Influence of different types of prophylaxis pastes on surface texture of tooth substrates and restorative materials

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Contents

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Summary

In the past decade, professional mechanical tooth cleaning (PMTC) pastes have been used as an effective way to clean stained tooth surfaces. A one-step PMTC paste is intended to remove harmful substances from the tooth surfaces and achieve polishing simultaneously. The abrasive particles in this type of PMTC paste gradually wear down and reduce in size during PMTC. Some one-step PMTC pastes contain components that enhance the acid resistance of the tooth surface or inhibit gingival inflammation through the bioactive reaction of the abrasive particles. However, previous studies have reported risks of wear and harm for teeth surfaces or restoratives when PMTC is performed inadequately or when an inappropriate PMTC paste is selected.

Since the surface hardness and properties of restoratives are material dependent and differ from those of teeth surfaces, it is necessary to consider the presence of various restoratives and differences in the surface properties between the tooth and the restoration. However, there is limited information about the influence of recently developed one-step PMTC pastes on the surface properties of tooth substrate and different types of restoratives. Therefore, this study aimed to determine the effect of one-step PMTC pastes on the surface roughness and morphological features of tooth substrates and the different types of restorative materials.

Three one-step PMTC pastes, Concool Cleaning Jell PMTC (CJ), Clinpro Cleaning Paste for PMTC (CP), and PRG Pro-Care Gel (PG), were used. For multiple-step PMTC pastes, pastes with different relative dentin abrasiveness (RDA) values, Merssage Regular (MR), Merssage Fine (MF), and Merssage Plus (MP), were used. The subjected materials used were bovine enamel (ENA), bovine dentin (DEN), Filtek Supreme Ultra (FSU) as a resin composite, and IPS e.max CAD (IEC) as a lithium disilicate ceramic. A total of 10 specimens were prepared for each group. All PMTC procedures were performed using a slow-speed contra-angle handpiece (at 1,000 rpm

for 15 s) with a PMTC brush under a contact pressure of 2.5 N monitored by a digital balance underneath the specimen. For each specimen, 0.1 mg of PMTC paste was used. For comparison, PMTC was performed using distilled water (DW) without using the PMTC paste.

After PMTC, the specimens were washed with DW and then cleaned with an ultrasonic cleaner for 1 min and dried with a three-way air syringe. The surfaces of all specimens were observed using a confocal laser scanning microscope (CLSM). Arithmetic average roughness was used (Ra) as the surface roughness parameter, and it was measured for the 10 specimens in each group in 2.0 × 2.0 mm regions using the software supplied with the CLSM. Profilometric measurements were performed in five regions near the center of the specimen, and the mean values were determined for each group. For Knoop hardness measurements, 10 specimens for each group were prepared following the same above-described procedures. The Knoop hardness number (KHN) was obtained from the indentation after the application of 0.493 N load for 15 s using a microhardness tester. Three measurements per specimen were conducted in different locations, and then the mean values were calculated. The shapes and sizes of the abrasive particles extracted from the pastes in each PMTC paste were observed using scanning electron microscopy (SEM).

Three-way ANOVA showed that all the factors had a significant influence on the Ra values ($p < 0.001$), and all the interactions between the factors were significant ($p < 0.05$). The Ra values after PMTC were dependent on both the material and the PMTC paste. The subjected materials with MR exhibited significantly higher Ra values post-PMTC than the other PMTC paste groups in all the subjected materials. For most of the subjected materials, the descending order of the Ra value after PMTC was MR ＞ CJ ＞ MF ＞ CP ＞ PG ＞ MP ＞ DW. The symmetric change rates (SCR) were in the range of 10.2–141.6% for ENA, 7.7–90.0% for DEN, 8.7–165.6% for FSU, and 19.6–156.8% for IEC.

The CLSM observations revealed different surface features with different materials and PMTC pastes. The groups with MR for all the materials exhibited deeper and clearer irregular scratches on the surfaces than the other PMTC paste groups. The MP groups exhibited relatively smoother surfaces than the other PMTC paste groups. The KHN was material-dependent, and IEC exhibited a significantly higher KHN than the other materials. DEN revealed a significantly lower KHN than the other materials. All differences in KHN were found to be statistically significant. Although the shapes of abrasive particles in most of the PMTC pastes were irregular, those in PG were rather rounded from the SEM observations. The sizes of the abrasive particles were different in different PMTC pastes, and the descending order of the size of abrasive particles was MR＞PG ＞CJ≧CP＞MF＞MP.

In the present study, the surface texture after PMTC was found to be dependent on both the subjected material and the PMTC paste. Although MR is categorized as a multiple-step PMTC paste, the Ra values, and the morphological surface alterations after PMTC, were greater than those of the other PMTC pastes, irrespective of the material. Using MR alone may be harmful to the surfaces of the subjected materials, and hence, successive PMTC procedures using MF and MP are necessary. Although CJ, CP, and PG appeared to be effective as one-step PMTC pastes, it is important to consider the features of the subjected material while performing PMTC.

