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Effects of professional mechanical tooth cleaning during maintenance on implant abutment surface

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In this study, we assessed the influence of professional mechanical tooth cleaning (PMTC) on the surface roughness of implant abutments. This study aimed to determine the optimal PMTC conditions for effectively cleaning the abutment surface without causing damage. To achieve this, we investigated the effects of load, rotation speed, and polishing time on surface texture during PMTC. We utilized a titanium disk measuring 5 mm in diameter and 1.5 mm in thickness. Using three types of pastes with different abrasive particle sizes, PMTC was performed at 1500 rpm, 250 gf, and 15 s, with different combinations of load, rotation speed, and polishing time. The roughness of the disk surface before and after PMTC treatment was compared using scanning electron and confocal laser scanning microscopes. In PMTC, using a paste with large abrasive particles, both load and polishing time influenced surface quality. Furthermore, even with light pressure and short duration, surface roughness increased, highlighting the suitability of using a paste with small abrasive particles for PMTC. (J Osaka Dent Univ 2024; 58: 383-390)

Key words: Professional mechanical tooth-cleaning; Implant abutment; Surface roughness; Titanium; Confocal laser scanning microscope

INTRODUCTION

Professional mechanical tooth cleaning (PMTC), proposed by Axelsson *et al.*[1] in the 1990s, is widely practiced as a standard professional care procedure to uphold oral health.[2-5] PMTC aims to remove plaque retention factors such as biofilms and stains through cleaning instruments. However, definitive guidelines regarding its procedural protocol or the choice of PMTC paste are lacking. Therefore, depending on the technique employed, a risk exists of causing damage to the tooth or restoration surface.[6-10] In a study investigating the surface roughness of dental crown restorations after using PMTC paste, Kawamoto *et al.*[11] reported that changes in surface roughness after PMTC differed depending on the characteristics of the abrasive particles in the PMTC paste and the working time. In our preliminary experiments, we investigated the effects of PMTC on different restoration materials. Our findings suggested the need for caution when using pastes containing large abrasive particles, as they may potentially damage surfaces of materials weaker than titanium, even under typical PMTC conditions (Fig. 1).

The widespread use of dental implants and the development of diverse dental prosthetic materials like zirconia have greatly enhanced the restoration of oral function and esthetics; thereby, improving patients' quality of life.[12-14] However, this has led to a more complex intraoral environment due to the presence of different prosthetic types. Therefore, in clinical practice, adequate knowledge and precise methods are essential for implementing PMTC effectively. However, in reality, uniform PMTC is repeatedly applied to various materials. In our prelimi-

