

## ORIGINAL ARTICLE

**A comparison of the fitting accuracy of thermoplastic denture base resins used in non-metal clasp dentures to a conventional heat-cured acrylic resin**JUNICHIRO WADA<sup>1</sup>, KENJI FUEKI<sup>1</sup>, MASARU YATABE<sup>1</sup>, HIDEKAZU TAKAHASHI<sup>2</sup> & NORIYUKI WAKABAYASHI<sup>1</sup><sup>1</sup>Section of Removable Partial Prosthodontics, Department of Masticatory Function Rehabilitation, Graduate School of Medical and Dental Sciences, and <sup>2</sup>Oral Biomaterials Engineering, Department of Oral Materials Sciences and Technology, Faculty of Dentistry, Tokyo Medical and Dental University, Tokyo, Japan**Abstract**

**Objective.** To incorporate a metal framework into removable partial dentures, the dimensional accuracy of thermoplastic resins requires precision equivalent to conventional acrylic resins. This study aimed to evaluate the fitting accuracy of thermoplastic resins compared to heat-cured acrylic resin. **Materials and methods.** Four thermoplastic resins (polyethylene terephthalate [EstheShot, ES; EstheShot Bright, ES-B], polyamide [Lucitone FRS, LF], polycarbonate [Reigning Resin N, RN] and a heat-curing acrylic resin [Acron, AC]) were used. The specimens were created on master casts constructed of high-strength stone that simulated a maxillary edentulous ridge. Additionally, high-expansion stone was used as the master cast for RN specimens. The ES-B, LF and RN specimens were prepared with and without annealing after injection molding. The gaps between the molded resin and the cast were measured. **Results.** ES had the smallest gap and was significantly smaller than AC ( $p < 0.05$ ). The gap sizes of ES-B, LF and RN (high-expansion stone) without annealing were similar to AC ( $p > 0.05$ ), while the gap size of RN (high-strength stone) with and without annealing was significantly greater than AC ( $p < 0.001$ ). The gap sizes of ES-B and LF with annealing were significantly less than AC ( $p < 0.05$ ). Further, the gap sizes of ES-B, LF and RN with annealing were significantly smaller than the gaps without annealing ( $p < 0.05$ ). **Conclusions.** The results suggested that ES, ES-B and LF have adequate fitting accuracy for incorporating metal framework into dentures and that annealing effectively improved the fitting accuracy of ES-B, LF and RN.

**Key Words:** denture base, fitting accuracy, removable partial denture, thermoplastic resin**Introduction**

Esthetics is a great concern for patients undergoing dental procedures. Consequently, to provide better patient satisfaction, clinicians must consider esthetic aspects when planning dental procedures, especially prosthetic treatments. In Japan, removable partial dentures (RPDs) made from thermoplastic resins have been used increasingly for patients who, for esthetic reasons, do not prefer conventional RPDs with metal clasps. Thermoplastic resin (nylon) RPDs were originally developed in the 1950s for patients with allergies to acrylic resin monomer [1,2] or other thermoplastic resins with a low elastic modulus,

such as polycarbonate, polyethylene terephthalate and poly (methyl methacrylate) (PMMA) resin used for non-metal clasp dentures (NMCD). Recently, the Japan Prosthodontic Society (JPS) acknowledged the use of NMCD for RPDs made from thermoplastic resins [3]. However, NMCDs without metal elements lack rigidity and adequate support on the abutment teeth. Therefore, because the occlusal force on RPDs cannot be transferred directly to the abutment teeth, wearing NMCDs without metal elements may be associated with the risk of abutment teeth displacement and resorption of the residual ridge under the denture base. A model study suggested that incorporating a metal

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Table I. The denture base resins used in the study.

Composition	Brand name	Batch number	Manufacturer
Polyethylene terephthalate	EstheShot (ES)	JBB	i-Cast, Kyoto, Japan
Polyethylene terephthalate	EstheShot Bright (ES-B)	2A8556150	i-Cast, Kyoto, Japan
Polyamide (Nylon)	Lucitone FRS (LF)	120308A	Dentsply/Trubyte, York, PA
Polycarbonate	Reigning Resin N (RN)	GSE12T	Toshinyoko, Niigata, Japan
Polymethyl methacrylate (PMMA)	Acron (AC)	Monomer 1203121 Polymer 1207121	GC Corp., Tokyo, Japan

framework into the NMCD was effective for decreasing denture deformation under occlusal force [4]. Hence, JPS recommended that metal elements be incorporated into NMCDs to ensure denture rigidity [3].