Introduction

Dental plaque, a type of biofilm, is one of the major biological factors responsible for causing these two oral diseases, in addition to increased risk factors for systemic diseases such as diabetes and cardiovascular disorders (1–3). The surface of dental plaque is covered with a matrix structure of dextran, which is difficult to remove by rinsing with water and inhibits the penetration of most antimicrobial agents (4). Therefore, it is important to remove dental biofilm using mechanical methods (5).

Professional mechanical tooth cleaning (PMTC) is a procedure performed by dental professionals that removes biofilm from the tooth surface (6–8). In clinical situations, supragingival biofilms and subgingival biofilms measuring within 3 mm can be removed mechanically using rotary instruments and a prophylaxis paste (9). PMTC also effectively improves the oral environment and esthetics by reducing biofilm retention factors and staining on teeth surfaces (10,11).

It is believed that the cleaning ability of PMTC pastes depends on the properties of the abrasive particles contained in them, and PMTC pastes can be characterized according to the types and sizes of abrasive particles (12). Abrasiveness and stain removal performance are indicated by relative dentin abrasiveness (RDA) and pellicle cleaning ratio (PCR), respectively (13). Although the relationship between polishing capability and RDA or PCR values is controversial, these parameters can be useful when selecting the optimal PMTC paste for use in the individual oral environment (14,15). In general, the cleaning and polishing effects of PMTC pastes are material dependent, and the effectiveness of cleaning seems to conflict with the polishing capability (12,14,15). Therefore, PMTC pastes with different RDA values are commonly used successively in multiple steps (16). However, multiple-step PMTC may require time-consuming procedures with different PMTC pastes and may be expensive.

In the past decade, new PMTC pastes have simplified the PMTC procedure. The one-step PMTC paste is intended to remove harmful substances from the tooth surfaces and achieve polishing simultaneously. The abrasive particles in this type of PMTC paste gradually wear down and reduce in size during PMTC (17). Some one-step PMTC pastes contain components that enhance the acid resistance of the tooth surface or inhibit gingival inflammation through the bioactive reaction of the abrasive particles (18). However, previous studies have reported risks of wear and harm for teeth surfaces or restoratives when PMTC is performed inadequately or when an inappropriate PMTC paste is selected (19–21).

Since the surface hardness and properties of restoratives are material dependent and differ from those of teeth surfaces, it is necessary to consider the presence of various restoratives and differences in the surface properties between the tooth and the restoration. However, there is limited information about the influence of recently developed one-step PMTC pastes on the surface properties of tooth substrate and different types of restoratives. Therefore, this study aimed to determine the effect of one-step PMTC pastes on the surface roughness and morphological features of tooth substrates and the different types of restorative materials. The null hypotheses tested in this study were i) the surface roughness and morphological features of the subjects after PMTC would not differ between the tested one-step PMTC pastes and ii) the surface roughness and morphological features after PMTC would not be influenced by the type of PMTC paste used or the materials polished.

Materials and methods

Study materials

Table 1 shows the materials used in this study. Three one-step PMTC pastes, Concool Cleaning Jell PMTC (CJ, Weltec), Clinpro Cleaning Paste for PMTC (CP, 3M Japan), and PRG Pro-Care Gel (PG, Shofu), were used. For multiple-step PMTC pastes, pastes with different RDA values, Merssage Regular (MR, Shofu), Merssage Fine (MF, Shofu), and Merssage Plus (MP, Shofu), were used. The subjected materials used were bovine enamel, bovine dentin, Filtek Supreme Ultra (FSU, 3M Oral Care) as a resin composite, and IPS e.max CAD (IEC, Ivoclar Vivadent) as a lithium disilicate ceramic. For polymerized FSU, a halogen-quartz-tungsten curing unit was used. The light intensity (600 mW/cm^2) of the curing unit was checked using a dental radiometer.

Specimen preparation

Bovine teeth were cut using a low-speed saw equipped with a diamond-impregnated blade (IsoMet 1000, Buehler). Specimens taken from the center of the tooth were shaped into a square (10 × 10 × 1 mm). Both enamel and dentin slabs were prepared with 10 specimens for each group. The specimen surfaces were ground using a wet #2,000-grit silicon carbide (SiC) paper.

A stainless-steel split mold (dimensions 10 × 10 × 1 mm) was set on a glass slide covered by a transparent matrix tape (Matrix tape and dispenser, 3M Oral Care). A resin paste of FSU was filled into the mold, and then the top side of the mold was covered with a second matrix strip. The resin composite paste was pressed with a second glass slide under a 5 N load, and then half of the specimen was irradiated for 30 s, after which the remaining half was irradiated for 30 s. After removing the hardened specimen from the mold, the top surface was wet-polished using a #2,000-grit SiC paper.

The lithium disilicate ceramic disk of IEC was cut using a low-speed saw equipped with a diamond-impregnated blade. For each group, 10 specimens were crystallized in a ceramic furnace (Proframat S, Ivoclar Vivadent). Next, 10 × 10 × 1 mm plates were obtained, and the top surface was wet-polished using a #2,000-grit SiC paper in the same way as for the other materials.

