Polishing systems for dental ceramics

Anna Karin Hulterström and Maud Bergman
Department of Dental Materials and Technology, Faculty of Odontology, University of Umeå, Umeå, Sweden

Hulterström AK, Bergman M. Polishing systems for dental ceramics. Acta Odontol Scand 1993;51:229–234. Oslo. ISSN 0001–6357.

The increasing use of ceramic crowns and inlays in posterior teeth has highlighted the clinical difficulties involved in achieving a good surface finish after corrective grinding. In the present work several polishing systems and techniques were compared, initially using only one dental ceramic, Vita Mark I. The two systems that produced the best results were then further used for the polishing of several different dental ceramics, mainly newer types. The initial surface roughness and the surface condition attained after various polishing stages were evaluated by using a surface roughness analyzer. In the initial test series the SofLex system and the Shofu Porcelain Laminate Polishing Kit produced the best results; they were therefore chosen for the second part of the investigation. In this the two polishing systems concerned produced a satisfactory surface finish in a clinically acceptable time for all the ceramics tested. The use of a diamond-containing polishing paste did not improve the surface smoothness obtained with the SofLex system but gave a more varied result for the Shofu system. □ *Computer-aided design/computer-aided manufacturing; dental polishing; dental porcelain; inlays*

Anna Karin Hulterström, Department of Dental Materials and Technology, Faculty of Odontology, University of Umeå, S-901 87 Umeå, Sweden

The increasing patient demand for tooth-colored posterior restorations, together with the improved dental ceramic materials and techniques that have become available during the past decade, have resulted in the more frequent use of ceramic inlays, even for class-I- and -II-type restorations. Ceramic inlays, onlays, and crowns are in most cases still made by means of an indirect technique, but computer-aided design/computer-aided manufacturing (CAD/CAM) methods, which facilitate the direct chairside placement of ceramic restorations and thus are economically favorable, are now being used to an increasing extent. The degree of occlusal and proximal grinding adjustments of the ceramic material may vary in accordance with whether an indirect or a direct method for making the restoration is used. There is evidence indicating that there are commercially available polishing systems well adapted to produce a good finish to surfaces that can be polished outside the oral cavity—that is, mainly proximal and buccal surfaces (1–4). However, since the final occlusal adjustment of a ceramic restoration has to be made after cementation, there is always a need for a careful intraoral polishing of the material. Several studies on how to polish dental ceramics have been published (5–9), but there seems to be a lack of information about the efficacy of different polishing systems and techniques for the newer types of dental ceramics.

The purpose of this study therefore was to compare currently proposed or recommended polishing systems and techniques, sort out the two best, and apply them to several ceramic materials in current use, to determine the capabilities of the systems.

Materials and methods

Eight specimen types of dental ceramics were investigated (Table 1). Initially, 39 Vita Mark I porcelain blocks designed for the Cerec (Siemens AG, Bensheim, Germany) technique were randomly divided into 13 groups with 3 specimens in each group. All specimens were first subjected to an ultrasonic bath (Bransonic B 221) for 30 min, using tap water. Their surfaces were then characterized by means of a surface roughness analyzer (Surtronic 3, Rank Taylor-Hobson, Leicester, England). Five parallel

Table 1. Ceramics tested

1. Vita-dur, Vita Zahnfabrik, Säckingen, Germany.
2. Dicor, Dentsply International Inc., York, Penna., USA (without glazing with shading porcelain).
3. Dicor, Dentsply International Inc., York, Penna., USA (glazed with shading porcelain)
4. Empress, Ivoclar AG, Schaan, Liechtenstein.
5. Mirage, Myron International Inc., Kansas City, USA (unglazed).
6. Cerec Vitablocs Mark I-porcelain, Vita Zahnfabrik, H. Rauter GmbH & Co KG, Säckingen, Germany.
7. Cerec Vitablocs Mark II-porcelain, Vita Zahnfabrik, H. Rauter GmbH & Co KG, Säckingen, Germany.
8. Dicor-MGC Glass-Ceramic, Dentsply International Inc., York, Penna., USA.

scans, 1.0 mm apart, were made of each of the 39 specimens, using the parameter R_a. The R_a value gives an average roughness value for each specimen—that is, the average height of the profile above and below a central line. Each scan was repeated twice, giving a total of 15 scans for each specimen. The cut-off value was set at 0.8 mm, with a traverse length of 4.5 mm and a measuring range of 0–9.99 μm. A standard pick-up was used.