In order to incorporate a metal framework into NMCDs, the dimensional accuracy of the thermoplastic denture base resins should be equivalent or greater than the precision required for conventional acrylic resin. If the thermal contraction of the thermoplastic resin during injection molding is greater than that of conventional acrylic resin, high-expansion stone must be used for the cast for injection molding, in order to compensate for the thermal contraction. Although several studies have described the mechanical properties of the thermoplastic denture base resins used for NMCDs [5], findings related to dimensional accuracy are limited. The linear dimensional changes of a polyamide resin (Valplast, Valplast Int. Corp., Long Island City, NY, USA), measured on a cast that simulated a maxillary edentulous arch, were reported to be 2.8-times greater compared to that of a conventionally processed PMMA resin [6], which suggested that it would be difficult to incorporate a metal framework into NMCDs made of Valplast.

Consequently, thermal annealing after injection molding is empirically applied to improve the dimensional accuracy of thermoplastic resins for NMCDs. While it has been reported that the annealing temperature had an effect on the shape memory performance of a thermoplastic polymer in the field of material science [7], the evidence for improvement in the dimensional accuracy of thermoplastic resins is lacking.

The current study aimed to investigate the fitting accuracy of thermoplastic denture base resins used for NMCDs compared to a conventional acrylic resin, as well as to assess the effect of annealing on fitting accuracy. The fitting accuracy was measured as the gap between the cast and the resins. The null hypotheses tested were that the fitting accuracy of thermoplastic resins for NMCDs was the same as PMMA and that annealing would not improve fitting accuracy.

## Materials and methods

### Resins

Four thermoplastic resins (EstheShot [ES], EstheShot Bright [ES-B], Lucitone FRS [LF] and Reigning Resin N [RN]) that are widely utilized for NMCDs in Japan and a heat-curing PMMA resin (Acron [AC]) were used in the current study (Table I). Valplast was not included in this study because its dimensional accuracy is extremely poor compared to that of PMMA [6].

### Specimen preparation and fitting accuracy

An impression of a brass master model (K887-01-000A, Morita, Kyoto, Japan; Figure 1) that simulated a maxillary edentulous ridge was taken using a silicone impression material (DUPLICONE, Shofu, Kyoto, Japan). The master casts of the brass master model were made of high-strength stone (NEW FUJIR-OCK, GC Corp., Tokyo, Japan). A dental paraffin wax with 1.5 mm thickness (PARAFFIN WAX, GC Corp., Tokyo, Japan) was fitted on the master casts with a counter die made of high-strength stone. After flasking and eliminating the wax from the master casts, the thermoplastic resins were injected and molded on the master casts using an injection-molding system (MIS-II, i-Cast, Kyoto, Japan), according to the manufacturer's instructions (Table II). The ES-B, LF and RN test specimens were treated with and without thermal annealing (storage

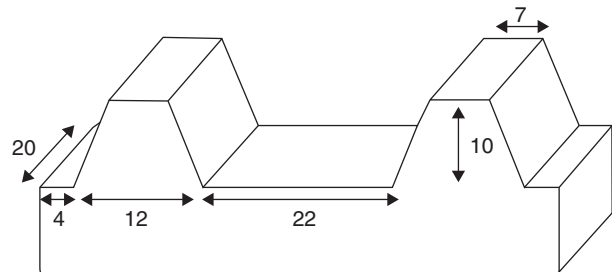


Figure 1. The brass master model simulating the maxillae edentulous ridge.

Table II. Molding conditions for injection-molded thermoplastic resins in MIS-II system.

Brand name	Drying		Pre-heat		Injection pressure (MPa)	Annealing	
	Temperature (°C)	Time (h)	Temperature (°C)	Time (min)		Temperature (°C)	Time (min)
EstheShot	60	24	240	20–30	0.90	—	—
EstheShot Bright	70	24	280	20–30	0.90–1.00	100	60
Lucitone FRS	—	—	300	20	0.85–1.00	100	60
Reigning Resin N	120	4–6	330–340	30	0.90–1.00	—	—

in boiling water at 100°C for 60 min after molding) after injection molding. In addition, RN specimens were prepared without annealing treatment on master casts made of high-expansion stone (Reigning Stone HE, Toshinyoko, Niigata, Japan), as recommended by the manufacturer. The AC specimens were fabricated in a conventional manner (polymerization in a water bath at 60°C for 60 min and 100°C for 30 min).