PMTC procedures

A total of 10 specimens were prepared for each group. All PMTC procedures were performed using a slow-speed contra-angle handpiece (at 1,000 rpm for 15 s) with a PMTC brush (Merssage Brush No.1, Shofu) under a contact pressure of 2.5 N monitored by a digital balance underneath the specimen. For each specimen, 0.1 mg of PMTC paste was used. A single operator performed all procedures to reduce variability between samples, and PMTC was performed in a spiraling pattern from the center of the specimen. For comparison, PMTC was performed using distilled water (DW) without using the PMTC paste.

Surface observations and surface roughness (Ra) measurements

After PMTC, the specimens were washed with DW and then cleaned with an ultrasonic cleaner for 1 min and dried with a three-way air syringe. The surfaces of all specimens were observed using a confocal laser scanning microscope (CLSM, VK-8700, Keyence). During the observation, the spectral maximum of the excitation light was 658 nm, and the intensity of the excitation light and the amplification of the photomultiplier were maintained at a constant. Arithmetic average roughness was used (Ra) as the surface roughness parameter, and it was measured for the 10 specimens in each group in 2.0 × 2.0 mm regions using the software supplied with the CLSM (VK Analyzer, Keyence). Profilometric measurements were performed in five regions near the center of the specimen, and the mean values were determined for each group. These measurements were also conducted before performing PMTC to serve as a baseline.

Knoop hardness measurements

For Knoop hardness measurements, 10 specimens for each group were prepared following the same above-described procedures. The Knoop hardness number (KHN) was obtained from the indentation after the application of 0.493 N load for 15 s using a microhardness tester (HMV-2; Shimadzu). Three measurements per specimen were conducted in different locations, and then the mean values were calculated.

Scanning electron microscopy (SEM) observations

The shapes and sizes of the abrasive particles extracted from the pastes in each PMTC paste were observed using SEM (FE-8000; Elionix). From each PMTC paste, 10 g of paste was collected and diluted with 100 g DW, filtered using a paper, and then dried in a 37°C incubator for 24 h. The dried abrasive particles were coated with a thin film of gold in a vacuum evaporator (Quick Coater Type SC-701, Sanyu Electron). The SEM observations were conducted at an operating voltage of 10 kV and a magnification of 1,000×.

Statistical analysis

After the confirmation of normal distribution (using the Kolmogorov-Smirnov test) and homogeneity of variance (using Bartlett's test), the Ra data for each group were subjected to analysis of variance (ANOVA) followed by Tukey's HSD test at a significance level of 0.05. The analysis factors involved 1) whether PMTC was conducted or not, 2) the type of the PMTC paste, and 3) the type of the material. One-way ANOVA followed by Tukey's HSD test ($\alpha = 0.05$) was used for comparisons within subsets of the Ra and KHN data. The statistical analyses were conducted using statistical software (Sigma Plot ver. 13.0, Systat Software).

Results

Surface roughness (Ra)

Three-way ANOVA showed that all the factors had a significant influence on the Ra values ($p < 0.001$), and all the interactions between the factors were significant ($p < 0.05$). The baseline Ra values and those after PMTC in each group are shown in Table 2.

Although the baseline Ra of most of the materials showed similar values, the Ra values of DEN were approximately seven times rougher than those of the other materials. In contrast, the Ra values after PMTC were dependent on both the material and the PMTC paste. However, the DW group after PMTC exhibited the lowest Ra values compared with the other PMTC paste groups irrespective of the subjected material, although the individual differences were often not statistically significant. The subjected materials with MR exhibited significantly higher Ra values post-PMTC than the other PMTC paste groups in all the subjected materials. For most of the subjected materials, the descending order of the Ra value after PMTC was MR＞CJ＞MF＞CP＞PG＞MP＞DW. For ENA, although the groups with CJ, MR, and MF exhibited significant differences in Ra between baseline and post-PMTC, the other PMTC paste groups did not reveal any significant differences between baseline and post-PMTC Ra values (Fig. 1). For DEN and FSU, there was no significant difference in Ra between baseline and post-PMTC using DW and MP. Still, the other PMTC groups exhibited significantly higher Ra values after PMTC. For IEC, all the groups after PMTC demonstrated significantly higher Ra values than those at baseline apart from DW. After PMTC, MR exhibited a significantly higher Ra value than the other PMTC pastes.

To understand the changes in Ra after PMTC, the symmetric change rate (SCR) was calculated using the following formula:

SCR (%) = (Ra value after PMTC − Ra value at baseline) / ([Ra value after PMTC + Ra value at baseline]/2) × 100

The SCRs were in the range of 10.2–141.6% for ENA, 7.7–90.0% for DEN, 8.7–165.6% for FSU, and 19.6–156.8% for IEC. The groups with MR exhibited higher SCRs and those with DW exhibited lower SCRs than the other groups, irrespective of the type of subjected material.

