Sandblasting of Inlay Margin
—Marginal Abrasion and Bond Strength—

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Specimens (such as metal inlays) with 30° or 45° marginal bevel were prepared by casting with a 12% Au-Pd-Ag alloy or a gold alloy. A form of the marginal bevel was traced on a profile projector before and after sandblasting, and the length of the abraded margin measured. All the blasting conditions abraded the marginal bevel, while the blasting at 20 mm for 2 seconds brought about the least abrasion of approximately 10 μm in the 45° specimen cast with Au-Pd-Ag alloy. The gold alloy specimens were abraded more than the Au-Pd-Ag alloy ones; those with marginal bevel of 30° were abraded more than those of 45°.

On the other hand, the effect of different blasting conditions on the bond strength of units bonded with resin cement was evaluated (under selected blasting conditions known to cause relatively less damage to the marginal bevel). Specimens treated by sandblaster exhibited a comparable tensile bond strength, while specimens without sandblasting but applied with only an alloy primer showed a statistically low value.

Key words: Sandblasting, Marginal abrasion, Bond strength

INTRODUCTION

Recently, adhesive resin cements are becoming popular due to their bonding efficacy, not only to tooth substances but also with casting alloys. To obtain a firm adhesion between a casting alloy and resin cement, it is very effective to treat the alloy surface by sandblaster and then apply a primer on the treated alloy surface. Indeed, on the treatment of resin-bonded fixed partial dentures, sandblasting is an essential procedure for bonding of the retainer. The trend seems to be spreading to bonding of metal inlays too. It can be easily visualized that sandblasting would abrade the margin of restorations. Especially in the case of metal inlays, the marginal bevel is intentionally prepared, resulting in a very thin marginal edge. Nevertheless, marginal abrasion of metal inlays is not investigated thoroughly, and the extent of marginal abrasion remains unclear.

In actual emission with a sandblaster, the emission pressure can be controlled by a pressure gauge. Likewise, the size and type of abrasive grain can be selected before emission. In addition, the distance between the blaster nozzle and the object would be another variable factor, as well as the blasting duration.

In this study, the extent of marginal damage was examined, using specimens that represented the marginal bevels of metal inlays, under variable factors of emission distance and emission time.

MATERIALS AND METHODS

Experiment I: Marginal damage

1. Preparation of specimen

Two types of plastic mold were used to fabricate the wax patterns. The shapes of the edge portion of the wax patterns are shown in Fig. 1. Size of each specimen was 5 mm in width and 15 mm in length. The sharp edge of the specimen represented the marginal bevel of a metal inlay. A gypsum-bonded cristobalite investment (Cistobalite Micro, GC, Tokyo) was used as the mold material. The casting rings were heated up to 700°C and kept at this temperature for at least 20 minutes. The specimens were fabricated by a dental casting procedure — with a centrifugal casting machine and a dental blow pipe — using Au-Pd-Ag alloy (Castwell MC 12% Gold, GC, Tokyo) or gold alloy (Casting Gold MC Type III, GC, Tokyo). After redness of the buttons subsided, the casting rings were immersed in water. The surface oxide film on the cast was not removed so as to examine the area after being treated by sandblaster. Notches were cut

Fig. 1 Marginal shapes of the specimens.
by a resin disc approximately 0.8 mm from the edge at the two lateral sides of the specimen to facilitate superimposing of images during re-tracing.

2. Tracing of edge form
A form of the edge portion was traced on a profile projector (V-12, Nikon, Tokyo) with a 0.5-mm mechanical pencil. In other words, the whole image of the edge portion was reflected on the screen under ×50 magnification. This drawing was used for specimen repositioning on the stage and not for measurement. Magnification was then raised to ×100 such that the whole image of the specimen could not be reflected on the screen. As a result, the upper and lower parts of the specimen were traced separately, ending up with three drawings on the same tracing paper.