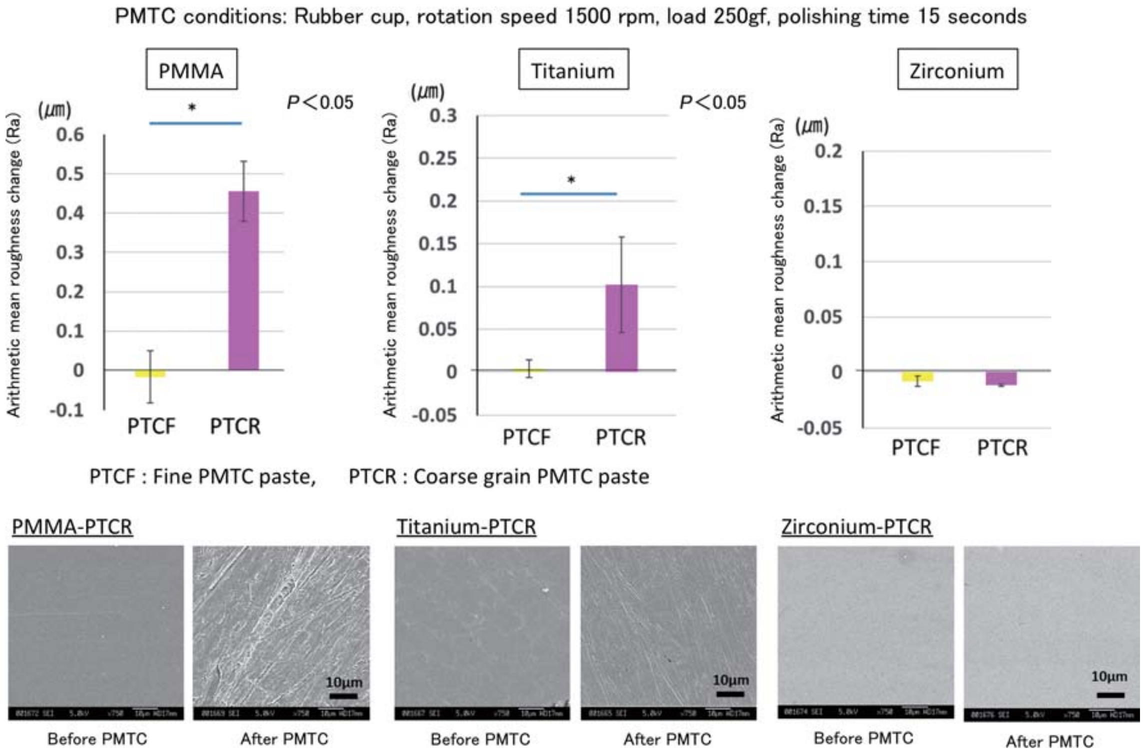

Fig. 1 Preliminary experimental results on the influence of PMTC on different crown restoration materials. PMTC, professional mechanical tooth cleaning.

nary survey of dental hygienists, we conducted a questionnaire survey regarding the actual state of PMTC in clinical practice. The findings, as shown in Fig. 2, revealed a diverse implementation status of PMTC, indicating that practitioners currently follow a uniform PMTC procedure outlined in their respective manuals. Kato[15] proposed the maintenance of a good oral environment by advocating for personalized professional care rather than the repetitive application of uniform PMTC. Although careful attention to the effects of PMTC on each material is imperative, reports on the impact of PMTC on the surface properties of restorations crafted from titanium, zirconia, and similar materials remain scarce.[11, 16]

In this study, we assessed the influence of PMTC on the surface roughness of implant abutments. This study aimed to determine the optimal PMTC conditions for effectively cleaning the abutment surface without causing damage. To achieve this, we investigated the effects of load, rotation speed, and polishing time on surface texture during PMTC.

MATERIALS AND METHODS

Titanium disc

For the experimental sample, Type III pure titanium, commonly employed for implant abutments, served as the material. A titanium disc (GC Co., Ltd., Tokyo, Japan) measuring 5 mm in diameter and 1.5 mm in thickness was fabricated through milling. The prepared titanium disk was mirror-polished using an automatic polishing machine (Maruto Instrument Co., Ltd., Tokyo, Japan) with waterproof abrasive paper #1200-4000 and 1 μm alumina paste (surface roughness Ra = 0.072 ± 0.014 μm) (Fig. 3).

PMTC paste

Three types of PMTC pastes with different particle sizes and mechanisms of action were used for PMTC (Fig. 4). The characteristics of each are shown below. MERSSAGE Regular® (MER) (Shofu INC., Kyoto, Japan) is a coarse-grained, two-step type paste for rough polishing. GLACIS® (GLA)

