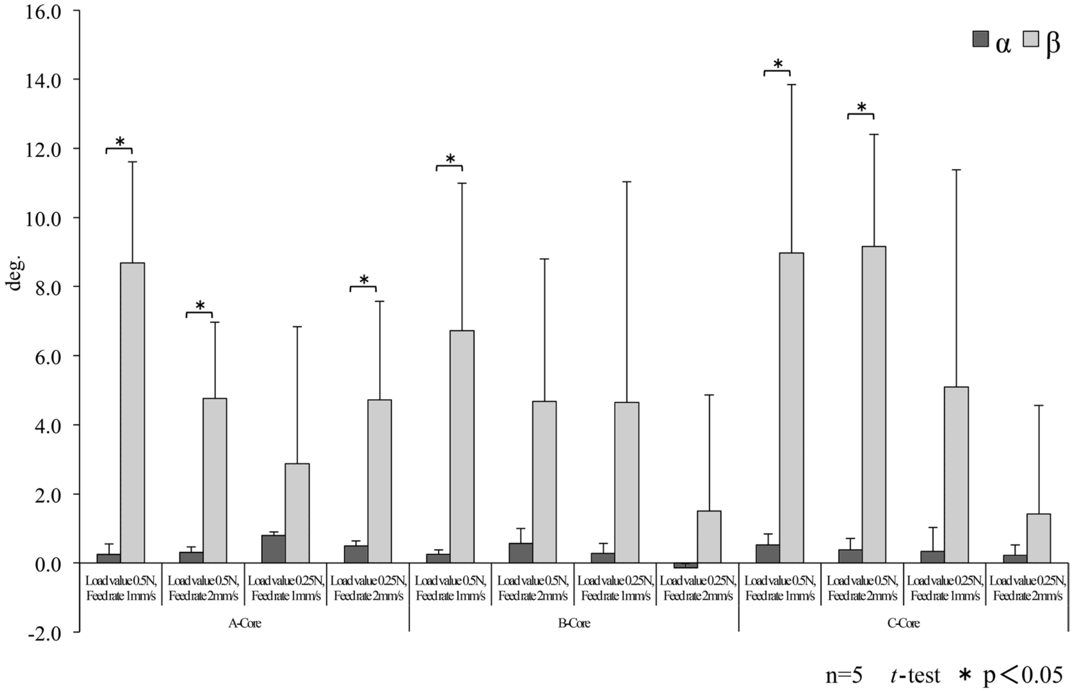

Fig. 12 Differences in angles α and β among various grinding conditions on 3rd grinding run

6. Description of areas in which composite resin alone was ground

On the 3rd run of grinding for A-Core, B-Core, and C-Core, and on the 4th and 5th runs for C-Core, the machinability of Z2 increased at a load of 0.5 N and feed rate of 1 mm/sec. When the load was 0.25 N on the 3rd run for A-Core, B-Core, and C-Core, the machinability of Z2 was small at feed rates of both 1 and 2 mm/sec. On the 4th and 5th runs, the machinability of Z2 was small under all grinding conditions for all cores and under all parameters except for C-Core at a 0.5 N load and 1 mm/sec feed rate, with γ exhibiting the same tendency.

The hardness of a composite resin indicates the toughness of the material, which includes a broad range of other properties[16]. Grinding refers to the deforming and cutting of a material by means of a shearing force. The factor most closely related to machinability is the toughness of the work material[6]. All three composite resins used in the present study exhibited Vickers hardness values which were smaller than those of dentin. Although machinability differed depending on the grinding conditions, all of the composite resins exhibited greater machinability than did dentin.

Multiple regression analysis, however, revealed no correlation between Vickers hardness and composite resin machinability. The mechanical properties of composite resin are influenced by filler particle size, distribution, content, and other factors[1]. A previous study found that machinability decreased when a small spherical filler with a mean particle diameter of 0.2 μm was used, with increases with increasing content when irregularly shaped or spherical fillers were used[5]. The composite resins used in the present study have been reported to have filler contents of approximately 70% (w/w) to 80% (w/w). In the present study, C-Core samples tended to exhibit greater machinability than did A-Core or B-Core, reflecting the influence of filler size and shape, choice of filler, filler content and density, and other factors. C-Core, which