3. Sandblasting
A pencil-type sandblaster (Jet Blaster III, J Morita, Tokyo) was used under a gauge pressure of 0.4 MPa, with Al₂O₃ powder (High alumina, Shofu, Kyoto) of average grain size of 50 μm. The sandblaster was held on a magnetic stand, and the specimen on a small vise. The tip of the sandblaster was aimed at right-angle with the center of the specimen's top edge. Distance between the blaster tip and the specimen was regulated using a spacer of 10-, 15-, and 20-mm thickness, respectively. A stopwatch was used to regulate emission time. In this experiment, the specimens of Au-Pd-Ag alloy with 45° marginal bevel were the main objects of study, while the specimens with 30° and those of gold alloy assumed a secondary role. Each group had five specimens.

4. Re-tracing
After sandblasting, the specimen was positioned on the stage of the profile projector. The whole image of the specimen was projected on the screen under ×50 magnification and the paper traced beforehand was superimposed to standardize the notches cut at the two lateral sides of the specimen. Then, the upper and lower parts of the specimen were traced under ×100 magnification.

5. Measurement of marginal damage
Discrepancy between the two lines, before and after sandblasting, was measured with a ruler and expressed in mm. A small deflection inevitably occurred as the specimen was positioned on the vise, such that the most abraded area differed for each specimen. So, the widest discrepancy was taken as a representative value of the specimen.

6. Statistical analysis
Concerning the Au-Pd-Ag specimen with 45° marginal bevel, two-way ANOVA was performed to examine the interactions between distance and emission time at 0.05 significance level. For comparison among the groups of Au-Pd-Ag alloy specimens emitted from the same distance but with different emission times, one-way ANOVA/post-hoc test (Scheffe) was used at a significance level of 0.05. Comparisons between the marginal bevel angle of 45° and 30°, and between Au-Pd-Ag alloy and gold alloy specimens, were analyzed using unpaired t-test at significance level of 0.05.

Experiment II: Bond strength
1. Preparation of adherend
A pair of adherends were fabricated by dental casting method with 12% Au-Pd-Ag alloy. One was a circular plate, approximately 10 mm in diameter and 1.4 mm in thickness, with a T-bur for the tensile test. The other was a block, approximately 25×10×5 mm. Both of the facing surfaces were finished flat with a #320 silicon carbide paper under water.

2. Preparation of bonded unit
Both facing surfaces of the adherend were treated with sandblaster. The treating condition was selected from Experiment I results, which showed considerably less damages as follows (distance-emission time): 10-2, 15-2 and 20-2. There were also two control groups. One of the controls was a sufficiently treated surface: 10-4 (control A). The other was without sandblasting, only applied with a primer (control B). An adhesive tape, measuring 0.2 mm in thickness, with a hole of 4 mm in diameter was pasted on the cast block to define a bonding area. Both adherends were treated with a primer for casting alloy (Metaltite, Lot No. 015, Tokuyama Dental, Tokuyama) and dried in air. Equal lengths of cement paste (Bistite II, Lot No. 02C and 28R, Tokuyama Dental, Tokuyama) were squeezed out on a mixing pad, and mixed cement mass was spread out thinly on the mixing pad. Care was taken to reduce air bubbles in the cement layer by using a small instrument to apply the cement on both adherends. A finger pressure was applied on the T-bur for approximately 10 seconds. Finally, the bonded units were left to stand on the bench for 1 day to secure cement polymerization.

3. Tensile bond test
For tensile test, bonded unit was mounted on a jig and loaded by a universal testing machine (DCS-500, Shimazu, Tokyo) with a cross-head speed of 1 mm/min. The results were recorded on a chart paper.

4. Statistical analysis
Data were subjected to ANOVA/post-hoc test (Scheffe) at a significance level of 0.05.
RESULTS

Marginal damage
Fig. 2 shows the degree of marginal damage of Au-Pd-Ag alloy specimens, and Fig. 3 shows that of the gold alloy specimens. All treating conditions damaged the marginal bevels by more than $1.0 \times 10^{-10} \mu m$.

