Experimental Impression Tray Fabricated with a NiTi Shape Memory Alloy Plate

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Received June 22, 1999/Accepted September 29, 1999

A small experimental impression tray was fabricated with a NiTi shape memory alloy plate. After recovery of the shape memory effect, the upper rims of the tray holding the impression were opened to some extent, the resistance during removal of the model from the impression was significantly decreased compared to a commercially available tray and the tray before recovery of the shape memory effect. The pull-out force of the model from the impression was 23.5(0.2)N for the commercially available tray, 23.5(3.9)N for the experimental tray before recovery of the shape memory effect and 14.7(4.0)N after recovery of the shape memory effect (heated for 15min at 70°C). Therefore the tray should be useful in teeth fracture free modeling.

Key words: Impression tray, Shape memory alloy, NiTi alloy

INTRODUCTION

When a stone model is removed from an impression, the teeth of the model are often fractured, especially when only a few teeth remain in a full mouth impression. This is due to the visco-elastic properties of the impression material. After setting the cast stone, a spreading force is applied to the impression, and the stone is often easily removed. Therefore, if the upper rims of a tray holding the impression are opened to some extent, the resistance during removal of the stone model from the impression decreases. A small experimental tray made of a NiTi shape memory alloy plate was fabricated for use as an impression tray.

MATERIALS AND METHODS

NiTi shape memory alloy plate: Furukawa electric Co. recently developed a NiTi shape memory alloy plate. A 50.2 at% Ni-Ti alloy plate 0.67 mm in thickness was used. The plate was heat-treated for the shape memory effect. This alloy plate was transformed at about 50°C(Aₛ) and finished at about 65°C(Aₚ). A typical DSC curve
of this alloy plate (DSC-50, Shimadzu, Kyoto) is shown in Fig. 1. Once recovered the shape memory of the alloy is irreversible. Therefore once the upper rims were opened to some extent, the shape of the tray could be corrected by hand at room temperature. These characteristic are different from the conventional NiTi alloys described by L. H. Lee et al.1)

Experimental impression tray: The experimental impression tray was 34 mm in length, 25 mm in width and 15 mm in depth as shown in Fig. 2. The tray was perforated in a similar manner to commercially available trays (Fusayama's, Yamaura, Tokyo). When the experimental tray was heated to over 70°C, the upper rims spread 5 mm in the transverse direction from the original position as shown in Fig. 2. Once opened, the process was irreversible even at room temperature. The shape of the tray could be corrected by hand.

Measurement of the force of the shape memory effect: The force generated in opening the space between the rims was determined using a three point bending apparatus with a universal testing machine (AG500-B, Shimadzu, Kyoto), and the tray lying on the jig as shown in Fig. 3. Silicone rubber heaters (Wattlow,
Sakagutidennetu, Tokyo) were attached to both sides on the bottom plate of the tray using double sided adhesive tape, and the tray was heated. The temperature elevation was measured at the end of a rim with a thermocouple (C060-T, Chino, Tokyo) and then the temperature of a rim was gradually elevated from room temperature through thermal conductivity of the alloy. Therefore the force was detected as the function of temperature on the end of a rim.

Three specimens were tested and the mean value was calculated.

Pull-out test of the model from the impression: A mandible dental study model (D15FE-500A, Nissin, Kyoto) was used for taking impressions. Paraffin wax of 16 × 30 mm and 1.4 mm thick was seated on one side of the posterior area of the model to gain space. A heavy bodied silicone impression material (Exafine, GC, Tokyo) was seated into the tray, and then the tray was pressed on the model. After removal of the wax, a light bodied silicone impression material (Exafine, GC, Tokyo) was injected around the model with four posterior teeth and the tray was repositioned. After setting the material, a constant weight of stone (New Fujirock, GC, Tokyo) was cast into the impression. A plastic mesh pattern, 10 × 20 mm with threaded steel wire was also embedded in the stone to conduct the pull-out test and to prevent fractures during testing.

