# Investigation of the Influence of Gastric Acid on the Surface Roughness of Ceramic Materials of Metal-Ceramic Restorations. An In Vitro Study

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The rehabilitation of eroded teeth in patients suffering from bulimia nervosa generally includes ceramics. This study compared the roughness of three ceramics before and after exposure to simulated vomit solution (SVS) with a pH of 3.8. Surface roughness parameters Ra, RMS, and AH were calculated using atomic force microscopy before and after exposure to SVS (novel peristaltic pump for 24 hours at 37°C) and were analyzed statistically. Apart from the initial high AH values of the glass-ceramic, none of the parameters evaluated were statistically significantly different after acid exposure. Under the limitations of this in vitro study, the investigated ceramics seem suitable for use in bulimia nervosa patients. *Int J Prosthodont 2011;24:26–29.*

Bulimia nervosa is characterized by self-induced vomiting,[1] which causes tooth erosion (perimylolysis).[2] The mean pH of vomit was estimated to be 3.8, and considering that enamel's critical pH value is 5.5, vomit can be an erosive factor.[3] Erosion can increase surface roughness, which is correlated with microbial plaque retention, enamel wear, and material strength.[4]

Dental rehabilitation of bulimia nervosa patients consists of metal-ceramic restorations, a result of their increased chemical stability.[4,5] Applied stresses and chemical dissolution are the two major degradation mechanisms.[4] As the initial stages of corrosion take place, corrosion can be investigated using advanced techniques that allow for investigation at the nanometer level, such as atomic force microscopy (AFM).

This study investigated whether the gastric acid of vomit influences the surface roughness of three ceramics used for metal-ceramic restorations.

## Materials and Methods

A pilot study was conducted to estimate the sample size. One high-fusing leucite-based feldspathic porcelain (C1; IPS Classic Margin, Ivoclar), one low-fusing leucite-based fluorapatite glass-ceramic (C2; IPS d.SIGN Shoulder, Ivoclar), and one low-fusing leucite-based feldspathic porcelain (C3; GC Initial LF Shoulder, GC) were used. By using polysiloxane molds (Optosil Xantopren, Heraeus Kultzer), round specimens of 2 × 1 mm were constructed and vacuum fired (Programat P95, Ivoclar Vivadent).

Specimens were polished using SiC abrasive papers (600, 800, 1,200, 2,000 grit; 5-μm and 0.3-μm aluminium oxide particles) and glazed, and a cross was created centrally with a fine diamond bur, forming four areas (upper right, upper left, lower right, lower left).

A contact mode AFM microscope was used to determine values of the roughness amplitude parameters; mean roughness (Ra), root mean square (RMS), and average height (AH) were recorded in nm (SPMLab 6.0.2 Analysis, Veeco). In each specimen, four measurements were made (one at each area) and were recorded twice, once before and once after a 24-hour period of acid exposure.

The simulated vomit solution (pH = 3.8) was prepared using 1,000 mL of artificial saliva (pH = 5.5) and 4.5 mL of simulated gastric fluid (pH = 1.2).

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**Table 1** Descriptive Statistics for Ra, RMS, and AH Before and After Exposure to Gastric Acid

| | Before | | | | | After | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Parameter/material | N | Min | Max | Mean | SD | N | Min | Max | Mean | SD |
| **Ra** | | | | | | | | | | |
| C1 | 28 | 76.7 | 893.5 | 450.4 | 222.7 | 28 | 146.1 | 1,850.4 | 719.6 | 480.2 |
| C2 | 28 | 87.0 | 1,776.9 | 738.4 | 470.7 | 28 | 197.2 | 2,449.5 | 747.4 | 532.5 |
| C3 | 28 | 127.5 | 1,558.8 | 578.0 | 357.4 | 28 | 64.6 | 1,867.5 | 668.9 | 488.4 |
| **RMS** | | | | | | | | | | |
| C1 | 28 | 97.3 | 1,056.5 | 533.3 | 252.8 | 28 | 176.6 | 2,162.1 | 862.4 | 559.6 |
| C2 | 28 | 121.5 | 2,269.4 | 969.4 | 619.3 | 28 | 344.0 | 4,312.8 | 1,026.5 | 814.8 |
| C3 | 28 | 155.3 | 1,839.7 | 691.0 | 414.8 | 28 | 78.6 | 2,226.5 | 798.4 | 570.5 |
| **AH** | | | | | | | | | | |
| C1 | 28 | 344.0 | 2,769.9 | 1,409.6 | 635.0 | 28 | 459.9 | 4,757.3 | 2,170.8 | 1,198.3 |
| C2* | 28 | 539.7 | 8,037.8 | 3,992.8 | 1,969.8 | 28 | 1,585.8 | 15,642.6 | 4,521.2 | 2,769.6 |
| C3 | 28 | 413.9 | 4,619.7 | 1,912.1 | 1,039.7 | 28 | 389.3 | 7,266.5 | 2,130.3 | 1,437.8 |