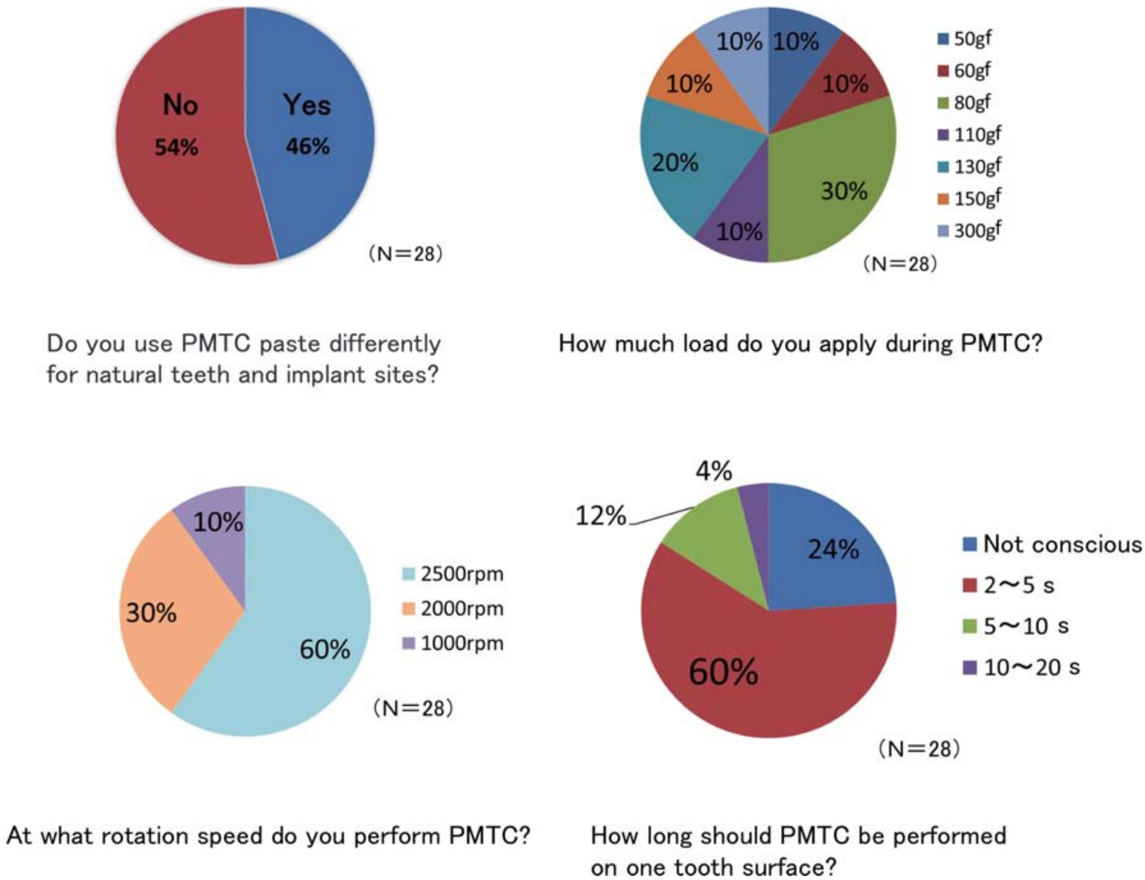

Fig. 2 Results of a questionnaire survey regarding the implementation status of PMTC among dental hygienists. PMTC, professional mechanical tooth cleaning.

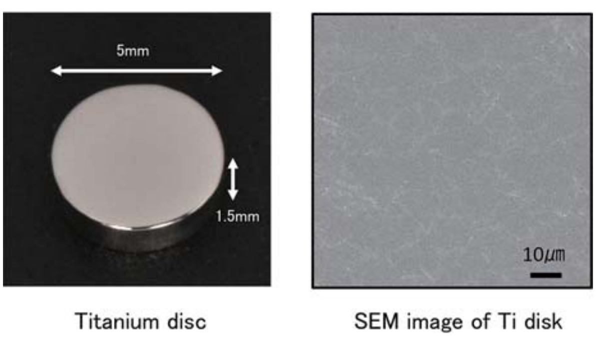

Fig. 3 Appearance and SEM image of the titanium disk used in the experiment. SEM, scanning electron microscopy.

