**Effect of polishing protocols on the surface roughness of polyetheretherketone**

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**Abstract:** The purpose of this study was to evaluate the influence of various polishing protocols on the surface roughness of polyetheretherketone (PEEK). This study also aimed to develop an effective polishing method of dental prostheses at the chairside. The PEEK specimens were assigned to seven groups with different protocols: no additional polishing (NT); polishing using a rubber point (C); polishing using “silky shine” (S); polishing using “aqua blue paste” (A); protocol C followed by protocol S (CS); protocol C followed by protocol A (CA); and protocol C followed by protocols S and A (CSA).

The surface roughness (Sa and Ra) of the polished surfaces was measured. The surface roughness decreased in the following order of groups: NT, C, S, CS, CSA, CA, and A. In Groups C and S, wide deep pits formed by abrasive grains of SiC paper were observed, whereas only fine linear structures were observed on the surface in other groups. With respect to the polishing protocol of PEEK, clinically acceptable surface roughness was obtained using a soft polishing brush and agent for more than 3 min.

**Materials and Methods**

**Materials**

Table 1 shows the materials prepared and used in this study: non-filler-type PEEK; two types of rotating polishing instruments, the abrasive rubber point and the soft polishing brush; and two types of polishing agents, a liquid-type “silky shine” and a paste-type “aqua blue paste.”

**Specimen preparation**

PEEK specimens were prepared as cylinders of 10-mm diameter and 10-mm height. The specimens were designed on a computer and machine-milled (RXP500 DSC, Röders GmbH, Soltau, Germany). All specimens were manually trimmed, and the bases of the cylinders were polished under water using 800-grit abrasive SiC paper, followed by ultrasonic cleaning in 70% isopropanol for 15 min. Finally, all specimens were washed three times with distilled water.

**Surface treatment modalities**

Six PEEK surface-polishing protocols were prepared, and all procedures were randomly performed by a single practitioner (K.K.) to minimize outcome variability.

NT: No additional polishing

C: Polishing using a rubber point for 1 min at a rotation speed of 20,000 rpm

CS: Polishing using a rubber point for 1 min at 20,000 rpm, followed by polishing using “silky shine” and a soft brush for 1 min at 10,000 rpm

CSA: Polishing using a rubber point for 1 min at 20,000 rpm, followed by polishing using “silky shine” and a soft brush for 30 s at 10,000 rpm and polishing using "aqua blue paste" and a soft brush for 30 s at 10,000 rpm (in that order)

CA: Polishing using a rubber point for 1 min at 20,000 rpm, followed by polishing using "aqua blue paste" and a soft brush for 1 min at 10,000 rpm

S: Polishing using “silky shine” and a soft brush for 3 min at 10,000 rpm

A: Polishing using “aqua blue paste” and a soft brush for 3 min at 10,000 rpm

All rotating polishing instruments were attached to a dental micromotor (EWL K11, KaVo Dental, Biberach, Germany). Polishing was repeated by adding the respective polishing paste every 30 s. The rotation number and polishing time were determined based on the operation manual of the polishing agents and previous literature, respectively.

The specimens were washed with distilled water and dried after every polishing step. Post-polishing, all specimens were ultrasonically cleaned in 70% isopropanol for 15 min, washed three times with distilled water, and then air-dried.

Ten specimens were prepared for each of the seven conditions mentioned above.

**Surface roughness measurement**

The specimens’ mean surface height (Sa) and the assessed surface profile’s mean deviation (Ra) were measured using a laser microscope (Optelics Hybrid, Lasertec Corp., Yokohama, Japan). Three points per base surface were measured, and the median value was used as the representative value of the specimen. Ra, the most widely used parameter in evaluating surface roughness, presents the average surface roughness in two dimensions, and Sa is obtained by extending Ra in three dimensions; thus, the influence of directional scratches becomes very small, making it possible to obtain a
stable result.

The mean values of the seven groups were compared using the Kruskal-Wallis and Games-Howell post-hoc test. A significance level of 0.05 was used. The data were analyzed using the IBM SPSS Statistics, Version 24.0 software package (IBM Corp., Armonk, NY, USA).

Results

Table 2 shows the Sa and Ra values for every polishing protocol. Sa and Ra for Group NT showed the largest values, 0.69 μm and 0.65 μm, respectively. These values were more than 0.5 μm, which represents recognizable roughness. Among the polished groups, surface roughness decreased in the following order: Groups C, S, CS, CSA, CA, and A. The surface roughness of Groups C and S exceeded the threshold value of 0.2 μm, whereas that of the other groups was below 0.2 μm, which is the threshold for bacterial adherence.

The surface roughness of the six polished groups was significantly lower than that of Group NT. Furthermore, the surface roughness of Group C was significantly higher than those of the other five polished groups. The Sa value of Group A was significantly lower than those of Groups CS, CA, and S, whereas its Ra value was significantly lower than those of Groups CS, CSA, and S.

The two-dimensional images captured using the laser microscope are shown in Fig. 1. In Group NT, roughness was observed throughout the surface. In Groups C and S, wide deep pits formed by abrasive grains of SiC paper were captured on the images, whereas only fine linear structures were observed on the surfaces in the other groups. Three-dimensional color-mapped images of the surfaces in Fig. 2 support this result. The find-
In this study, the three-body abrasive wear mode of PEEK surface in Groups CS, C, A, and S showed lower surface roughness than the two-body mode in Group C, as suggested in the two aforementioned previous studies [8,9]. Further, the effect of “silky shine” for thermoplastics was smaller than that of the polish used in the other five polished groups, and the surface roughness for the three polishing protocols that included “silky shine,” CS, C, and S, was high. In contrast, protocols that used the “aqua blue paste” for the resin/metal offered more effective polishing, especially when only the “aqua blue paste” was used for a long duration in Group A.

Compared with the polished surface roughness of other polymer materials used in dental prostheses, it has been reported that the average roughness of the thermoplastic resin polished using a paste-type polishing agent/compound in combination with the buff ranged between 0.12 and 0.28 μm [10-12]. In the present study, as the surface roughness of the six polished groups of PEEK was lower than that reported in previous works, the researchers suggest that the surface properties of PEEK are better than those of other thermoplastic resins. Additionally, it has been reported that the average roughness of acrylic resin polished using a paste-type agent/slurry ranged between 0.02 and 0.20 μm [13-16]. These values are lower than those of the five polished PEEK groups. It has also been reported that Ra and Sa values of the resin composites used as restorative materials that need to be polished in the oral cavity range between 0.1 and 0.3 μm and between 0.13 and 0.23 μm, respectively [17-21]. The abovementioned inferences and results obtained in this study suggest that PEEK can be polished into a sufficiently smooth surface for use as a dental prosthesis.

Although a multiple-step polishing protocol can provide a smoother surface, a single-step polishing protocol is preferable at the chairside to save time and expense [20]. In the actual polishing procedure, the following measures are also needed: reducing frictional resistance and minimizing change in temperature of the material surface during polishing, avoiding splashing the polishing agent, and ensuring that the polishing agent can be easily washed away after polishing to avoid bacterial adherence. Furthermore, preferably, polishing should be performed while adding a soluble paste, such as the “aqua blue paste,” at regular intervals.

Thus, it can be concluded that clinically acceptable surface roughness of PEEK was obtained using polishing agents with a soft polishing brush; in particular, the polishing agent for resin/metal is more effective than that for thermoplastic resin.

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Conflict of interest

The authors have no conflict of interest in the companies whose materials are mentioned in the article.

References


