Recycling of used alginate impression materials into final polishing powder for methacrylate denture base resins

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Abstract

Purpose: The purpose of this study was to recycling diatomite from alginate impression materials and investigate its potential as an abrading agent for denture base resins.

Materials and Methods: After heating hardened alginate impression materials, a lump-like solid was powdered using a mortar and a pestle. The powder (experimental sand, ES) was characterized by X-ray diffraction (XRD). To explore the suitable ES/wax ratio, three amounts (1, 3, and 5 g, corresponding to samples ES1, ES3, ES5, respectively) were blended with 6 g of casting wax. Casting wax bars without ES were also prepared as the control. In addition, commercial diatomite (reagent-grade diatomite, RD) and a commercial final polishing product for acrylic resin (TE) were examined and compared. A disk-shaped self-curing resin (diameter: 30 mm, thickness: 3 mm) was prepared as a specimen and ground by polishing paper (#800 -1,000). Surface gross measurements and surface roughness values after polishing were determined using a gross meter. These surface roughness and gloss data were statistically analyzed by one-way ANOVA and Tukey’s multiple comparison test ($\alpha = 0.05$).

Results: Based on the XRD results, diatomite was successfully detected in the heated alginate impression material. Sample ES3 showed good performance in experimental polishing tools, and its polishing effects were almost identical to those of RD. However, ES3 was inferior to TE in terms of surface gloss, and ES0 exhibited no polishing effect.

Conclusion: Within this limited study, diatomite obtained from alginate gel was found to be effective as the final polishing material in denture base resin.

Key Words: alginate impression material, denture base resin, diatomite, final polishing, surface gloss

Introduction

Environmental problems such as climate variability and air and marine pollution are becoming increasingly serious globally each year [1]. It is known that industrial activities are the main cause of these environmental issues; the activities of industries are controlled by regulations and/or penalties. However, each individual also contributes in terms of their diligence toward waste disposal. One solution is to build a recycling-oriented society based on the “three Rs” (i.e., reduce, reuse, recycle) in addition to resource and energy saving [2].

Re-melting of metallic materials is the most common method of recycling in the dental field [3-5]. For metallic materials used in casting, the removed metal blocks are often reused by adding virgin metal. In particular, this practice is performed for precious metal alloys. On the other hand, researches with wrought alloy have been conducted on the reuse of dental mini-implants for orthodontic treatment [6,7]. NiTi alloy as an orthodontic wire is also non-castable that frequently used in clinical practice. However, these have also been reported to change characteristics with the sterilization process for reuse [8]. Relevant studies have also been conducted in the field of dental implants [9,10].

In routine dental treatments, alginate impression materials are extremely popular. Although this material is inappropriate for precision gypsum model fabrication due to large dimensional change, it is reasonable to make a snap impression and/or a combination with agar impression. Alginate impression materials are flammable because of their large elastic strain and are composed of calcium phosphate (CaSO$_4$), diatomite (SiO$_2$), tri-sodium phosphate, and sodium alginate [11]. Diatomite is an inorganic material that accounts for approximately 70% of alginate impression materials and is incorporated to increase their strength. Silicon dioxide (silica, SiO$_2$) is contained in numerous dental materials and is used in refractory materials (cristobalite and quartz) in dental investment, as glass components for dental porcelain, as a filler in esthetic composite resin restoration, and as the main powder component in glass ionomer cement. Alginate impression materials become industrial waste after the construction of the gypsum cast.

According to dentistry textbooks, diatomite is helpful as an abrasive grain for the final polishing of denture base resin. Diatomite is incorporated into several polishing tools in the form of free, abrasive grains. Diatomite is added to reinforce the alginate impression material and is not involved in the reaction; therefore, it remains in the alginate impression material after use. Based on these facts, the recycling of diatomite in alginate impression materials for use as abrasives in denture base resins was investigated. The purpose of the present study was to construct an original polishing tool from the alginate impression material used as an abrading agent.
Materials and Methods

Experimental diatomite powder from alginate impression
A commercial alginate powder (Algiace Z, Dentsply Sirona, Tokyo, Japan) was used in this experiment. Referring to the instruction manual, a powder of 8.4 g was mixed with 20 mL water. The obtained alginate gel was prepared by recycling. After heating in a laboratory furnace (KDF009; Denken, Kyoto, Japan) at 800°C for 30 min, a lump-like solid was left inside, which was powdered using a mortar and pestle. The sequence of steps is shown in Fig. 1.

To identify the newly formed compound, the powder (experimental sand, ES) was analyzed by X-ray diffraction (LabX XRD6100; Shimadzu, Kyoto, Japan) with Cu Kα radiation at 40 kV and 30 mA. The scanning range was 10-80 degrees at 2θ with a scanning speed of 2˚/min. Under these conditions, reagent-grade diatomite (RD, diatomaceous earth, 08272-65; Nakarai Tesque, Kyoto, Japan) was also examined and compared. Furthermore, microscopic imaging was conducted using a scanning electron microscope (SEM; S-5500, Hitachi High-Tech, Tokyo, Japan) to determine the microstructure of ES.