(Yoshida Co., Ltd., Kyoto, Japan) is a single-paste type with particle sizes transitioning from coarse to fine. Its abrasive gradually degrades, enabling rough polishing and finishing with a single paste. RUSCELLO WHITE® (RW) (GC Co., Ltd., Tokyo, Japan) is a fine particle paste characterized as weakly alkaline, facilitating the lifting and removal of stains.

Cleaning equipment and PMTC conditions

A rubber cup designed for surface polishing and cleaning (T-251S Prophy Cup, Premium Plus Japan Co., Ltd.) was attached to the contra-angle handpiece, ensuring perpendicular contact with the titanium disk. PMTC was performed at 1500 rpm, 250 gf, and 15 s, with different combinations of load, rotation speed, and polishing time. To maintain uniformity across all PMTC procedures, a dedicated holder with the disk securely installed was positioned on a scale. An experienced dental hygienist conducted the PMTCs while monitoring the prescribed conditions (Fig. 5).

Fig. 4 Characteristics of the three types of PMTC paste used in the experiment. PMTC, professional mechanical tooth cleaning.

The load	50gf	150gf	250gf	350gf

Rotation speed	500rpm	1500rpm	2500rpm

Polishing time	5s	15s	45s

(N=5)

Fig. 5 PMTC condition settings and implementation using a scale. PMTC, professional mechanical tooth cleaning.

Analysis of surface roughness

The roughness of the disk surface before and after PMTC treatment was compared using scanning electron microscopy (SEM, S-4800, Hitachi, Tokyo, Japan) and confocal laser scanning microscope (vk 9710, Keyence, Osaka, Japan).

Statistical analysis

Statistical software was used to compute the mean and standard deviation for each parameter in every group, and a one-way analysis of variance was employed for comparison (Statcel 4; OMS Publisher, Tokorozawa, Japan). Statistical significance was set at $p < 0.05$.

RESULTS

Table 1 displays the changes in arithmetic surface roughness before and after PMTC under each condition.

Regarding the relationship between load and surface roughness, MER and GLA, characterized by larger particle sizes, exhibited a notable trend of surface roughness increasing significantly with higher loads. Furthermore, even at a light pressure of 50 gf, an increase in surface roughness of 0.0799 ± 0.0811 μm and 0.0896 ± 0.0709 μm was observed for MER and GLA, respectively. However, RW, characterized by a smaller particle size, demonstrated no alteration in surface roughness irrespective of the load magnitude (Table 1, Fig. 6).

Regarding the relationship between rotational speed and surface roughness, both MER and GLA, featuring large particle sizes, showed no significant difference between high and low rotational speeds; however, an increase in surface roughness was observed under all conditions. Furthermore, RW,

Table 1 Changes in arithmetic surface roughness before and after PMTC under each condition

	Arithmetic mean roughness change (Ra) (μm)		
	RW	GLA	MER
The road (1500rpm, 15s)			
50gf	−0.0031±0.0234	0.0896±0.0709	0.0799±0.0811
150gf	0.0036±0.004	0.1191±0.0461	0.2046±0.1035
250gf	0.0217±0.0266	0.1959±0.0772	0.1993±0.0753
350gf	0.0056±0.0069	0.2663±0.0391	0.2495±0.0601
Rotation speed (250gf, 15s)			
500rpm	0.0057±0.0085	0.272±0.0875	0.1683±0.0604
1500rpm	0.0217±0.0266	0.1959±0.0772	0.1993±0.0753
2500rpm	0.0155±0.0065	0.3036±0.0535	0.2325±0.0644
Polishing time (250gf, 1500rpm)			
5s	0.0075±0.0053	0.1639±0.0779	0.1799±0.0838
15s	0.0217±0.0266	0.1959±0.0772	0.1993±0.0753
45s	−0.008±0.0084	0.2903±0.0574	0.2799±0.0148

