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Initial enamel wear of glazed and polished leucite-based porcelains with different fusing temperatures

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This study used the radiotracer method to measure the initial enamel wear caused by low- and high-fusing porcelains after glazing or polishing. It also tested the correlation between enamel wear and porcelain surface roughness (R_a). Surface morphology was assessed by optical microscopy. Cylindrical specimens of three porcelains (two high-fusing, one low-fusing) were either autoglazed or polished. Flattened enamel specimens were irradiated with neutrons and submitted to the wear assay for 2,500 cycles in distilled water using a 285 g load; the released beta ^{32}P particles were measured for 10 minutes. For all samples, R_a was recorded with a profilometer before and after testing.

Enamel wear was not significantly different for porcelain or finishing method but there was a trend of interaction between the two variables ($p = 0.08$). A positive correlation was found between enamel wear and the initial R_a of porcelain ($r = 0.71$). The glazed surfaces of high-fusing porcelains were wavy and had a greater R_a , while the polished surfaces had grooves and pores prior to wear testing. The low-fusing porcelain demonstrated lower R_a and a more homogeneous surface. All abraded surfaces had similar morphology after the wear assay.

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Dental porcelain is widely used in restorative dentistry, mainly because of its excellent esthetic properties; however, it is not without disadvantages, including low impact strength and the wear it causes on both tooth and dental material.¹⁻³ It is important to understand the tribological behavior of occlusal surface materials, because the chewing system inevitably produces some physiological tooth wear. Ideally, clinical decision-making should be oriented toward restorative materials with a wear rate similar to that of the opposing tooth and a low capacity for abrading antagonistic occluding surfaces. The degree of wear may vary, depending on the abrasive qualities of the patient's diet and parafunctional habits and the different composition and physical properties of various dental materials.⁴⁻⁶

Low-fusing ceramics with a reduced amount of crystalline

phase and more glassy matrix than conventional high-fusing feldspathic porcelains have been developed to improve wear resistance. Furthermore, crystal structure and distribution inside the glassy matrix can affect the material's homogeneity and cause defects to form.⁷ These features should make low-fusing porcelains more wear-friendly to enamel; however, the literature shows contradictory results, depending on the wear test and measuring instrument utilized.⁷⁻⁹

Dental and material wear have been investigated by using a number of methods, including clinical evaluation, correlation with assumed related properties such as hardness and surface roughness, and measurement of loss of material or dental structure after mechanical chewing simulation. *In vitro* wear can be measured quantitatively by a profilometer (before and after wear testing), by the gravimetric method

(to record specimen weight loss), by digital mapping of the abraded surfaces, or by utilizing the radiotracer technique, which assesses the abrasiveness of dentifrices and has proved to be accurate in recording early dental structure loss.⁹⁻¹⁴ The radiotracer method involves exposing the abraded enamel to neutrons from a nuclear reactor, making it radioactive; subsequently, the ^{32}P activity released from the abraded enamel is measured.¹⁵

In addition to ceramic composition and microstructure, porcelain's abrasiveness is modified by glazing and polishing, which can seal or smooth out surface irregularities and defects.⁸ Polishing is necessary after the chairside adjustment of ceramic restorations; several finishing systems have been tested, each yielding different surface characteristics.¹⁶⁻¹⁹ It is possible that glazed and polished porcelains have different levels of abrasiveness for antagonistic

enamel, which may be relevant for establishing a clinical protocol for installing and maintaining ceramic restorations.

This study used the radiotracer method to evaluate the initial wear on dental enamel due to glazing or polishing dental porcelain surfaces. The *a priori* hypothesis was that enamel wear differs, depending on the type of porcelain and finishing method involved. The association between enamel wear and porcelain surface roughness (R_a) was tested. An optical microscope was used to qualitatively assess the alteration of surface morphology.

Materials and methods

This study evaluated three dental porcelains used for veneering and all-ceramic restorations: two high-fusing porcelains (Ceramco II, Dentsply Ceramco; Super Porcelain EX, Noritake Co., Inc.) and one low-fusing leucite-based dental porcelain (Finesse, Dentsply Ceramco). The properties of these materials are listed in Table 1.