Polishing rod manufacturing
Clinically, denture-base acrylic resin is normally polished with diatomite or zinc oxide powder using a high-speed lathe device. However, it is difficult to apply this method for small-sized restorations made of acrylic resin. Thus, preparation of rod-shaped abrasives as well as green and red rouge for metal finishing was investigated.

A commercial AA battery was planted on the plastic palate, and the impression was made using a silicone rubber impression product (Duplicon, Shofu, Kyoto, Japan). The hole (diameter 12 mm, height 25 mm) was intentionally formed. A commercial dental casting wax (Blue inlay wax, GC, Tokyo, Japan) was melted in a small pot, and then the ES was mixed and poured into the hole. Figure 2 shows the manufacturing process of the polishing rod. To determine the ideal ES/wax ratio, three amounts (1, 3, and 5 g, corresponding to sample codes ES1, ES3, ES5, respectively) were blended for 6 g of casting wax. Casting wax rods without ES were also prepared as a control. In addition, the commercial diatomite described above and commercial final polishing product for acrylic resin (TE, Terukijin, Eikan-sizaisha, Tokyo, Japan) were also examined and compared.

Specimen preparation
Self-curing methyl methacrylate (MMA) resin (UniFast II, GC, Tokyo, Japan) was selected to simulate the final polishing of interim restoration. After molding into a disk shape (diameter 30 mm, thickness 3 mm), the self-curing resin was mixed and poured according to the manufacturer's instructions and then polymerized at room temperature. Twelve specimens were prepared and fashioned into a disc-like shape. Prior to polishing examination, all specimens were ground by abrasive paper #800-1,000 (Waterproof silicon carbide paper, Riken Corundum, Tokyo, Japan) under the same experimental conditions.

Polishing examination
As shown in Fig. 3, each disk-shaped specimen was baff-polished by a free hand with slight pressure. Before the polishing examination, the rotating felt wheel was intermittently pressed into an experimental polishing rod, and then both wax and diatomite were infiltrated to the inside of the wheel. Baff polishing time was limited to 30 s, and one operator engaged in all polishing experiments.
Evaluation of polishing effects
Surface gross measurements after polishing were performed using a gross meter (GM 26Dual, Murakami Color Research Laboratory, Tokyo, Japan). The incident angle was set at 60˚, depending on the subject. Similarly, surface texture was also evaluated by the surface roughness (Ra) value. Measurements were performed using an accuracy surface roughness and contour measuring instrument (Surfcom480A, Tokyo Seimitsu, Kawasaki, Japan). The measuring distance and cut-off value were 4 mm and 0.8 mm, respectively. Each test was repeated five times per specimen, and the calculated average value was adopted as the data.

Statistical analysis
All data were evaluated for dispersibility by Bartlett's test and then both average values of surface roughness and surface gross were statistically analyzed by one-way ANOVA and Tukey’s multiple comparison test (KareidaGraph software, ver. 4.0; Hulinks Inc., Tokyo, Japan) to evaluate the differences between ES and controls. The level of significance was set at 0.05.

Results
The SEM image of the ES is shown in Fig. 4. Diatomite is widely known as a photomicrograph sample due to its characteristic shape; a regular, mesh-like shape, indicated by an arrow, can be observed in this SEM image.

Figure 5 shows the XRD results for alginate impression materials before and after firing. Initially, hemihydrate gypsum was present in the powder, but it changed to dihydrate gypsum with hardening by kneading with water. Further, calcium sulfate anhydrite appeared after heating. In both charts, a steep, conspicuous peak corresponding to diatomite appears. The XRD patterns of ES, RD, and TE are shown in Fig. 6. Compared to ES, the pattern for RD was relatively similar; however, the peaks for ES were sharp and those for RD seemed to be amorphous. In contrast, the commercial product was not mainly composed of diatomite, and a strong peak of quartz was detected, even with the same silica.

First, the ratio of the appropriate abrasive to the amount of wax was examined. Prior to testing, the surface of the specimen had 2.78 ± 1.38 (Gs 60˚) and 0.31 ± 0.06 µm (Ra). The results are shown in Figs. 7 and 8. Although the Ra value improved after polishing compared to before polishing, ES0 without ES was found to be less effective. The Ra value from polishing with ES0 was 0.23 ± 0.06 µm. In addition, no significant differences were observed in those
specimens containing ES, in which the Rs values ranged from 0.065-0.075 µm. A similar tendency was observed for the surface gloss, as shown in Fig. 8. Surface gross polished by ES0 showed 10.61 ± 5.96 (Gs 60°) and a small shining effect. The value from ES1 was 63.72 ± 6.50 (Gs 60°), and ES1 exhibited significantly less gloss than both ES3 (72.43 ± 2.09) and ES5 (75.54 ± 3.44). From these results, it was determined that the ratio of ES3 was optimal.