Surface observations before and after PMTC

The CLSM observations revealed different surface features with different materials and PMTC pastes. For ENA, although generally parallel scratches were observed in the baseline group, the other groups exhibited several irregular scratches. All the post-PMTC groups exhibited similar surface features, besides the MR group. When MR was used, the scratches on the subjected materials were deeper and more clearly visualized (Fig. 1). For baseline DEN, opened dentinal tubules and parallel scratches were clearly visualized. Although the opened dentinal tubules were not observed for the groups of DW, MF, and MR, the other groups exhibited opened dentinal tubules clearly. Relatively deep and irregular scratches were observed for the groups of CJ, CP, MR, and MF (Fig. 1). In the baseline groups of FSU and IEC, smoother surfaces were observed than those of specimens subjected to the PMTC paste (Fig. 2). The surface features in FSU and IEC after PMTC were similar to those for ENA and DEN. The groups with MR for both FSU and IEC exhibited deeper and clearer irregular scratches on the surfaces than the other PMTC paste groups. The MP groups exhibited relatively smoother surfaces than the other PMTC paste groups (Fig. 2).

KHN

The mean KHN values of the tested materials are shown in Table 3. The KHN was material-dependent, and IEC exhibited a significantly higher KHN than the other materials. The KHN of

IEC was three times higher than that of ENA and approximately 8-10 times higher than those of FSU and DEN. DEN revealed a significantly lower KHN than the other materials. All differences in KHN were found to be statistically significant.

SEM observations of abrasive particles

Fig. 3 depicts the representative SEM images of abrasive particles in each PMTC paste. Although the shapes of abrasive particles in most of the PMTC pastes were irregular, those in PG were rather rounded. The sizes of the abrasive particles were different in different PMTC pastes, and the descending order of the size of abrasive particles was MR＞PG＞CJ≧CP＞MF＞MP. The abrasive particles in MR were typically 10-30 μm in size, and those in PG were typically 10-20 μm. The other PMTC pastes used in this study had a wide size range of abrasive particles as follows: CJ, CP, and MF had particles measuring＜10 μm in size, and MP had nanosized filler particles. The abrasive particles of MF and MP were aggregated.

Discussion

The results of surface roughness measurements after PMTC showed that the type of the PMTC paste and the subjected material had a significant influence on the Ra values. Furthermore, the CLSM observations revealed different surface features obtained with different subjected materials and PMTC pastes. Therefore, the second null hypothesis of this study, that the surface roughness and morphological features after PMTC would not be influenced by the used type of PMTC paste and the subjected materials, was rejected. However, when comparing Ra values after PMTC with CP and PG, no significant differences in Ra were observed for any subjects, apart from FSU. Therefore, the first null hypothesis, that the surface roughness and morphological features of the subjects after PMTC would not differ between the tested one-step PMTC pastes, was only partly rejected.

The RDA value does not directly indicate the polishing or biofilm removal ability of PMTC pastes because this value is based on the quantity of wear of the tooth (13). However, the RDA of PMTC pastes is one of the important parameters defining the rate of abrasion. The RDA of CJ and CP was not available, but the RDA of the tested PMTC pastes ranged approximately from 10 to 180 (Table 1). In general, the factors affecting the rate of abrasion of PMTC are assumed to be the speed and pressure of the rotary instrument, the amount of paste applied, and the features of the abrasive particles (12). The difference in RDA among the PMTC pastes may be attributed to the different abrasive particles used. In particular, the material, shape, size, and hardness of abrasive particles affect the performance of PMTC pastes (12). To date, several types of abrasive materials, including pumice, silicon carbide, aluminum silicate, silicon dioxide, aluminum oxide, zirconium silicate, boron, and calcium carbonate, have been used. These abrasive particles possess different intrinsic hardness and strengths. Although the Mohs hardness scale is a relative measure of mineral hardness based on scratching rather than indentation, the Mohs hardness of abrasive particles is a useful indicator scale when attempting to understand the characteristics of PMTC pastes (12). In the present study, although all PMTC pastes contained silicon dioxide, the structural formulas differed. The primary material of the abrasive particles of MR is pumice, which is composed predominantly of silicon dioxide, some aluminum oxide, and trace amounts of other oxides. The other PMTC pastes contain silica. The Mohs hardness of pumice and silica ranges from 6.0 to 7.0, which is greater than those of enamel (5.0) and dentin (3.0–4.0) (12).

The shape, size, content, and distribution of abrasive particles in PMTC pastes may also influence the surfaces of the subjected material. In the SEM observations, MR and PG exhibited larger abrasive particles than the other PMTC pastes. Regarding the shape of the abrasive particles, all the PMTC pastes have irregular abrasive particles, besides PG. It is likely that large, irregular abrasive particles scratch the surface more deeply and widely than smaller, rounder abrasive particles. The CLSM images obtained after PMTC performed using different types of pastes revealed deep, wide scratches with MR irrespective of the subjected material. Although PG has large abrasive particles, the Ra values after PMTC and the SCR values were lower than those of CJ, CP, MF, and MR in all the subjected materials besides IEC. PG's primary abrasive particles, namely pre-reacted glass-ionomer fillers, are created by an acid-base glass ionomer reaction between polyacrylic acid and fluoroaluminosilicate glass in the presence of water. They form a stable glass-ionomer phase within the glass particles through a process in which they are freeze-dried, milled, silanized, and ground (18). Studies have reported that PG imparts a buffering effect and inhibition of demineralization in addition to possessing antibacterial properties due to the release of different types of ions (22,23). Although the mechanical properties of the core glass remain unaffected, the reacted surface of the PRG filler might be softer than that of untreated fluoroaluminosilicate glass (24). It can be inferred that the lower Ra values and the smoother surfaces after PMTC with PG might be attributed to the surface properties and shape of PRG fillers. MP also exhibited lower Ra values and smoother surfaces similar to PG. This phenomenon can be explained by the lower abrasive ability of MP due to the aggregated nanosized abrasive particles.