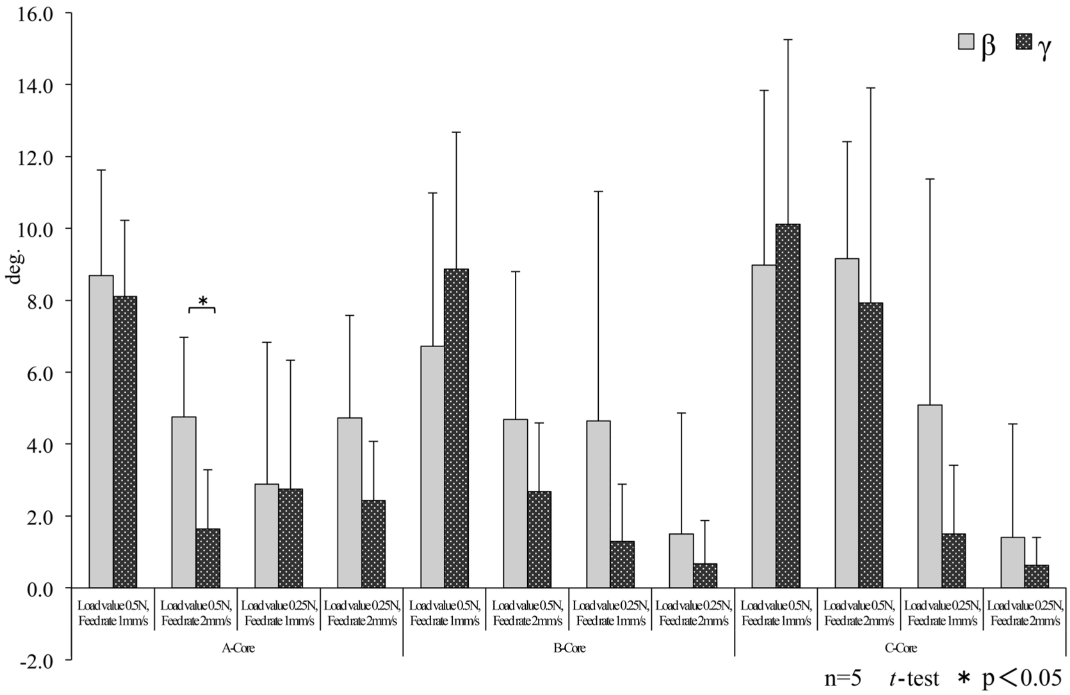

Fig. 13 Differences in angles β and γ among various grinding conditions on 3rd grinding run

had a filler of small particles, was believed to be the most susceptible to the influence of grinding load and feed rate.

Multiple regression analysis was performed for load, feed rate, and Vickers hardness in areas comprising composite resin alone. The results demonstrated a correlation between the machinability of areas in which only the composite resin was ground and grinding load and feed rate. Machinability, in particular, moderately or strongly correlated with load. In addition, high interpretability (r^2) was observed for the 3rd grinding run. As such, caution is suggested when determining the grinding load and feed rate to be used in grinding composite resin with the initial use of a diamond point. In clinical practice, fast-speed grinding and a feather-like touch are desirable.

7. Continuity of grinding surfaces

The area in which both dentin and composite resin were simultaneously ground was extremely small, making evaluation under each condition here more difficult than in those areas where only composite resin was ground. Therefore, the continuity of grinding surfaces was evaluated based on angle.

Once grinding was initiated, the angle (α) of the dentin grinding surface exhibited minimal variation, with grinding proceeding nearly horizontally. However, in the portions in which both dentin and composite resin were ground simultaneously, the angle (β) of the ground surface increased in all cases, irrespective of type of composite resin, number of runs, or grinding conditions (Fig. 12). In contrast, in portions where both dentin and composite resin were ground simultaneously, the angle (β) of the ground surface was nearly the same as the angle (γ) of the ground surface in the portions where only the composite resin was ground (Fig. 13). Hence, when contact was also made with composite resin on the dentin grinding surface, the angle of the grinding surface increased. However, even after the grinding surface changed from an area in which both dentin and composite resin were being ground to an area in which only composite resin was being ground, the direction of grinding remained unchanged, with only a small change in grinding angle. Great caution should therefore be exercised in a clinical setting when the boundary between the dentin and composite resin is to be ground, as the angle of the grinding surface changes when the rotating diamond point begins grinding the composite resin.

Conclusion

In this study, the grinding surfaces of continuously ground bovine dentin and built-up composite resin, the appearance of the ground surface produced when grinding from dentin to composite resin, the effect of the use of a diamond point, and the effects of feed rate and load applied during grinding were all observed and the following conclusions reached:

1. With a newly adopted diamond point, the dentin grinding angle varied widely between the 1st and 2nd runs of grinding, even under constant conditions of load and feed rate. On the 3rd, 4th, and 5th runs, the effect of grinding conditions showed a reduction.

2. When grinding was performed at a constant load and feed rate, a greater grinding angle was found in areas in which both dentin and composite resin were ground simultaneously or in which composite resin alone was ground than in areas where only dentin was ground.

3. A correlation was found between machinability and load or feed rate in those areas where both dentin and composite resin were ground simultaneously or in which only composite resin was ground, with a particularly high correlation being observed between machinability and grinding load.