In the next step, the polishing effect of ES3 was evaluated by comparing RD and commercially available polishing products, based on the value from ES0. Based on the value from ES0, Fig. 9 shows the results for surface roughness. Ra values resulting from the use of ES3, RD, and TE were 0.12 ± 0.01 µm, 0.09 ± 0.02 µm, and 0.06 ± 0.01 µm, respectively. The difference was not significant between ES3 and the others. On the other hand, the surface gross for TE was 81.73 ± 3.33 (Gs 60°), which was highly superior to the values for ES3 and RD, which were 72.51 ± 4.49 (Gs 60°) and 64.71 ± 10.57 (Gs 60°), respectively. Although the surface gross for ES3 was brighter than that for RD, the difference was not significant. This information is shown in Fig. 10.

**Discussion**

Generally, most dentists would give smooth-finish surfaces to dental prostheses [12]. Excellent surface texture may not only remarkably improve esthetics but also prevent any stains and/or severe halitosis with bacterial adhesion, keep the oral environment clean, and improve mechanical properties [13,14]. In particular, for soft materials such as denture base resins, the hydrophobic surface must be finished without any grinding scratches. In contrast, since soft materials are easily scratched, it is difficult to finish them smoothly [15]. This is because most of the prostheses made of soft materials are composed of organic polymers and are also affected by heat.

High-speed lathe devices have often been used for the final polishing of denture base resins. In that case, it is well known that zinc oxide, diatomite, and/or quartz sand are available as free abrasive grains using a brush type tool, a chamois wheel, or a felt wheel. As specified above, diatomite is a large component of alginate impression materials and can help to increase mechanical strength. Diatomite is a type of silicon dioxide and is nonflammable. Consequently, the
authors examined the possibility of recycling the used alginate impression material for other applications.

First, the hardened alginate impression material was heated in order to extract diatomite. Figures 5 and 6 show the XRD results before and after firing the alginate impression material. Based on the XRD spectra, it was confirmed that dihydrate gypsum was present along diatomite after heating. Originally, gypsum was added as hemihydrate gypsum and contributed to ionic binding with the supply of calcium ions. In other words, dihydrate gypsum is irrelevant to hardening of the alginate impression material. Fundamentally, it would be appropriate to evaluate the polishing effect using only diatomite. However, when the elastic component was incinerated by firing, the volume of other components aside from diatomite was extremely small. Then, the authors decided to directly use the crushed powder in the experiment without any arrangement.

When conducting the experiment, the authors imagined the rod shape to be like a green rouge on the chair side because it is common to press a chamois wheel or felt wheel against the rod-shaped abrasive to allow it to soak. Commercially available products have an abrasive added to the thermoplastic component. With reference to this method, the hand-made, rod-shaped polishing sample was obtained simply by casting ES powder in molten wax. The dental modeling compound was excluded from the target because it was considered difficult to mix due to its high viscosity.

As a result, ES was found to be suitable as a polishing material. Initially, it was expected that even a wax itself would improve the surface gloss and surface texture. Practically, the effect of ES was noticeable in Figs. 3 and 4. With continuous examination, the polishing efficiency was comparable to that of the diatomite reagent. In comparison with TE, which is a commercially available product, it was found that its ability to produce a glossy surface was highly inferior. Nevertheless, the difference in the surface roughness data between the two samples was not significant. The surface roughness depends on the specific composition of the TE. The XRD spectrum reveals that TE contains alumina in addition to silica. Moreover, the presence of silica indicates quartz, not diatomite. This is why TE showed a significantly higher value in the surface gloss measurement.

Because it is difficult to form a smooth surface for such a soft plastic material, the authors need to check not only the polishing abrasive but also the binder. In this study, the authors selected dental casting wax for convenience. Originally, the wax itself was frequently used in daily life for cleaning. In addition, it has the advantages of acquiring various shapes because of its low melting temperature. On the other hand, it was also clarified that usage without E did not contribute to the improvement of surface texture and gloss. As an alternative material to wax, thermoplastic materials should also be considered.

To summarize, the current study revealed that diatomite obtained from alginate impression material was obviously effective as a polishing abrasive. On the other hand, concerns for human health have also been reported for alginate impression materials, particularly for diatomite [16]. Therefore, even a small amount should be handled with great care. The authors will continue to explore more desirable binding compounds as alternatives to wax as well as study the effects of particle size and/or shape, which may be important factors in obtaining a shiny and smooth surface.

Conflicts of Interest
The authors declare that there are no conflicts of interest related to the manuscript.

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