After injection molding, the specimens were removed from the master casts and immersed in water for 24 h. Next, the specimens were replaced on the master casts and vertical load was applied on the specimens with 20 N for 5 min using the counter die. Immediately after the loading task, the specimens on the master casts were embedded using high-strength stone (Vel-Mix Classic, Kerr Dental Laboratory Products, Orange, CA, USA). After re-shaping the samples, the surfaces of the samples to be measured were polished using waterproof abrasive paper (#1000, FUJI STAR, Sanyo-Rikagaku Co., Ltd., Saitama, Japan). For each material under each condition, 15 samples were prepared.

The gaps between the molded resins and the master casts were measured for each sample at five locations across the specimen using a microscope (MM-200, Nikon Instruments Co., Ltd, Tokyo, Japan; Figure 2).

#### Statistical analyses

An average value of the gaps measured at the five locations in each sample was calculated and the mean gaps ( $n = 15$ ) for each resin were used for statistical analysis. For three resins (ES-B, LF and RN), statistical analysis was performed and compared with other

resins both with and without annealing. One-way ANOVA was used to compare the mean of the gaps among the denture base resins and *post-hoc* multiple pairwise comparisons were performed using a Tukey's test. A *t*-test was used to evaluate the effect of annealing on the mean of the gaps for ES-B, LF and RN. The significance level was set at 5% ( $\alpha = 0.05$ ). The Statistical Package for the Social Sciences (SPSS) software for Windows 11.5J (SPSS Japan, Inc., Tokyo, Japan) was used for all statistical analyses.

#### Results

The means of the gaps at the five measurement points for each resin are shown in Figure 3. The results of the one-way ANOVA with Tukey's multiple comparisons of the gap means across the five measurement points and the results of the *t*-test to evaluate the effect of annealing are shown in Table III. Significant differences in the gap means among the denture base resins were detected using ANOVA ( $p < 0.001$ ). Among the resins tested in the study, ES exhibited the smallest mean gap size and was significantly smaller than that of AC ( $p < 0.05$ ). ES-B and LF with annealing displayed significantly smaller mean gap sizes compared to that of AC ( $p < 0.05$ ), but the differences without annealing were not significant ( $p > 0.05$ ). ES-B and LF without annealing showed significantly greater mean gap sizes compared to ES ( $p < 0.05$ ), but the mean gap sizes of ES-B and LF with annealing were comparable to that of ES ( $p > 0.05$ ). The mean gap size of RN was the greatest among the resins tested in the study. RN with and without annealing showed greater mean gap sizes compared to that of AC, while no significant difference was found

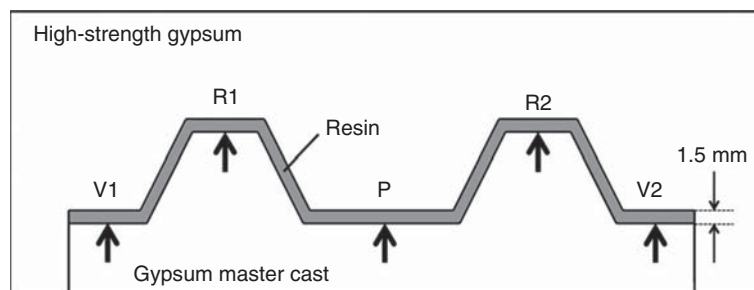


Figure 2. Schematic representation of specimen and measurement points. V, vestibule point; R, ridge point; P, palate point.

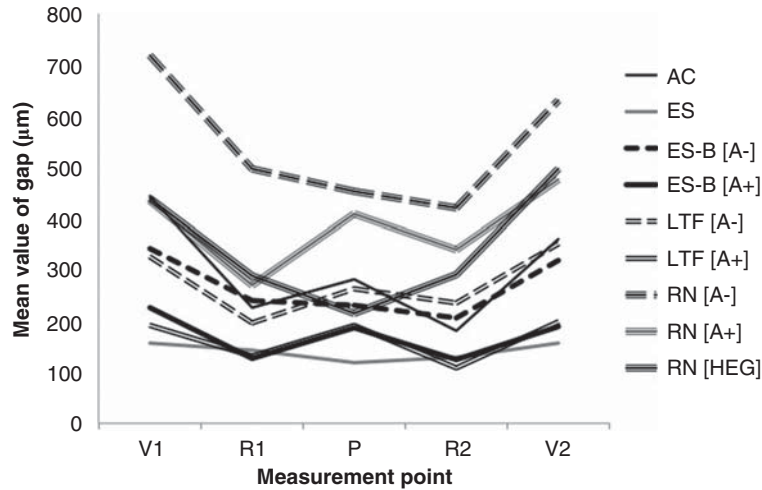


Figure 3. Mean value of gap between resin specimens and the plaster models at five measurement points. A–, without annealing; A+, with annealing; HEG, high-expansion stone.