SD = standard deviation.
*Statistically significant difference ($P < .001$) between C2 and C1 and C3 for both before and after measurements.

**Table 2** Estimates of ANOVA for Ra, RMS, and AH Before and After Exposure to Gastric Acid

| | Before | | | After | | |
|---|---|---|---|---|---|---|
| | | 95% CI | | | 95% CI | |
| Parameter/material | Mean | Lower bound | Upper bound | Mean | Lower bound | Upper bound |
| **Ra** | | | | | | |
| C1 | 388.7 | 245.2 | 616.1 | 568.2 | 335.3 | 962.8 |
| C2 | 587.6 | 370.6 | 931.5 | 612.1 | 361.2 | 1,037.2 |
| C3 | 494.1 | 311.7 | 783.3 | 489.4 | 288.8 | 829.4 |
| **RMS** | | | | | | |
| C1 | 466.5 | 298.1 | 730.3 | 687.3 | 414.3 | 1,140.2 |
| C2 | 770.5 | 492.2 | 1,206.0 | 839.1 | 505.8 | 1,392.0 |
| C3 | 596.5 | 381.1 | 933.7 | 594.5 | 358.4 | 986.3 |
| **AH** | | | | | | |
| C1 | 1,260.3 | 886.7 | 1,791.1 | 1,808.5 | 1,252.2 | 2,612.1 |
| C2* | 3,392.2 | 2,386.8 | 4,821.1 | 4,012.7 | 2,778.3 | 5,795.6 |
| C3 | 1,660.5 | 1,168.4 | 2,360.0 | 1,745.8 | 1,208.7 | 2,521.4 |

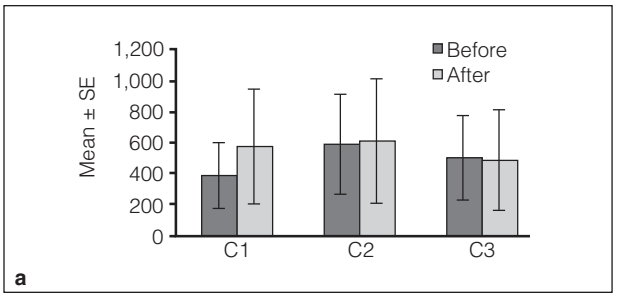
*Statistically significant difference ($P < .001$) between C2 and C1 and C3 for both before and after measurements.

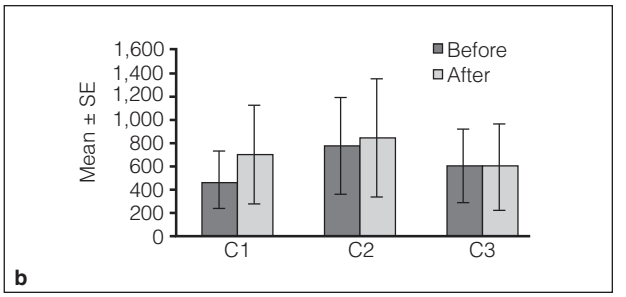
A novel peristaltic pump was used to simulate vomiting for 24 hours at 37°C. By using seven specimens for each ceramic, the null hypothesis was rejected with a probability of 90.2% for Ra, 80.7% for RMS, and 71.2% for AH.

Following this methodology, seven specimens were used for each ceramic (n = 21). The analysis model was three-way analysis of variance and the Bonferroni post hoc test with a level of statistical significance set at $P \leq .05$ (SPSS version 15, IBM).

## Results

Statistically significant differences were recorded for the parameter AH ($P < .001$, Tables 1 and 2). Glass-ceramic (C2) gave higher AH values, independent from the area examined, both before and after acid exposure (Fig 1, Tables 1 and 2). Concerning the other parameters, no statistical differences were found between or within the groups. The images acquired from the AFM examination showed that the glass-ceramic demonstrated a rougher surface (Fig 2).