Of the PMTC pastes used in this study, MF, MR, and MP were designed as multiple-step PMTC pastes and were used in the following order of RDA value: MF, MR, and finally, MP. Although separating PMTC pastes by purpose makes sense, PMTC procedures are time consuming and expensive (17). In contrast, one-step PMTC pastes can remove harmful substances from the surface and polish it simultaneously. In the present study, CJ, CP and PG were categorized as one-step PMTC pastes. Regarding the Ra values and surface alterations, after PMTC performed using CP and PG, the results were found to be intermediate between MF and MP for DEN, FSU, and IEC. However, the Ra values for ENA with CP and PG were comparable to those of MP. Considering the clinical situations of PMTC, the most common subjected material of PMTC is the enamel surface. Therefore, the tested one-step PMTC pastes may help reduce the complexity of PMTC procedures in clinics. However, the effectiveness of this type of PMTC paste in removing stains and dental plaque remains unclear, and further research is needed to clarify this issue.

In this study, different types of material were used as subjects for PMTC. It is probable that, in the clinic, PMTC will be performed on various restoratives with different hardness and surface properties. In order to understand the surface characteristics of the used materials, the Knoop hardness of the materials was measured. The descending order of KHN value of the materials was IEC ＞ ENA ＞ FSU ＞ DEN. For ceramic restorations, an increase in surface roughness seems to reduce the restoration strength and provides an uneven stress distribution (25,26). Moreover, an increase in surface roughness not only increases plaque accumulation (27) but also affects the color appearance of a restoration due to changes in reflection and diffusion patterns of light (28). In particular, although IEC demonstrated a significantly higher KHN than the other materials, the SCR value with different PMTC pastes was somewhat higher than that with other materials. The SCR values of CJ, CP, and PG in IEC were particularly higher than those of the other subjected materials. IEC contains a higher concentration of silicon dioxide (57.0–80.0%) and has a greater level of the crystalline phase. Vichi *et al*. (29) investigated the effect of finishing and polishing on the roughness of IPS e.max CAD (IEC in this study) and reported that the IPS e.max CAD revealed a rough surface even when polishing was conducted for 60 s. It can be inferred that it might be difficult to recover a smooth surface once the surface is damaged due to its surface characteristics. Although the Ra values of DEN were higher than those of other materials, the SCR values of DEN were lower than those of most of the subjected materials, irrespective of the PMTC paste. This phenomenon might be explained by the rather higher Ra values of DEN at baseline due to the presence of dentinal tubules. However, the Ra values of DEN after PMTC were >0.2 μm, which is the critical threshold surface roughness for inducing biofilm accumulation (30). Therefore, when conducting PMTC on restorations or exposed dentin in the cervical area, care should be taken to select the appropriate PMTC pastes.

Conclusions

1. The surface texture after PMTC was found to be dependent on both the subjected material and the PMTC paste.
2. The Ra values and the morphological surface alterations after PMTC using MR were greater than those of the other PMTC pastes, irrespective of the material.
3. Although CJ, CP, and PG appeared to be effective as one-step PMTC pastes, it is important to consider the features of the subjected material while performing PMTC.

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Tables and Figures

Table 1 Materials used in the study

Code	PMTC paste (Lot No.)	Main components	RDA*	Manufacturer
CJ	Concool Cleaning Jell PMTC (D430)	glycerin, silicic acid, polivinylpyrrolidone, water, others	N/A	Weltec, Osaka, Japan
CP	Clinpro Cleaning Paste for PMTC (9T0050)	silicic acid, glycerin, zeolite, sodium fluoride, sodium lauryl sulfate, isopropylmethylphenol, cetylpyridinium chloride, tricalcium phosphate, others	N/A	3M Japan, Tokyo, Japan
PG	PRG Pro-Care Gel (4G0011)	hydrated silica, S-PRG filler, glycerol, carboxymethylcellulose sodium, sorbitol, sodium dodecyl sulfate, mint flavoring	5-15	Shofu, Kyoto, Japan
MR	Merssage Regular (41256)	pumice, glycerin, carboxymethylcellulose sodium, paraben, sodium monofluorophosphate, others	170-180	Shofu
MF	Merssage Fine (004067)	silica, glycerin, carboxymethylcellulose sodium, paraben, sodium monofluorophosphate, others	40-50	Shofu
MP	Merssage Plus (5852494)	silica, glycerin, carboxymethylcellulose sodium, sodium fluoride, chlorhexidine, hydrochloride, phenoxyethanol, paraben, sodium lauryl sulfate, flavoring, others	< 10	Shofu
	Resin composite			
FSU	Filtek Supreme Ultra (N870378)	bis-GMA, UDMA, TEGDMA, bis-EMA, PEGDMA, zirconia/silica clusters, silica, zirconia		3M Oral Care, St. Paul, MN, USA
	Lithium disilicate			
IEC	IPS e.max CAD (380094)	SiO_2, Li_2O, K_2O, P_2O_5, ZrO_2, ZnO, other oxides, coloring oxides		Ivoclar Vivadent, Schaan, Lichtenstein