Ten cylindrical specimens (6 mm high and 3.8 mm in diameter) of each porcelain were fabricated according to the manufacturer's instructions. Five specimens from each porcelain group were autoglated following standard procedures; the other five specimens in each group were polished using a sequence of three silicone rubber wheels (Ceramate Points, Shofu Dental Corporation), with moderate manual pressure, for 30 seconds each, followed by using a felt wheel to apply 6 μm of polishing diamond paste (KG 7030, KG Sorensen) for 30 seconds.

A total of six experimental groups were formed from the combination of three types of porcelain and two types of finishing method. The porcelain specimens were embedded in

Table 1. Technical information on the dental porcelains used for veneering and all-ceramic restorations in this study.^{19,24}

Porcelain	Fusing temperature (°C)	Type of material
Ceramco II	1,000	High-fusing, feldspathic porcelain containing dendritic leucite particles; leucite content (by volume) of 22%; mean particle size of 4.4 μm
Super Porcelain EX	925	High-fusing, feldspathic porcelain containing dendritic leucite particles; leucite content (by volume) of 10%; mean particle size of 1.7 μm
Finesse	760	Low-fusing, feldspathic porcelain containing fine-grained equiaxial leucite particles; leucite content (by volume) of 6%; mean particle size of 3.5 μm

self-cured methacrylate resin, with 1.5 mm of each specimen exposed outside of the resin cylinder.

Five specimens of human enamel (4 mm x 7 mm) were flattened with 240-, 400-, and 600-grit silicon carbide paper and polished with 6 μm diamond paste. The enamel specimens and a phosphorus standard (30 mg of $\text{NH}_4\text{H}_2\text{PO}_4$) were irradiated under a thermal neutron flux of 10^{12} neutrons/ $\text{cm}^2 \times$ seconds⁻¹ for 30 minutes.¹⁵ After one week of decay time, the irradiated enamel was submitted to the wear assay, using backward and forward sliding movements that completed a cycle, at a rhythm of 120 cycles/minute.

Each of the five enamel specimens was tested against one specimen of the six porcelain groups for 2,500 cycles, in 10 mL of distilled water, under a load of 285 gf. To obtain dried particles of the abraded enamel, the distilled water (with the residual enamel released from the specimen after the wear test) was dried in a stove with forced ventilation at 35°C for eight hours.

The beta particles of ³²P released from the enamel were measured for 10 minutes using a Geiger-Muller

counter; the number of beta particles ranged from 234–6,985 cpm. Data were collected in triplicate and averaged for phosphorous analysis. Using the counting rates from the specimen and the phosphorus standard, the amount of P was calculated by a comparative method of neutron activation analysis.²⁰ The amount of worn enamel was obtained by considering the enamel P content.

R_a was measured before and after the wear test by using a profilometer (Surcorder SEF-30D, Kosaka Laboratory, Ltd.). R_a recordings were performed in duplicate and the mean value was considered for statistical analysis. The specimens were photographed with an optical microscope (Olympus BX60M, Olympus Imaging America, Inc.) to qualitatively evaluate any alterations in surface morphology.

Enamel wear (in μg) and initial R_a (in μm) data were analyzed by a factorial ANOVA (with porcelain and finishing method as factors and enamel as the replication variable) and Tukey's test for *post hoc* multiple comparisons. Before and after wear testing, R_a means were compared by Student's *t*-tests for paired samples.

Table 2. Enamel wear (μg) caused by the experimental groups of porcelain/finishing method (mean \pm SD).

Porcelain	Glazed ($n = 5$)	Polished ($n = 5$)
Ceramco II	88 \pm 104	55 \pm 24
Super Porcelain EX	84 \pm 82	39 \pm 11
Finesse	44 \pm 31	82 \pm 62

Table 3. Porcelain roughness R_a (μm) before and after wear testing (mean \pm SD). Means followed by the same letters are not statistically different at a 0.05 level of significance.