Concerning the Au-Pd-Ag specimens of $45^\circ$ bevel, two-way ANOVA revealed no interactions between emission time and emission distance. The emission time was significant ($p<0.0001$), while emission distance was close to predetermined significance level but not significant ($p=0.0504$). The results of a statistical treatment among the groups emitted from the same distance but with different emission times were dotted in Fig. 2.

As to the comparison of differences in marginal bevel angle, specimens with $30^\circ$ were abraded more than those with $45^\circ$, where two out of four groups (Au-Pd-Ag specimen, 10 mm - 2 sec; gold alloy specimen, 10 mm - 4 sec) were statistically significant.

Concerning the differences in casting alloy, specimens of the Au alloy were abraded more. Only one (10 mm - 4 sec, $30^\circ$) out of four groups compared was statistically significant.

Tensile bond strength
Fig. 4 shows the results of the tensile bond test. The groups treated with the sandblaster showed comparable values (22-26 MPa) despite the different blasting conditions. The group without sandblasting (control B) showed a statistically low value (17 MPa) instead. In other words, a longer emission time did not contribute to higher bond strength. But sandblasting was effective in increasing bond strength.
DISCUSSION

Marginal bevel angle
The ideal marginal bevel angle for a metal inlay cavity is considered to be 45 degree\(^5\). Another textbook\(^6\) recommended bevel angles of 25-35\(^\circ\). This angle range of 25-35\(^\circ\) seems to be close to the actual condition of cavity preparation, as it is apt for the marginal bevel angle to be thin due to the cuspal inclination of the occlusal surface. A thin margin of 30\(^\circ\) is prone to be abraded more than that of 45\(^\circ\), but this factor of bevel angle showed a statistical significance only among half of the groups tested. Therefore, marginal bevel angle was not a crucial factor, but neither was it safe to be too thin.

Blasting condition with less damage
In this study, sandblasting was performed mainly at 10-mm distance from the specimen, according to a discussion with dental technicians of the University Hospital of Nagasaki about the fundamental techniques of sandblasting. They shared that they usually performed sandblasting at approximately 10-mm distance from the object with the intent of removing the surface oxide film. Moreover, they added that beginners were prone to blast for too long a time. Considering their suggestions, the basic experimental conditions were set at emission distance of 10 mm and emission time of 2 seconds.

When emitted at 5-mm distance, the treated area was narrow — less than 4 mm. This meant that emission must be performed many more times in order to treat the same area, it would result in much damage to the casting. Therefore, the condition of emitting at 5-mm distance was omitted from the data of Experiment I. The measured values emitted at 5-mm were as follows: \(1.8 \times 10^{\pm 5} \mu m\) for 1 second blasting, \(2.2 \times 10^{\pm 5} \mu m\) for 2 second blasting, and \(3.4 \times 10^{\pm 11} \mu m\) for 4 second blasting. These values were much higher compared to those emitted from a longer distance.

From the results of this experiment, the condition of emitting at 20-mm distance seemed to be safer and to cause less damage.

Effect of sandblasting on bond strength
When the groups were treated for 2 seconds from different distances, they showed comparable bond strength to the group that was treated for 4 seconds (control A). This showed that it was not necessary to be treated so long, if the intent was just to remove the surface oxide film. Effectiveness of sandblasting on bond strength exhibited the same results as those of the other studies\(^1\text{--}^3\).

Clinical suggestion for less damage
It was shown that emission time was a crucial factor from the analysis of Experiment I. It would be useful if a guideline for a less damaging emission can be provided for the internal surface of the casting, when sandblasting is needed. It is suggested that the surface oxide film should remain after casting, without any acid pickling. Oxide film on the external surface of casting can be removed by finishing and polishing. The surface oxide film on the internal surface should be used as the guideline basis for sandblasting. In other words, the emission time should be just long enough to remove the surface oxide film, and a longer blasting time would not contribute to increasing the bond strength (as shown in the bond strength test).

This is a dilemma. It is very difficult to decide which is more important: to obtain a higher bond strength with approximately 10\(\mu m\) of marginal abrasion, or to avoid marginal abrasion with a slightly lower bond strength.

REFERENCES