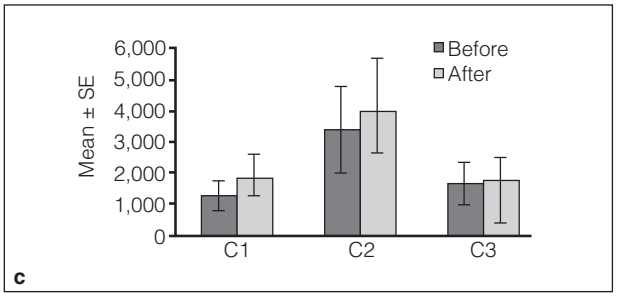
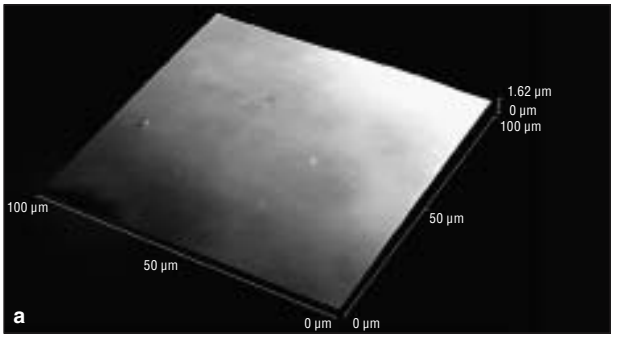
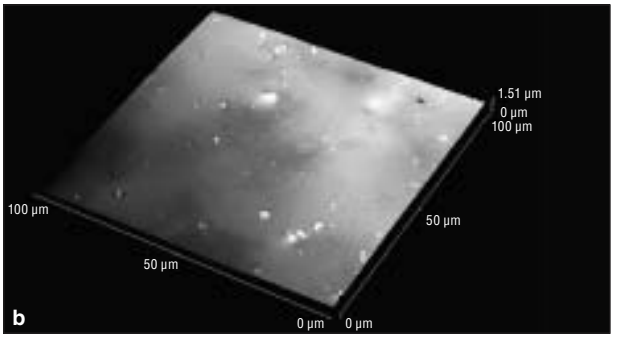
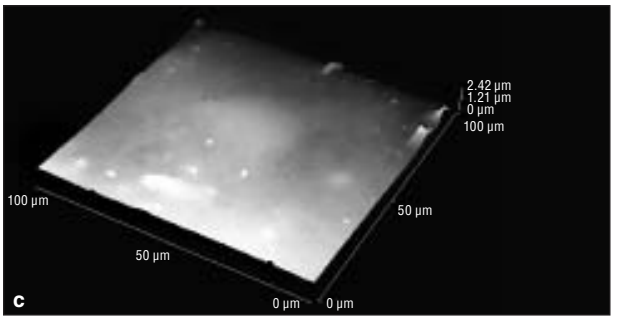
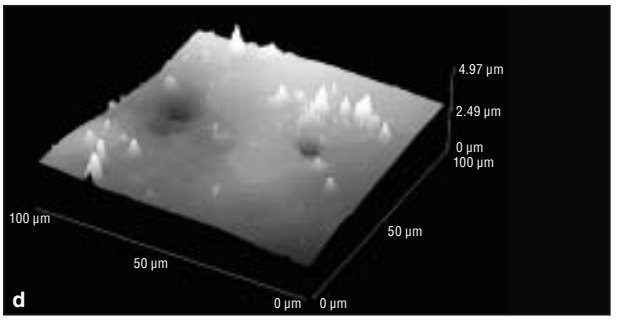



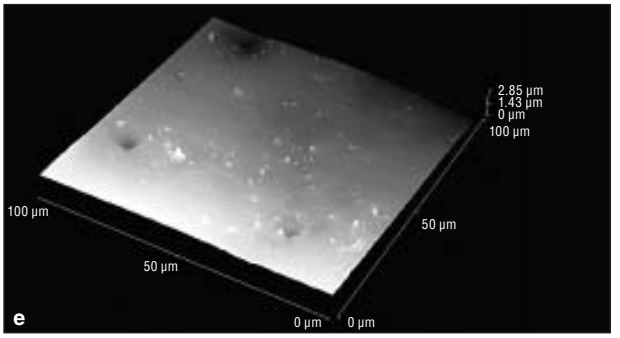

**Fig 1** Mean values ± SE for **(a)** Ra, **(b)** RMS, and **(c)** AH for all materials before and after exposure to gastric acid for 24 hours.