After the initial surface recording, all the Vita Mark I samples were ground with a 40-μm diamond bur, followed by a 15-μm diamond bur, to simulate the surface condition after an intraoral corrective grinding of the occlusal surface. The different polishing systems subsequently used are shown in Table 2. The choice of polishing systems also included a comparison between discs and points—that is, the SofLex (3M Dental Products Division, St. Paul, Minn., USA) system versus the Shofu Porcelain Laminate Polishing Kit (Shofu Inc., Kyoto, Japan). The 13 specimen groups were polished with different polishing systems and times (Table 3).

After being polished, all specimens were cleaned in the ultrasonic bath for 30 min, using tap water. Then new recordings of their surfaces were made, using the same technique as previously described. When the specimens had been surface-analyzed, groups 2–10 were polished with Shofu Ultra II Porcelain Polishing Paste, a diamond-containing paste (Shofu Inc.) on a Super-Snap

Table 2. Polishing systems and materials used

I. Shofu Porcelain Laminate Polishing Kit; Shofu Inc., Kyoto, Japan (Ceramisté points: Standard, Ultra, and Ultra II).
II. 3M SofLex discs; 3M Dental Products Division, St. Paul, Minn., USA (Coarse, Medium, Fine, and Superfine).
III. Slurry of flour of pumice (average particle size, 40 μm) + a slurry of flour of chalk (average particle size, 1 μm) on rag wheels.
IV. Shofu Brownie, Greenie, and Supergreenie minipoints; Shofu Inc., Kyoto, Japan.
V. Identoflex Blueline rubber disc + Identoflex Diam-Superfinish felt polishing wheel; Identoflex, Buchs SG, Switzerland.
VI. Cerapol Plus polishing points for ceramics; Edenta AG Dental Products, Au/SG, Switzerland.
VII. Shofu Ultra II Porcelain Polishing Paste; Shofu Inc., Kyoto, Japan.
VIII. Mirage diamond paste; Chameleon Dental Products, Inc., Kansas City, USA.

Table 3. Cerec Vita Mark I. Specimen groups classified in accordance with polishing method

Group 1. Slurry of flour of pumice + a slurry of flour of chalk. Polishing time, 2 × 180 sec*.
Group 2. Shofu Porcelain Laminate Polishing Kit. Polishing time, 3 × 120 sec*.
Group 3. 3M SofLex. Polishing time, 4 × 120 sec*.
Group 4. Shofu Brownie, Greenie, Supergreenie. Polishing time, 3 × 120 sec*.
Group 5. Shofu Porcelain Laminate Polishing Kit. Polishing time, 3 × 60 sec*.
Group 6. 3M SofLex. Polishing time, 4 × 60 sec*.
Group 7. Shofu Brownie, Greenie, Supergreenie. Polishing time, 3 × 60 sec*.
Group 8. Shofu Porcelain Laminate Polishing Kit. Polishing time, 3 × 30 sec*.
Group 9. 3M SofLex. Polishing time, 4 × 30 sec*.
Group 10. Shofu Brownie, Greenie, Supergreenie. Polishing time, 3 × 30 sec*.
Group 11. Identoflex Blueline, the diamond paste-containing felt wheel used without water. Polishing time, 60*, 60*, 60 sec* + 60 sec* with the felt wheel.
Group 12. Identoflex Blueline, the diamond paste-containing felt wheel used with water. Polishing time, 60*, 60*, 60 sec* + 60 sec* with the felt wheel.
Group 13. Cerapol Plus. Polishing time, 60*, 60*, 60 sec*.

