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EFFECT OF SANDBLASTING OF ZIRCONIA ABUTMENT ON SURFACE ROUGHNESS AND BACTERIAL ADHESION

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ABSTRACT

Statement of problem. Factors associated with implant periodontal disease of zirconia restorations such as surface roughness remain largely unknown.

Purpose. The purpose of this study was to investigate how sandblasting abrasion before sintering affects roughness and bacterial adhesion on the surface of zirconia.

Material and methods. Thirty presintered zirconia specimens were divided into 6 groups of 5 after being polished with silicon carbide paper (1200 grit). A different surface treatment was applied to each group (no treatment [group Ct] and {A 30 μm, B 50 μm ,C 120 μm, D 175 μm and E 250 μm alumina particle size abrasion for 5 seconds]), and the specimens were then densely sintered. The mean centric linear roughness (Ra) was measured, and the 3D measurement of surface roughness (3D roughness) was determined. The number of colony forming units (CFUs) of Streptococcus mutans adhering to the surface was also examined. One-way ANOVA was used for data analysis (a=.05).

Results. Airborne-particle abrasion before sintering significantly increased surface roughness. Groups A, C, and E showed statistically significant higher CFU/mL than did group B (P<.05). No difference was found in CFU/mL between group Ct and B (P=.230).

Conclusions. Airborne-particle abrasion before sintering is a useful method of increasing the surface roughness of zirconia. Ra < 0.58 mm is necessary to inhibit the adherence of S. mutans to zirconia.

INTRODUCTION

With the rapid growth in dental materials, dental implants are being used worldwide. An abutment is the connecting element passing through the mucosa and is considered important in preventing bacterial invasion into the maxilla or mandible. Both tissue cells and bacteria adhere to implant surfaces.[1] Most studies report that cell attachment is significantly stronger on a rough surface than on a smooth surface and a rough surface could favor human oral fibroblast attachment and soft tissue growth.[2-5] However, a roughened surface may be more conducive to the formation and retention of

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bacterial plaque,[6-9] resulting in plaque-induced inflammation.

Implant and restorative materials have different surface characteristics. A zirconia abutment provides a better esthetic result than titanium since its bright white color has a better appearance under the tissue than metal. It has been reported that titanium roughness lower than 0.4 mm can effectively prevent plaque accumulation.[10]

Some studies have also shown that zirconia exhibits lower bacterial adherence at the same roughness level[11,12] and that a slight increase in zirconia surface roughness may promote fibroblast cell attachment without affecting bacterial adherence.

The most widely used surface modification technique for removing the surface of fully sintered zirconia is chemical etching or mechanical techniques such as grinding, airborne-particle abrasion, and laser ablation. However, these methods easily lead to the phase transformation of zirconia,[13] which may reduce its functional Strength,[14-16] and other high roughness coatings present adhesion problems and discontinuities.[17] Airborne-particle abrasion before sintering, removes zirconia particles without phase transformation effects[18] and has been shown to be more effective in increasing roughness than abrading fully sintered zirconia[19,20]; the mechanical properties of abraded zirconia are thus improved.

Indeed, airborne particle abrasion before sintering is effective for increasing the surface roughness of zirconia. The degree of roughness depends on the balance between bacterial and fibroblast adhesion to the material surface.[21]

The purpose of this study was to investigate how airborne-particle abrasion before sintering affects the roughness of zirconia and to explore possible relationships between zirconia surface roughness and bacterial adhesion

MATERIALS AND METHODS

Sample preparation;

Prefabricated ceramic blocks, a highly transparent material consisting of ZrO_2+HfO_2 +Y_2O_3+Al_2O_3 greater than 99.9% and less than 0.1% of other oxides, were cut with a diamond saw (Isomet 4000; Buehler) into 30 specimens (10×10 ×2 mm) under copious water irrigation. The surface of each specimen was polished with waterproof silicon carbide paper (1200 grit).

The 30 polished specimens were then divided into 6 groups (n = 5). Five groups were airborne-particle abraded with **{A 30 μm, B 50 μm, C 120 μm, D 175 μm and E 250 μm}** 5 seconds at 0.1 MPa pressure at a distance of 10 mm. One group without any treatment was used as the control (group Ct). The 30 specimens were sintered in a programmable furnace (ZSK 1700; Cinite) at 1450˚C for 2 hours and sterilized in the autoclave (MLS-3750; Sanyo) for 20 minutes at 121˚C before placement in bacterial culture.

Surface roughness was measured with a surface texture and contour measuring instrument (JB-4C; Taiming Optical Instrument) with a 0.2-mm radius stylus tip and a 4-mm traversing length. The cut-off value of the instrument was set at 0.8 mm. For each specimen, the Ra was measured at 4 different locations, and the average of 4 measurements was used for analysis. The 3-dimensional measurement of the surface roughness (3D roughness) of each specimen was determined with scanning electron microscopy (Phenom proX; Phenom- World B.V.) at an accelerating voltage of 10 kV. All photographs were made at a magnification of ×1000.