Porcelain	Before wear	After wear
<i>Ceramco II</i>		
Glazed	0.34 \pm 0.03 ^a	0.33 \pm 0.06 ^a
Polished	0.16 \pm 0.07 ^b	0.18 \pm 0.08 ^b
<i>Super Porcelain EX</i>		
Glazed	0.39 \pm 0.09 ^a	0.38 \pm 0.06 ^a
Polished	0.20 \pm 0.04 ^b	0.18 \pm 0.06 ^b
<i>Finesse</i>		
Glazed	0.18 \pm 0.08 ^b	0.19 \pm 0.08 ^b
Polished	0.19 \pm 0.02 ^b	0.20 \pm 0.02 ^b

The correlation between enamel wear and initial R_a of each experimental group before wear testing was assessed by means of Pearson's correlation. A two-tailed significance level of 0.05 was set for all tests.

Results

No significant effect was found in terms of the porcelain ($p = 0.89$) or the finishing method ($p = 0.39$) and the interactions were marginally non-significant ($p = 0.08$) (see Table 2). There was a difference in terms of R_a for glazed and polished surfaces with the Ceramco ($p < 0.001$) and Super Porcelain EX ($p = 0.004$) samples but no difference for the Finesse samples ($p = 0.783$) (see

Table 3). R_a did not change before and after wear testing, but a moderate positive correlation was found between enamel wear and the initial R_a of porcelain ($r = 0.71$).

Glazed high-fusing porcelains displayed more undulation compared with their polished surfaces, although the polished surfaces showed directional grooves and more porosity (Fig. 1). The low-fusing Finesse exhibited large pores when polished, with the exception of glazed Finesse samples, which had a homogeneous glassy surface with less irregularity. The morphology of all abraded areas was similar after wear testing, with grooves, pores, and porcelain chipping (Fig. 2).

Discussion

This study showed that the type of porcelain or finishing method had no effect on initial enamel wear. The high-fusing porcelains (Ceramco II and Super Porcelain EX) showed a tendency for greater enamel wear when their surfaces were glazed rather than polished. Conversely, polished low-fusing porcelain (Finesse) displayed approximately twice as much enamel wear as glazed low-fusing porcelain. The negative results are partly due to the limited sample size and large variability in data collected by using the radiotracer.

The radiotracer technique has been used as an alternative to gravimetric and profilometric methods for measuring a dentifrice's abrasive wear on enamel and dentin.^{13,14} The radiotracer method is highly sensitive; as a result, it was chosen to measure initial enamel wear by opposing porcelain surfaces. This technique made it possible to test the wear effect of the same enamel antagonist on specimens from all groups, to reduce the variability in terms of dental composition and structure.

In the present study, each sample was subjected to 2,500 wear cycles to assess how glazing and polishing each affected the initial wear of enamel. Longer wear tests could disrupt the surface finish and confound the evaluation of wear rates, which could partly explain the different results reported previously in the literature. Magne *et al* used a profiling method and reported similar wear rates between polished and glazed porcelains after 300,000 masticatory cycles; however, a low-fusing glass ceramic caused more enamel wear in specimens than feldspathic and aluminous porcelains.¹¹ Conversely, a 2001 study by Clelland *et al* subjected specimens to 50,000 cycles of