The R_a measurements were taken after every 60 sec for groups 11–13, with a total polishing time of 180 sec, before polishing with diamond paste/felt wheel.
* Denotes surface roughness analysis.

Buff Disk (Shofu Inc.). The polishing times were 120 sec for groups 2–4, 60 sec for groups 5–7, and 30 sec for groups 8–10 (Table 3).

The system used for groups 11–12 was advertised as a complete system needing no further polishing. Group 13 was polished with the Mirage diamond paste (Chameleon Dental Products, Inc., Kansas City, USA). After the polishing with diamond paste, followed by ultrasonic cleaning of the specimens, new surface roughness recordings were carried out in the same manner as previously described.

In the initial test series thus carried out the SofLex system and the Shofu Porcelain Laminate Polishing Kit proved to produce the best polishing results with regard to surface finish; they were therefore chosen for the second part of the investigation.

After the initial surface recording the seven remaining types of dental ceramics, 2 × 3 specimens of each type (nos. 1–5 and 7–8, Table 1), were subjected to the same grinding and polishing procedures as specimen groups 5 and 6 (Table 3). A polishing time of 60 sec was chosen as a clinically relevant time for producing an acceptable finish. The specimens were cleaned and analyzed as previously described and then polished with Shofu Ultra II Porcelain Polishing Paste and once again cleaned and analyzed.

Statistical methods

Initial data from surface roughness measurements were tested, using analysis of variance and Student's *t* test. Repeated measures analysis and Student's *t* test were used in the second series.

Results

Fig. 1 shows the mean R_a values for the initial test series on the Vita Mark I ceramic specimens before the use of the polishing paste. The SofLex system produced the best results ($p < 0.001$) for all polishing times when no polishing paste was used. The Shofu Porcelain Laminate Polishing Kit was the next most effective system, but the result for the Brownie system came very close to it for the polishing time of 30 sec. The use of a diamond-containing polishing paste on the Vita Mark I specimens after the SofLex system had been used made no statistically significant difference except for the 120-sec polishing time, in which case it increased the surface roughness ($p < 0.001$). The use of a polishing paste after the Shofu system, on the other hand, significantly altered the surface for the better ($p < 0.01$) for the 30-sec and 60-sec polishing times but made no statistically significant difference at the 120-sec polishing time.

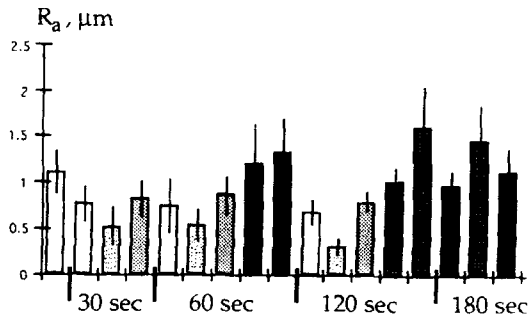

Fig. 1. Surface roughness (MV ± SD) for the different polishing systems used on Vita Mark I specimens, before polishing with diamond paste or felt wheel. (□) Untreated; (□) Shofu Porcelain Laminate Polishing Kit; (▨) SofLex: (▨) Brownie, Greenie, Supergreenie; (■) Identoflex Blueline; (▦) Cerapol Plus; (■) pumice, chalk.

The one-component polishing systems, Blueline and Cerapol, were the least effective of the systems tested and could even increase the surface roughness (Fig. 1). The Identoflex Diam felt wheel produced almost the same surface finish with and without water.

Fig. 2 shows the mean R_a values for the different dental ceramics polished with SofLex and the Shofu Porcelain Laminate Polishing Kit, respectively. Vita Mark I, Empress, and Dicor MGC showed the best results with regard to surface smoothness.

A final polishing with a diamond-containing polishing paste after completed polishing with the SofLex system produced no significant decrease in the R_a values. The use of a diamond paste after the Shofu system produced more varied results with regard to surface roughness.