Bacterial adherence measurement:

a) Sterility test of samples:

The discs are wrapped in sterilization pouches and sterilized in an autoclave (DAC professional

sirona dental system Germany) at 121°C for 20 minutes. The sterility of the discs was checked by placing one disc of each group in clear brain heart infusion where they were incubated* at 37°C for 24 hours. Any turbidity in the brain heart infusion indicates the contamination of the discs.

b) Bacterial strain and culture conditions

The reference strain used in this study was S. mutans. S. mutans was seeded and cultured in a 5 mL Mitis-Salivarius liquid (MMS) medium at 37˚C for 48 hours under microaerophilic conditions (10% CO_2, 10% H2, and balance N2), and the concentration of bacteria was adjusted to 109 CFU/mL. Sterilized specimens were placed in 6-well plates (1 specimen per well) and secured in position by Mitis-Salivarius agar (MSA) to cover nonprocessing surfaces. A 100-mL bacterial solution (109 CFU/mL) diluted to 2 mL with MMS medium was added on each specimen surface and then incubated at 37˚C for 48 hours.

c) Adhesion test

The specimens were gently rinsed with saline to remove unbound bacteria. The attached bacteria were isolated by shaking vigorously in a vortex. After diluting the bacterial solution to 1:1000, the S. mutans counts were examined by smearing 0.1-mLportions of the dilution on MSA plates (each dilution plated in triplicate and then averaged), and plates were incubated at 37˚C for 48 hours. The number of colonies was converted into CFU/mL according to the dilution ratio.

All results were expressed as the mean ± standard deviation (SD). Ra and Log CFU/mL were analyzed with the 1-way ANOVA test. Multiple pairwise comparisons were analyzed with the least significant difference (LSD) test. P<.05 was considered statistically significant.

RESULTS

Table 1 presents the mean centric linear roughness (Ra) of the respective specimens. Group Ct without abrasion gave the smallest Ra value. The Ra values of treatment groups increased with abrasion time. The statistical analysis revealed no significant difference in the 4 Ra measurements of the 5 specimens in each group (P>.05), suggesting no intragroup variances. Statistically significant differences were found among all 6 groups (P<.05)

TABLE (1) Mean value of Ra of specimens in 6 groups (mm)

Group	Ra (mm ± SD)	P
Ct	0.10 ±0.01	.423
A 30 μm	0.31 ±0.02	.707
B 50 μm	0.58 ±0.01	>.999
C 120 μm	0.98 ±0.03	.846
D 175 μm	1.48 ±0.03	.214
E 250 μm	1.83 ±0.03	.726

The reconstructed images of 3D roughness Compared with group Ct, microscopic flaws and pores were enlarged and more noticeable in airborne-particle abrasion groups, indicating that alumina abrasion before sintering produces more uneven surface. Severe damage to the zirconia surfaces was not observed for any of the abrasion groups.

Table 2 lists the number of adhered bacteria on specimens in each group. No statistically significant difference in CFU/mL was found between group Ct and B 50 mu (P=.230). Group A, C, D, and E showed statistically significantly higher CFU/mL than that of group A5s (P<.05). The 250 um (group E) abraded surface, which had the highest Ra value, exhibited the highest number of adhered bacteria. Multiple pairwise comparisons showed significant differences among all the 5 abrasion groups (P<.05), except between group C120um and D 175 um (P=.210).

TABLE (2) Log CFU/mL of specimens of 6 groups

Group	Ra (mm)	Log CFU/mL
Ct	0.10 ±0.01f	5.41 ±0.12d
A 30 μm	0.31 ±0.02e	5.35 ±0.10d
B 50 μm	0.58 ±0.01d	5.62 ±0.04c
C 120 μm	0.98 ±0.03c	5.73 ±0.05b
D 175 μm	1.48 ±0.03b	5.79 ±0.06b
E 250 μm	1.82 ±0.03a	5.95 ±0.06a

a-f Different superscript letters indicate statistically significant difference (P<.05). (1-way ANOVA and LSD test).

DISCUSSION

Periimplantitis has been proposed as a critical reason for implant failure. Zirconia implant abutments such as Straumann, 3i, Zimmer, and Dental were in the range of 0.1 to 0.76 mm. To date, a number of studies have been conducted on the relationship of abutment surface topography and soft tissue adhesion. Most reports have supported the statement that increased surface roughness results in greater tissue adhesion and that a significantly higher number of fibroblast cells attach to a porous or grooved surface than to a smooth one.[2-5] 3D images of airborne-particle abrasion groups revealed microscopic pores with controllable erosion depth that may provide an effective interlocking mechanism with tissue, as well as removing the grinding lines produced by silicon carbide paper. The result could also be controlled by adjusting the abrasion time.

Surface roughness has been found to be correlated with bacterial attachment.[7] Abutments have been designed to enhance soft tissue seal and minimize bacterial colonization. Previous studies have shown the association between roughness and bacterial adhesion, finding that bacteria could attach more easily to rough surfaces.[6-9] Consistent with previous reports, we observed higher numbers of S. mutans adhering to the surface after 8 to 15 seconds of abrasion, suggesting a positive correlation between surface roughness and bacterial adhesion. The statistical analysis suggests that the higher roughness of zirconia exerts some effect on bacterial adhesion, indicating that a proper roughness should be selected for zirconia abutments to inhibit the adherence of S. mutans and to reduce plaque accumulation. Abrasion of 8 to 15 seconds may not be helpful in inhibiting bacterial adherence to zirconia.

In summary, the present study showed that airborne particle abrasion before sintering is effective for increasing the surface roughness of zirconia. The degree of roughness depends on the balance between bacterial and fibroblast adhesion to the material surface. More studies aiming to reveal the growth behavior of human gingival fibroblasts on zirconia surfaces and the mechanism of bacterial interactions with zirconia are needed.

CONCLUSIONS

Airborne-particle abrasion before sintering is a useful method of increasing the surface roughness of zirconia. In the present sample size, Ra<0.58 mm is needed to inhibit the adherence of S. mutans to zirconia.

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