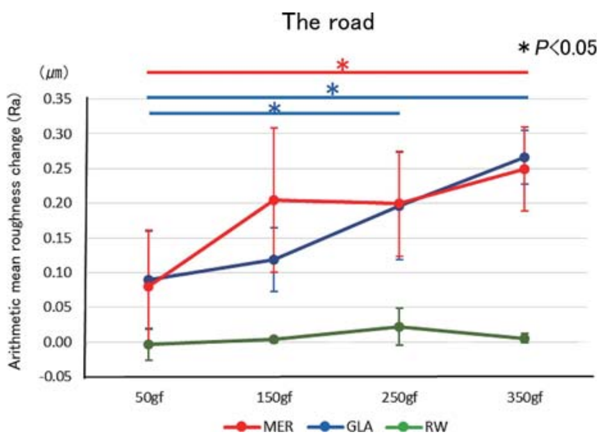

Fig. 6 Changes in surface roughness before and after PMTC under different loads for each paste. PMTC, professional mechanical tooth cleaning.

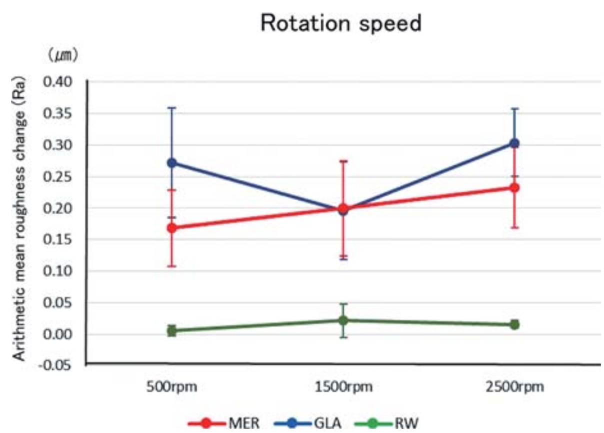

Fig. 7 Changes in surface roughness before and after PMTC at different rotation speeds for each paste. PMTC, professional mechanical tooth cleaning.

characterized by a small particle size, displayed no alteration in surface roughness regardless of the rotation speed (Table 1, Fig. 7).

Although no significant difference was observed in the relationship between polishing time and surface roughness, similar to the relationship with load, MER and GLA, featuring large grain sizes, showed a tendency for surface roughness to increase with prolonged polishing time. Furthermore, even for a short period of 5 s, an increase in surface roughness of 0.1799±0.0838 μm and 0.1639±0.0779 μm was observed in MER and GLA, respectively. Conversely, RW, with a small grain size, demonstrated no alteration in surface roughness regardless of the polishing time (Table 1, Fig. 8).

DISCUSSION

In this study, we investigated factors influencing surface roughness during PMTC on titanium, a frequently utilized material for implant abutments. The results revealed that when using coarse-grained PMTC paste, the load and polishing time affected

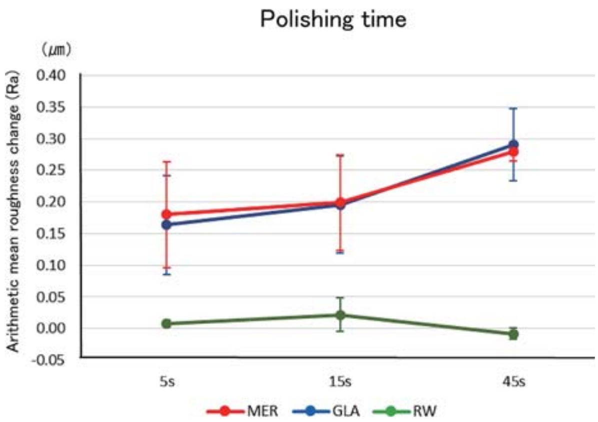

Fig. 8 Changes in surface roughness before and after PMTC for different polishing times for each paste. PMTC, professional mechanical tooth cleaning.

the surface roughness. These results align with previous studies, highlighting the role of PMTC paste properties in determining surface roughness.[6-9] Few studies have detailed the influence of PMTC conditions on surface roughness as extensively as our study, making the data on polishing pressure and time particularly valuable. Furthermore, aligning our experimental data with the findings from our preliminary survey on actual clinical PMTC conditions, we found that PMTC was performed within the range shown in Fig. 9. Within this range, rotational speed and polishing time showed no significant differences. Therefore, when employing PMTC paste with large grain sizes in clinical practice, particular attention should be paid to the load. What adds to the intrigue is that surface roughness increased even under the lowest conditions for each factor. Specifically, in PMTC using paste with large particle size, surface roughness escalated even with light pressure and short durations.