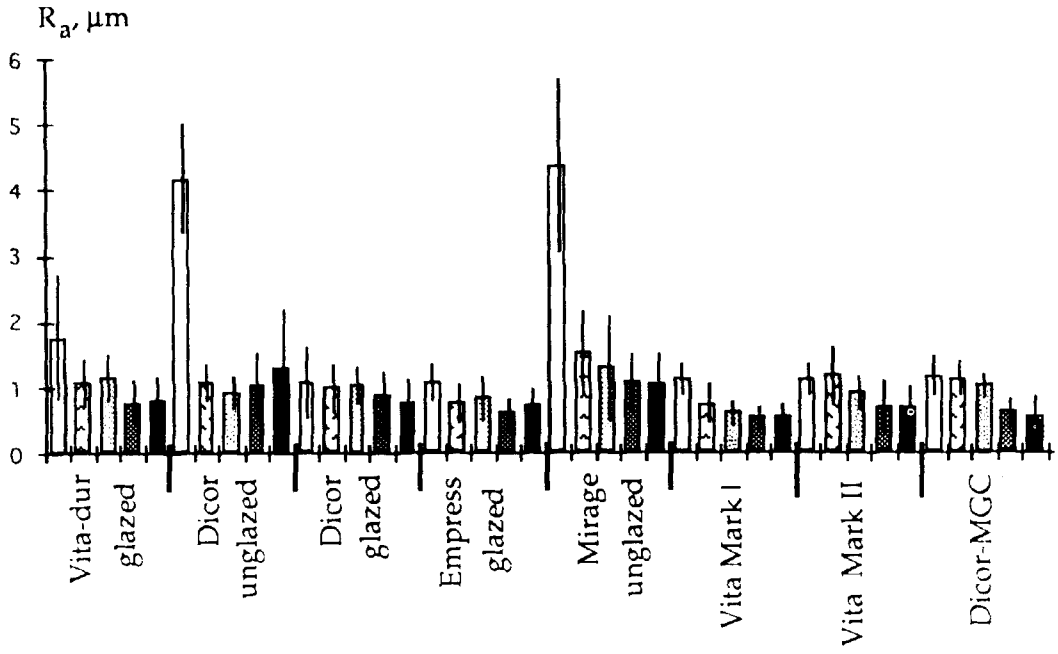

Fig. 2. Surface roughness (MV ± SD) obtained with the Shofu and SofLex systems on the ceramics tested. (□) Untreated; (▨) Shofu, 60 sec; (▩) Shofu + diamond paste; (■) SofLex, 60 sec; (■) SofLex + diamond paste.

Discussion

Dental ceramics have good biocompatibility and often excellent esthetic qualities and, consequently, a multitude of applications. However, like all materials they have shortcomings, and for ceramics this is mainly their brittleness and low tensile strength. In addition, the increasing use of ceramics for crowns and inlays in posterior teeth has highlighted the clinical difficulties of achieving a good surface finish after corrective grinding.

Apart from influencing the strength of certain types of dental ceramics (10–14), a glaze has long been considered to give the best surface finish. However, experimental studies have shown that with proper choice of polishing methods a surface smoothness equal to that obtained by glazing can be achieved (15–20). Furthermore, certain dental ceramics available today are intended for use without any glazing. For example, inlays and onlays made of ceramic blocks manufactured for the CAD-CAM technique are not glazed, but it must be possible to polish them, partly intraorally, to a satisfactory surface finish.

Optimum finishing of the surface of a dental ceramic restoration after corrective grinding may limit plaque and stain accumulation (21–23) and reduce mechanical irritation of the surrounding soft tissue (24). In addition, it minimizes wear of both adjacent surfaces and opposing occlusal surfaces (25–27).