The pull-out test of the stone model from the impression was conducted with a universal testing machine with a cross-head speed of 10 mm/min (Fig. 4). Two testing conditions were examined at room temperature; the tray before recovery of the shape memory effect and that after recovery of the shape memory effect (heated for 15 min at 70°C in an oven).

The commercially available tray was also tested as a reference.

Six specimens were examined under each condition and the results were statistically analyzed using a t-test.

RESULTS

Fig. 5 shows a typical example of the force generated to open the space between the rims as a function of the temperature. The force was determined to be 69.6(2.6)N over 60°C.

Table 1 shows the results of the pull-out test of the model from the impression. The pull-out force before recovery of the shape memory was 23.5(3.9)N and showed an equivalent value to the commercially available tray of 23.5(0.2)N. However, after recovery of the shape memory, the force required was 14.7(4.0)N. The value was significantly decreased compared to that before recovery (p<0.05).

Our findings confirmed that the tray facilitated easy removal of the stone model from the impression.
DISCUSSION

NiTi alloy has unique properties of a shape memory effect and a super-elastic effect\(^2,3\). It is well known that Ni causes an allergic reaction in vital tissues\(^4-6\). Due to its high content of Ni, NiTi alloy is difficult to utilize for biomaterials, despite its unique properties. NiTi alloy is only commonly used for the orthodontic wire because of its super-elastic property in dental materials\(^7\).

The authors propose that this alloy plate would be useful as an impression tray to facilitate easy removal of stone casts from impressions. The experimental tray was rigid enough to be seated on the model\(^8\). After setting the cast, when the tray was heated in an oven at 70°C for 15 min, the pull-out force of the stone model from the impression was significantly decreased compared to that before recovery of the shape memory effect as shown in Table 1.

Therefore applying the shape memory effect to an impression tray was found to be useful. Considerable time was required to recover the shape memory effect in the experiment, and the time depended on the large thermal capacity of the impression and the stone cast compared to the thin plate of the tray. In addition, the tray was heated under dry conditions to recover the shape memory effect and avoid water absorption by the stone. However, in clinical situations when the tray would be immersed in hot water over 70°C, the recovery of the shape memory effect of the tray will occur instantaneously.

![Fig. 5 Force generated by the shape memory effect as a function of temperature.](image1)

![Fig. 6 Overview after pull-out test of the impression.](image2)

<table>
<thead>
<tr>
<th>Table 1</th>
<th>Results of the pull-out test of the stone model from the impression</th>
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<tbody>
<tr>
<td></td>
<td>Experimental tray</td>
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<tr>
<td>After recovery (70°C×15 min)</td>
<td>14.7 (4.0)</td>
</tr>
<tr>
<td>Before Recovery</td>
<td></td>
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</tbody>
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Unit: Newton, ( ) : SD
Once this plate recovers its shape memory effect, the process is irreversible. Therefore, the shape of the tray after recovery cannot change at room temperature. This is convenient when removing the stone model from the impression and retrieving the impression material from the tray. The bond between upper rims of the tray and the impression was separated after the recovery of shape memory effect as shown in Fig. 6. When the impression was taken again, the shape of the tray could be corrected by hand. The durability of the shape memory effect was considered to be sufficient for practical use\(^9\). As the shape of the tray had to be corrected by hand when the impression was taken again, the plastic deformation was occurred to some extent. Therefore the durability of the tray is being tested.

**CONCLUSION**

An experimental tray was fabricated with a NiTi shape memory alloy plate. After setting the cast stone the tray was heated to recover the shape memory, and the cast stone model was easily removed from the impression. The tray should prove useful for tooth fracture free modeling.

**ACKNOWLEDGMENTS**

This study was partially supported by a Grant-in-Aid for Scientific Research (B)(2) 10557180 of The Ministry of Education, Science, Sports and Culture.

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