Peri-implantitis, the primary complication associated with dental implants,[17] arises from bacterial infection due to plaque accumulation. Preventing bacterial adhesion around implants is crucial in averting peri-implantitis.[18] Previous reports frequently indicate a positive correlation between surface roughness and bacterial adhesion.[19-23] Teranaka *et al.*[24] reported that Ra of 0.1 μm or more tends to affect the number of viable bacteria. Additionally, Dhir *et al.*[25] suggested a threshold of approximately 0.2 μm for surface roughness affecting biofilm formation. These findings imply a potential threshold, either at 0.1 or 0.2 μm, for surface roughness influencing biofilm formation. Therefore, from a bacteriological point of view, using a PMTC paste like RW, which avoids relying on abrasives and causing damage, is advisable, rather than MER or GLA, both of which elevate surface roughness beyond 0.1 μm.

"I want to remove dirt, but I do not want to cause scratches." This challenge has gained prominence with the increasing popularity of PMTC. Establishing a PMTC methodology is crucial to prevent peri-implantitis and ensure long-term stability. However, as previously mentioned, a clear guideline for the surgical technique of PMTC is currently absent, re-

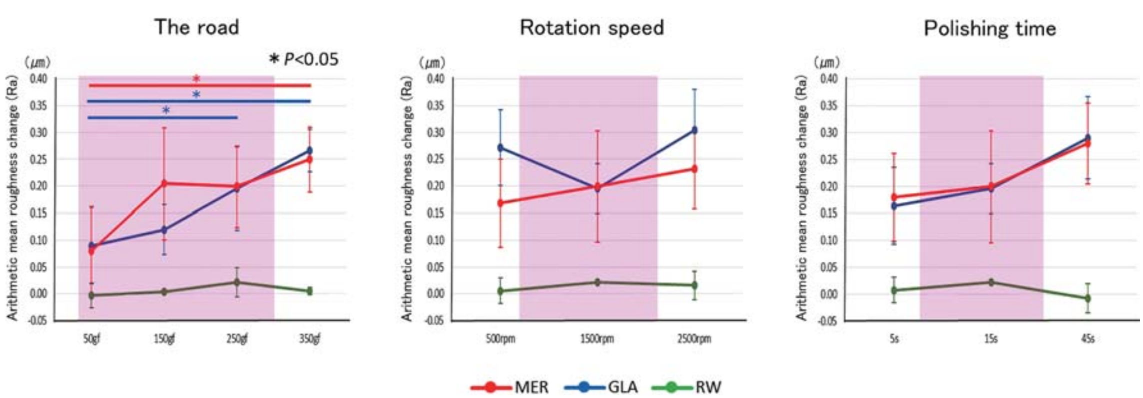

Fig. 9 Impact of each condition on PMTC based on the implementation status reported by dental hygienists. PMTC, professional mechanical tooth cleaning.

sulting in variations in its implementation across clinical practices. Moreover, a uniform PMTC with a unique manual for each individual is lacking. The hope is for continued progress in PMTC research and the prompt establishment of a protocol.

In this study, load and polishing time affected the surface texture in PMTC using paste with large abrasive particles. Furthermore, surface roughness increased even with light pressure and for a short duration. Therefore, using a PMTC paste that avoids damaging the surface and employs a mechanism not reliant on abrasives is advisable.

Acknowledgments
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Conflicts of interest
The authors declare no conflicts of interest associated with this study.

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