RDA*: relative dentin abrasiveness (manufacturers' information), N/A: not available
bis-GMA: 2,2-bis[4-(2-hydroxy-3- methacryloyloxypropoxy) phenyl] propane, UDMA: urethane dimethacrylate, TEGDMA: triethyleneglycol dimethacrylate, bis-EMA: bisphenol A ethoxylate dimethacrylate, PEGDMA: poly ethylene glycol dimethacrylate

Table 2 Surface roughness (Ra: µm) of the specimens cleaned with different PMTC pastes

Code	ENA			DEN			FSU			IEC		
	before	after	SCR	before	after	SCR	before	after	SCR	before	after	SCR
DW	0.028^{Aa} (0.002)	0.031^{Ac} (0.007)	10.2%	0.188^{Aa} (0.028)	0.203^{Ac} (0.034)	7.7%	0.022^{Aa} (0.002)	0.023^{Ac} (0.005)	8.7%	0.023^{Aa} (0.001)	0.028^{Ad} (0.006)	19.6%
CJ	0.028^{Aa} (0.01)	0.051^{Bb} (0.009)	58.2%	0.183^{Aa} (0.022)	0.422^{Ba} (0.067)	79.0%	0.022^{Aa} (0.004)	0.041^{Bb} (0.009)	60.3%	0.025^{Aa} (0.001)	0.062^{Bb} (0.006)	85.1%
CP	0.027^{Aa} (0.001)	0.034^{Ac} (0.004)	23.0%	0.188^{Aa} (0.018)	0.276^{Bbc} (0.040)	37.9%	0.022^{Aa} (0.003)	0.039^{Bb} (0.006)	55.7%	0.024^{Aa} (0.001)	0.054^{Bbc} (0.002)	76.9%
PG	0.027^{Aa} (0.002)	0.033^{Ab} (0.005)	20.0%	0.189^{Aa} (0.016)	0.264^{Bbc} (0.070)	33.1%	0.021^{Aa} (0.004)	0.027^{Bc} (0.004)	25.0%	0.024^{Aa} (0.002)	0.062^{Bb} (0.004)	89.7%
MR	0.026^{Aa} (0.002)	0.152^{Ba} (0.095)	141.6%	0.185^{Aa} (0.016)	0.488^{Ba} (0.046)	90.0%	0.021^{Aa} (0.002)	0.223^{Ba} (0.098)	165.6%	0.023^{Aa} (0.001)	0.190^{Ba} (0.037)	156.8%
MF	0.028^{Aa} (0.003)	0.038^{Bc} (0.009)	30.3%	0.184^{Aa} (0.015)	0.318^{Bb} (0.049)	53.4%	0.019^{Aa} (0.002)	0.045^{Bb} (0.007)	81.3%	0.024^{Aa} (0.001)	0.059^{Bbc} (0.008)	84.3%
MP	0.025^{Aa} (0.003)	0.032^{Ac} (0.005)	24.6%	0.187^{Aa} (0.008)	0.216^{Ac} (0.045)	14.4%	0.020^{Aa} (0.002)	0.024^{Ac} (0.008)	18.2%	0.022^{Aa} (0.001)	0.050^{Bc} (0.006)	77.8%

DW: distilled water, CJ: Concool Cleaning Jell PMTC, CP: Clinpro Cleaning Paste for PMTC, PG: PRG Pro-Care Gel, MR: Merssage Regular, MF: Merssage Fine, MP: Merssage Plus, ENA: Enamel, DEN: Dentin, FSU: Filtek Supreme Ultra, IEC: IPS e.max CAD, SCR: symmetric change rate (%)
The same upper case letter indicates no statistically significant difference for values in the same row at 5% significance level.
The same lower case letter indicates no statistically significant difference for values in the same column at 5% significance level.

Table 3 Knoop hardness number of the tested materials

Code	Mean hardness (KHN)
ENA	295.6 (15.1)[b]
DEN	61.6 (1.6)[d]
FSU	78.1 (6.4)[c]
IEC	619.0 (11.7)[a]

The same lower case letter indicates no statistically significant difference at 5% significance level.