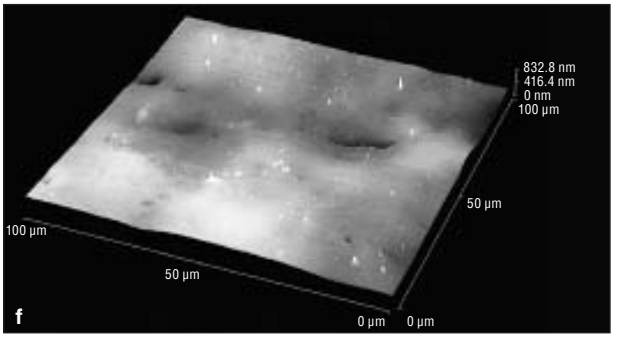




**Fig 2** AFM images of representative ceramic specimens before and after exposure to gastric acid for 24 hours. C1 **(a)** before and **(b)** after exposure; C2 **(c)** before and **(d)** after exposure; C3 **(e)** before and **(f)** after exposure.

## Discussion

The results of this study can be attributed to microstructural differences. Glass-ceramics contain fluorapatite crystals, which are small in size (0.4 μm) and can be detected by AFM. In agreement with this study, it has been reported that glass-ceramics present statistically significantly higher roughness values,[6] probably due to their higher porosity[7] and the presence of surface flaws and voids.

This study found that the influence of gastric acid was not statistically significant. According to ISO 6872,[8] acetic acid is a proposed cause when examining the corrosion phenomena in ceramics. In this study, hydrochloric acid and a temperature of 37°C were selected to better simulate vomit and oral conditions. Other studies that used hydrochloric acid suggested a much higher duration of acid exposure because of the chemical instability of ceramics.[9] The low temperature and the short duration of this study are probably restricting factors for a corrosive effect.

A unique feature was the simulated vomit solution flow rate. However, the amount of kinetic energy produced may not have been sufficient enough to cause surface alterations, since large amounts of energy are needed to break ceramic bonds.

## Conclusions

Taking into consideration the limitations of the present study, the following conclusions can be drawn:

- Glass-ceramic demonstrated statistically significantly higher AH roughness values before its exposure to gastric acid.
- Simulated vomit does not induce short-term surface alterations on the ceramic of metal-ceramic restorations at the nanometer level.
- The short-term (24 hours) and experimental design used should be reconsidered to safely determine these ceramics as the restorative materials of choice for bulimia patients suffering from tooth erosion.

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*Literature Abstract*

**Comparison of a high and a low intensity smoking cessation intervention in a dentistry setting in Sweden: A randomized trial**

This study assessed the effectiveness of a high intensity intervention (HIT) compared with a low intensity intervention (LIT) for smoking cessation support in a dental clinic setting. HIT included eight 40-minute individual sessions, while LIT included one 30-minute counseling session and a leaflet containing an 8-week program (self-help). Three hundred smokers were assigned randomly to the two methods. The measures included self-reported point prevalence and continuous abstinence at the 12-month follow-up. HIT smokers were twice as likely to report continuous abstinence compared with LIT. There was a difference, but not significant, between the groups in point prevalence abstinence in favor of the HIT protocol. Point prevalence cessation rates in the LIT group reporting additional support were relatively high compared with available data assessing abstinence in smokers trying to quit without professional support. The quitting rate was higher with a higher level of education in both groups. HIT was significantly more effective in terms of reporting abstinence at the 12-month follow-up. Offering smoking cessation support within dentistry may be an effective model for smoking cessation. The more extensive and expensive HIT protocol should be offered to those who are unable to quit with the LIT approach, in combination with other forms of support.

**Nohlert E, Tegelberg A, Tillgren P, Johansson P, Rosenblad A, Helgason AR.** *BMC Public Health* 2009;9:121. **References:** 24. **Reprints:** Dr Eva Nohlert, Centre for Clinical Research, Uppsala University, Central Hospital, Västerås, Sweden. Email: eva.nohlert@ltv.se—*Majd Al Mardini, Hamilton, Ontario, Canada.*