References

1) Braem M, Finger W, Van Doren VE, Lambrechts P, Vanherie G (1989) Mechanical properties and filler fraction of dental composites. Dent Mater 5:346–348.
2) Farhana S, Roxana S, Okada N, Kitamura E, Kurokawa K, Yagi M, Nomura S (2009) Effect of post type and loading condition on the failure resistance and primary failure mode of flared canal teeth restored with fiber-reinforced or cast posts. Niigata Shigakkai Zasshi 39:15–24.
3) Inoue T, Miyazaki T, Nishimura F (2005) Mechanical properties of human and bovine dentin. Nihon Shika Rikô Gakkai Shi 24:93. (in Japanese)
4) Iwasaki N (2001) A new machinability test machine and the machinability of composite resins for core built-up. Kokubyo Gakkai Zasshi 68:208–214. (in Japanese)
5) Iwasaki N, Takahashi H, Aoyagi Y, Kim K, Tonami K, Nishimura F (2003) Effect of filler shape and filler contents on the machinability of Bis-GMA Based Composite Resins. Nihon Shika Rikô Gakkai Shi 22:194–200. (in Japanese)
6) Kosaka H (2007) Basic knowledge of machining, pp.27–46, The Nikkan Kogyo Shimbun, Tokyo. (in Japanese)
7) Matsui K (1982) Effects of choice of dental rotary tool on high-speed grinding load and tool revolution rate. Shikwa Gakuho 82:517–539. (in Japanese)
8) Miyawaki H, Taira M, Yamaki M (1996) Cutting effectiveness of diamond points on commercial core composite resins and cements. J Oral Rehabil 23:409–415.
9) Nagai M, Muramatsu A (1980) Grinding performance and durability of dental diamond points. Baiomekanizumu Gakkai Shi 4:1–9. (in Japanese)
10) Nishimura Y, Tsubota Y, Fukushima S (2008) Influence of cyclic loading on fiber post and composite resin core. Dent Mater J 27:356–361.
11) Petra S, Ibrahim N, Fekry S, Martin R (2012) Preparation time and surface roughness of core foundation resins and dentin. J Prosthet Dent 108:244–249.
12) Suese K, Iwata M (2005) A study of machinability of composite resin for core build-up materials. Nihon Hotetsu Shika Gakkai Shi 49 special issue: 143. (in Japanese)
13) Takahashi H, Iwasaki N, Aoyagi Y, Jin J, Tonami K, Arksornnukit M (2004) Properties of recent dual-cure type of composite resins for foundation restoration. Nihon Shika Rikô Gakkai Shi 23:287–293. (in Japanese)
14) Takamatsu T, Fujita S (1994) Laser microscope. Byouri To Rinsho 12:997–1002. (in Japanese)
15) Tanaka N, Taira M, Wakasa K, Shintani H, Yamaki M (1991) Cutting effectiveness and

wear of carbide burs on eight machinable ceramics and bovine dentin. Dent Mater 7: 247–253.
16) Terasawa M, Iwasaki S (2001) A Story of Hardness, pp.29–52, Japanese Standards Association, Tokyo. (in Japanese)
17) Tsubota Y, Amakawa Y, Kobayashi K, Ishihara M, Kokubo Y, Fukushima S (1998) Adhesive resin core in coronal radicular stabilization—with a focus on resin core build-up. Setchaku Shigaku 16:96–103. (in Japanese)
18) Ueda S (1982) A note on grinding load during use of dental turbine engine—with a focus on cavity side wall preparation—. Shikwa Gakuho 82:21–60. (in Japanese)
19) Unno K (2006) Basis of basic grinding process with pictorial explanation, pp.20–51, The Nikkan Kogyo Shimbun, Tokyo. (in Japanese)
20) Wakami M, Toyoshima A, Takahashi T, Omura Y, Watanabe T, Gotoh H, Sakurada T, Masuda M, Aida M (2003) A study on laminate veneers prepared using dental CAD/CAM GN-I—Report 1—. Nichidai Koku Kagaku 29:135–141. (in Japanese)
21) Yamauchi M, Cho E, Iwahori M, Koda T, Kawano J (1989) Basic studies on cutting of composite resin cores. Nihon Hotetsu Shika Gakkai Shi 33:1350–1358. (in Japanese)
22) Yuzuriha M, Ito A, Satoh Y, Murakami S, Uchida Y (1987) Measurement of load in tooth-grinding. Kyûshû Shika Gakkai Zasshi 41:555–559. (in Japanese)

Reprint requests to:
Dr. Otoaki Miho
Department of Crown and Bridge Prosthodontics,
Tokyo Dental College,
2-9-18 Misaki-cho, Chiyoda-ku,
Tokyo 101-0061, Japan
E-mail: miho@tdc.ac.jp