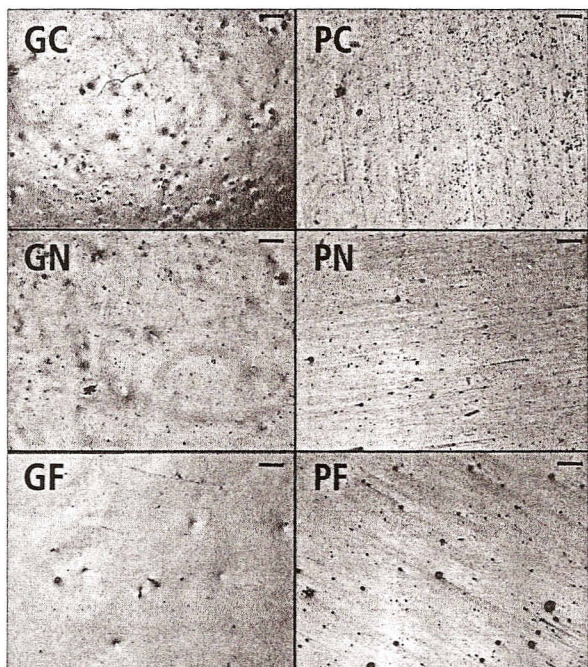


Fig. 1. Microphotographs of the glazed (G) and polished (P) tested dental porcelains (C: Ceramco II, N: Super Porcelain EX, F: Finesse) prior to wear testing (2,500 wear cycles) (magnification 100x). Bars indicate 100 μ m.

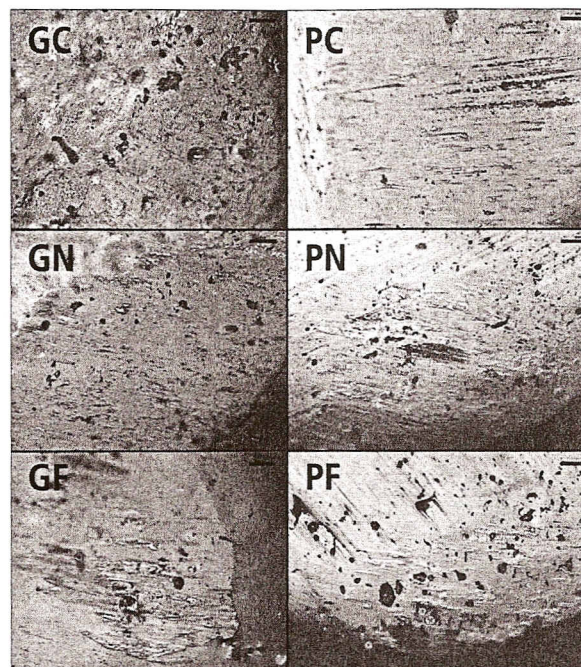


Fig. 2. Microphotographs of the glazed (G) and polished (P) tested dental porcelains (C: Ceramco II, N: Super Porcelain EX, F: Finesse) after wear testing (2,500 wear cycles) (magnification 100x). Bars indicate 100 μ m.

sliding abrasive wear and found no difference in wear for enamel or a conventional, low-fusing porcelain (in this case, Finesse).⁹

The present study found a positive correlation between porcelain surface roughness and initial enamel wear; however, polished Finesse was the smoothest porcelain but did not produce the lowest amount of wear. The glazed high-fusing porcelains were rougher than their polished counterparts and Finesse showed R_a means that were comparable to those of the polished high-fusing porcelains.²¹ Metzler *et al* reported a significant correlation between surface roughness of polished porcelains and enamel wear, but Ceramco II yielded more wear than Finesse when other polishing procedures and surface profile measurements were used to record enamel wear.²²

This study found that R_a values did not change before and after wear testing for all porcelains, although the micrographs showed differences in surface morphology. A qualitative analysis of the porcelain surfaces showed several large pores in the polished porcelain surfaces, although these surfaces seemed smoother visually. A 1996 study by Fuzzi *et al* utilized a scanning electronic microscope and reported that the surfaces of the glazed porcelain samples had fewer pores and more waves.²³ By comparison, all abraded surfaces in the present study had similar morphology after the wear assay.

Qualitative analysis of the porcelain topography suggests that the relationship between porcelain roughness and enamel wear is more complex than the

quantitative correlation displayed. The high- and low-fusing ceramics tested in the present study have different leucite characteristics.^{19,24} However, it appears that the differences observed in surface roughness and wear rates have less to do with leucite volume and mean particle size than with the shape of leucite particles.

Conclusion

Within the limitations of this study, the results showed no significant difference in initial enamel wear of glazed or polished porcelains; however, there was a correlation between enamel wear and porcelain R_a . Qualitative analysis of the porcelain topography showed differences among the glazed and polished porcelain surfaces before and after wear testing.

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Manufacturers

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