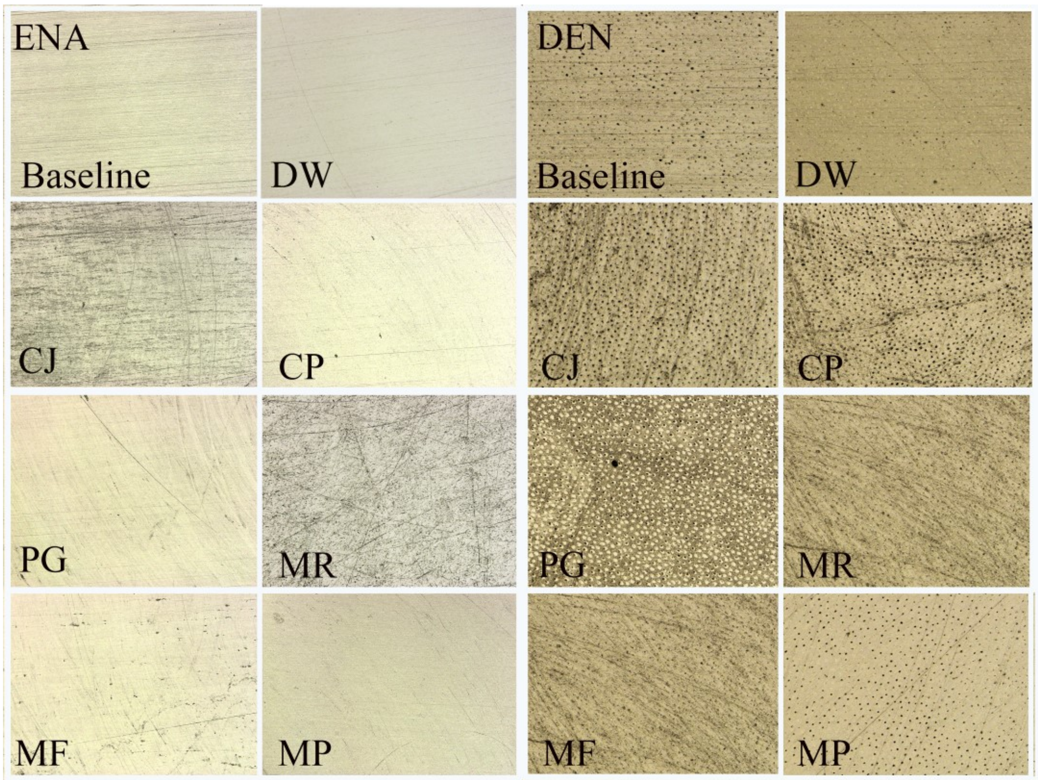

Fig. 1 Representative CLSM images of the ENA and DEN groups after PMTC
ENA, enamel; DEN, dentin; DW, distilled water; CJ, Concool Cleaning Jell PMTC; CP, Clinpro Cleaning Paste for PMTC; PG, PRG Pro-Care Gel; MR, Merssage Regular; MF, Merssage Fine; MP, Merssage Plus

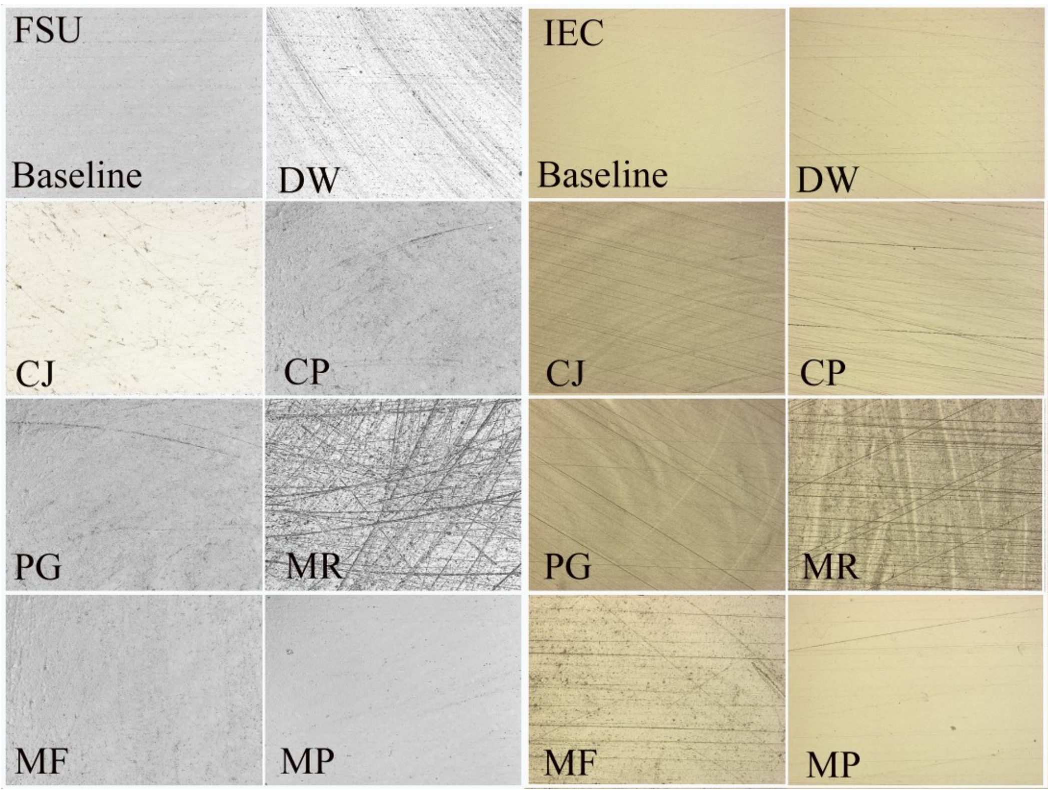

Fig. 2 Representative CLSM images of the FSU and IEC groups after PMTC
FSU, resin composite (Filtek Supreme Ultra); IEC, lithium disilicate (IPS e.max CAD); DW, distilled water; CJ, Concool Cleaning Jell PMTC; CP, Clinpro Cleaning Paste for PMTC; PG, PRG Pro-Care Gel; MR, Merssage Regular; MF, Merssage Fine; MP, Merssage Plus