Clinical evaluation of both directly and indirectly made inlays and onlays of dissimilar types of dental ceramic has shown that neither proximal dental plaque nor bleeding on probing occurs more often on surfaces restored with ceramics than on control homologous surfaces (3, 4, 27). This finding suggests that the initial smoothness or, in the case of corrective grinding, the polishing of proximal surfaces is satisfactory. However, in two of these studies (3, 4), using similar types of evaluation criteria, the most notable deviation from excellence was due to surface roughness, mainly with regard to

the occlusal parts of the restorations. This indicates that the time-consuming polishing after intraoral corrective grinding is not always properly carried out.

Although several experimental studies (25, 26, 28–31) have shown the abrasive capacity of dental ceramics, the optimum degree of smoothness needed to avoid or minimize noticeable antagonist abrasion is not known. This is because not only material-related factors such as hardness, toughness, or microstructural variations but also individual patient-related factors will influence the degree of abrasion that occurs. However, on the basis of both theoretical considerations and general clinical experience, the aim should be to obtain a ceramic surface with a smoothness at least as fine as that of a glazed surface. Furthermore, it must be possible to do this in a convenient and clinically realistic manner.

The different polishing systems used in the present study were chosen because they have been recommended as quick, efficient polishing systems with a minimum of work stages (Table 2). Flour of pumice and flour of chalk were included as a means of comparison with a well-tried laboratory technique.

After consideration of the publications by Leitão & Hegdahl (32) and Bessing & Wiktorsson (18) the surface roughness parameter R_a was used in the present work to characterize the surface of the ceramic specimens after different polishing methods following a simulated corrective grinding with diamond burs. However, it should be noted that the R_a values accounted for are valid only for the experimental conditions defined and cannot be directly compared with R_a values from other studies.

The results of the present work have shown that when polishing ceramic surfaces that have been adjusted by grinding with diamond burs of the commonly used types, among the systems tested the SofLex system and the Shofu Porcelain Laminate Polishing Kit produced the smoothest surfaces. The polishing time used—that is, 60 sec for each of the four and three steps, respectively, is clinically realistic. With regard to the surface area of the specimens compared with the occlusal surface area of a dental restoration, somewhat shorter polishing times may be sufficient.

Although the Vita Mark II is marketed as an improvement of Vita Mark I with regard to, among other things, polishability, such a claim is not supported by the results of the present study.

Further, it is important to note that a final polishing with the fairly expensive diamond paste did not significantly improve the smoothness of the ceramic surface polished with the SofLex system. However, it could give a slight improvement when used after the Shofu system. The smoothness of the ceramic surface polished with both the SofLex and Shofu systems was already better than that of the glazed surface before any diamond paste was used. This additional step can therefore, in the light of the results of the present work, be omitted in intraoral polishing.

Acknowledgements.—This work was supported by the Swedish Medical Research Council (Projects 09447 and 10418). Dr. Susanna Marklund gave valuable help in specimen preparation and initial tests.

References

1. Mörmann W, Lutz F, Curilovic Z. Die Bearbeitung von Gold, Keramik und Amalgam mit Composhape-Diamantschleifern und Proxoshape Interdentalfeilen. Quintessenz 1983;8:1575–83.
2. Haywood VB, Heymann HO, Kusy RP, Whitley JQ, Andreaus SB. Polishing porcelain veneers: an SEM and specular reflectance analysis. Dent Mater 1988;4:116–21.
3. Sjögren G, Bergman M, Molin M, Bessing C. A clinical examination of ceramic Cerec® inlays. Acta Odontol Scand 1992;50:171–8.
4. Molin M, Karlsson S. A clinical evaluation of the Optec inlay system. Acta Odontol Scand 1992;50: 227–33.
5. Smith GA, Wilson NHF. The surface finish of trimmed porcelain. Br Dent J 1981;151:222–4.
6. Wirz J, Jäger K, Schmidli F. Politur von Keramik-Oberflächen. Schweiz Monatsschr Zahnmed 1987; 97:906–14.
7. Campbell SD. Evaluation of surface roughness and polishing techniques for new ceramic materials. J Prosthet Dent 1989;61:563–8.
8. Kunzelmann KH, Hickel R. Feinpolitur von Cerec-Inlays mit Diamantpoliersystemen. Dtsch Zahnaerztl Z 1990;45:680–2.
9. Patterson CJ, McLundie AC, Stirrups DR, Taylor WG. Refinishing of porcelain by using a refinishing kit. J Prosthet Dent 1991;65:383–8.