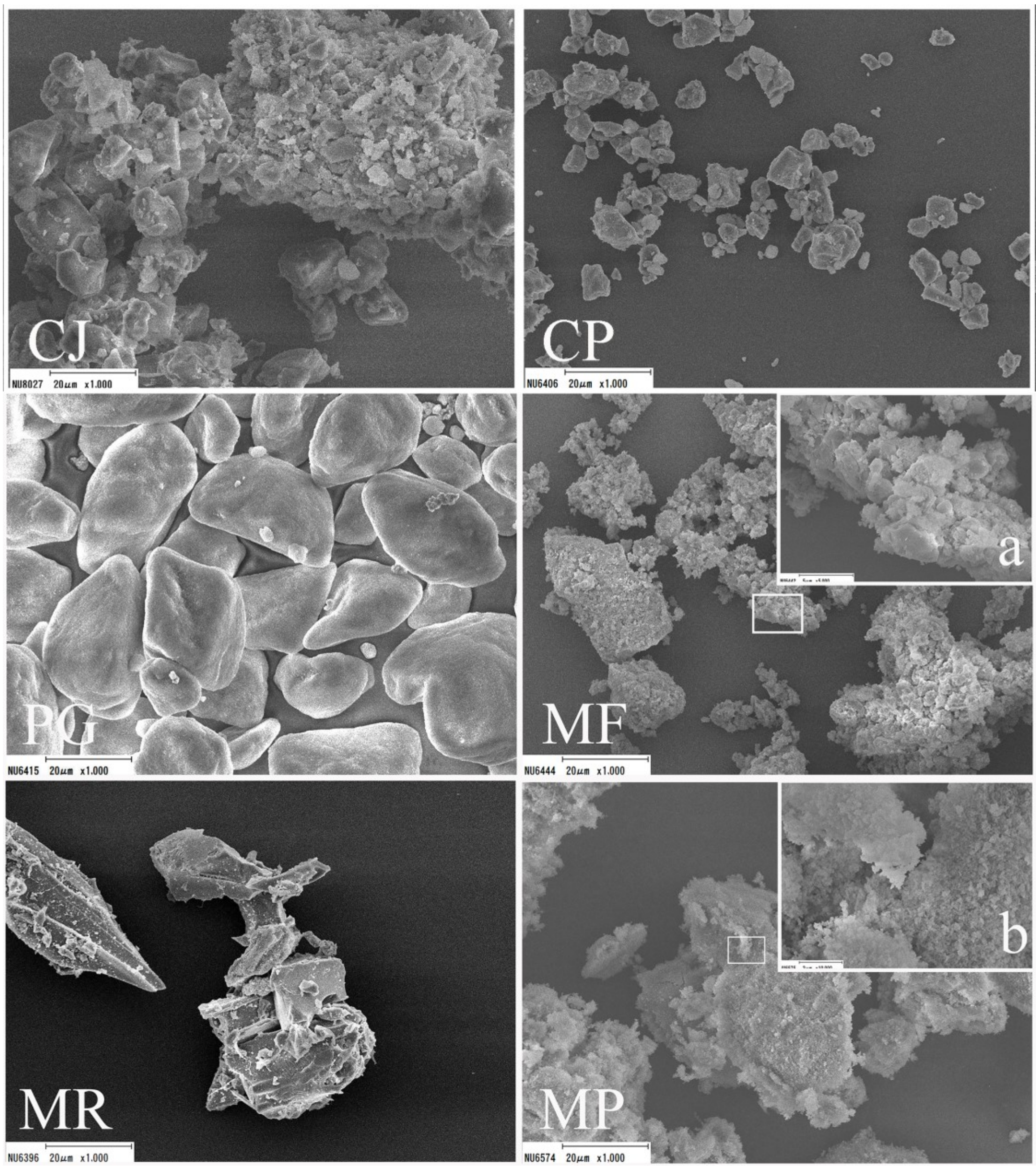

Fig. 3 SEM images of abrasive particles of the PMTC pastes
CJ, (1,000×); CP, (1,000×); PG, (1,000×); MR, (1,000×); MF, (1,000× and [a] 5,000×);
MP, (1,000× and [b] 10,000×)
CJ, Concool Cleaning Jell PMTC; CP, Clinpro Cleaning Paste for PMTC; PG, PRG Pro-Care Gel; MR, Merssage Regular; MF, Merssage Fine; MP, Merssage Plus