10. McLean JW, Hughes TH. The reinforcement of dental porcelain with ceramic oxides. Br Dent J 1965;119:251–67.
11. McLean JW. Science and art of dental ceramics. Vol. 1. The nature of dental ceramics and their clinical use. Berlin: Quintessence Publishing Co., 1979.
12. Brackett SE, Leary JM, Turner KA, Jordan RD. An evaluation of porcelain strength and the effect of surface treatment. J Prosthet Dent 1989;61:446–51.
13. Rosenstiel SF, Baiker MA, Johnston WM. Comparison of glazed and polished dental porcelain. Int J Prosthodont 1989;2:524–9.
14. Fairhurst CW, Lockwood PE, Ringle RD, Thompson WO. The effect of glaze on porcelain strength. Dent Mater 1992;8:203–7.
15. Schlissel ER, Newitter DA, Renner RR, Gwinnett AJ. An evaluation of postadjustment polishing techniques for porcelain denture teeth. J Prosthet Dent 1980;43:258–65.
16. Sulik WD, Plekavich EJ. Surface finishing of dental porcelain. J Prosthet Dent 1981;46:217–21.
17. Klausner LH, Cartwright CB, Charbeneau GT. Polished versus autoglazed porcelain surfaces. J Prosthet Dent 1982;47:157–62.
18. Bessing C, Wiktorsson Å. Comparison of two different methods of polishing porcelain. Scand J Dent Res 1983;91:482–7.
19. Raimondo RL Jr, Richardson JT, Wiedner B. Polished versus autoglazed dental porcelain. J Prosthet Dent 1990;64:553–7.
20. Brewer JD, Garlapo DA, Chipps EA, Tedesco LA. Clinical discrimination between autoglazed and polished porcelain surfaces. J Prosthet Dent 1990; 64:631–5.
21. Swartz ML, Phillips RW. Comparison of bacterial accumulations on rough and smooth enamel surfaces. J Periodontol 1957;28:304–7.
22. Johnston JF, Mumford G, Dykema RW. Modern practice in dental ceramics. Philadelphia: Saunders, 1967: chapter 23.
23. Clayton JA, Green E. Roughness of pontic materials and dental plaque. J Prosthet Dent 1970;23:407–11.
24. Caputo AA. Biological implications of dental materials. Dent Clin North Am 1980;24:331–41.
25. Monasky GE, Taylor DF. Studies on the wear of porcelain, enamel, and gold. J Prosthet Dent 1971;25:299–306.
26. Jacobi R, Shillingburg HT Jr, Duncanson MG Jr. A comparison of the abrasiveness of six ceramic surfaces and gold. J Prosthet Dent 1991;66:303–9.
27. Wiley MG. Effects of porcelain on occluding surfaces of restored teeth. J Prosthet Dent 1989;61: 133–7.
28. Bessing C, Molin M. An in vivo study of glass ceramic (Dicor®) inlays. Preliminary report. Acta Odontol Scand 1990;48:351–7.
29. Ekfeldt A, Øilo G. Occlusal contact wear of prosthodontic materials. An in vivo study. Acta Odontol Scand 1988;46:159–69.
30. Palmer DS, Barco MT, Pelleu GB Jr, McKinney JE. Wear of human enamel against a commercial castable ceramic restorative material. J Prosthet Dent 1991;65:192–5.
31. Seghi RR, Rosenstiel SF, Bauer P. Abrasion of human enamel by different dental ceramics in vitro. J Dent Res 1991;70:221–5.
32. Leitão J, Hegdahl T. On the measuring of roughness. Acta Odontol Scand 1981;39:379–84.

Received for publication 17 February 1993