Table III. Mean (SD) of mean gap size ( $\mu\text{m}$ ) with and without annealing treatment ( $n = 15$  for each resin).

Condition	Brand name						$p^s$	Tukey test <sup>ss</sup>
	AC	ES	ES-B	LF	RN	RN[H] <sup>#</sup>		
Without annealing	298 (113)	141 (43)	267 (73)	274 (113)	544 (159)	346 (140)	< 0.001	ES < ES-B, LF, AC, RN[H] < RN
With annealing	—	—	171 (71)	164 (33)	386 (104)	—	< 0.001	ES, ES-B, LF < AC < RN
$p^{sss}$			0.001	0.001	0.003			

<sup>#</sup>High-expansion stone; <sup>s</sup>One-way ANOVA; <sup>ss</sup>< Indicates significant difference between resins ( $p < 0.05$ ); <sup>sss</sup> $t$ -test.

between RN (high-expansion stone) and AC. Further, the results of the  $t$ -test revealed that annealing resulted in a significant improvement in the mean gap sizes for ES-B, LF and RN ( $p < 0.05$ ).

## Discussion

The four NMCD thermoplastic denture base resins tested in the current study exhibited marked variation in mean gaps (ranging from 141  $\mu\text{m}$  for ES to 544  $\mu\text{m}$  for RN), which suggested that the fitting accuracy varied according to the thermoplastic resin type. Further, the results indicated that the fitting accuracy of ES was significantly higher than the accuracy of AC, whereas the fitting accuracies of ES-B and LF were similar to that of AC, but were more precise than AC after annealing. Therefore, the cast made of high-strength stone typically employed for AC, into which a metal framework can be incorporated, may be used for ES, ES-B and LF. Conversely, the fitting accuracy for LN prepared on the high-strength stone cast was inferior to that of AC, even after annealing treatment, but the fitting accuracy for LN prepared on the cast made of high-expansion stone was similar to that of AC. Thus, to ensure appropriate fitting, the cast made of high-expansion stone, into which a metal framework cannot be incorporated, should be used for

NMCDs constructed of LN, as recommended by the manufacturer.

In the current study, the fitting accuracy was evaluated using a microscope. In a separate study that evaluated the fitting accuracy of denture base materials using a microscope, the specimens were removed from the master cast and subsequently re-fixed on the master cast with sticky wax applied only at the sample borders [8]. The fabrication method used in the prior study may have resulted in specimen instability, which potentially affected the reliability of the measurements of the gap between the specimens and the cast. In the present study, high-strength stone was used to re-fix the removed specimens. Thus, the evaluation method employed in our study had measurement precision advantages over the methods used in the previous study [8]. In contrast, we could not evaluate the three-dimensional fitting accuracy in the current study, because the dimensional change was measured in only one dimension.

The thermal contraction due to cooling that occurs when the pre-heated sample is brought to room temperature after injection molding is thought to result in a dimensional change in thermoplastic resins. In this study, the lowest pre-heat temperature was applied to ES (240°C), which showed the best fitting accuracy. Conversely, the highest pre-heat temperature was

utilized for LN (330–340°C), which showed the least accurate fitting. Thus, the pre-heat temperature of thermoplastic resins may be correlated with the degree of fitting accuracy.

Following treatment with thermal annealing, substantial improvements in the fitting accuracy were obtained for ES-B (36%), LF (40%) and RN (29%). Thus, the annealing treatment applied in the current study could be recommended to improve the fitting of NMCDs constructed from these resins. Although thermal annealing is not addressed in the manufacturer instructions, it is commonly performed to achieve better denture base fitting. The annealing conditions used in this study (storage in boiling water at 100°C for 60 min after molding) were recommended based on clinical experience. However, the storage conditions and the duration of thermal annealing vary in the literature [9,10]. A study that evaluated the mechanical properties of polycarbonate treated with annealing under a nitrogen atmosphere used 140°C for either 1 h or 5 h [9]. In a separate study that assessed the surface morphology of polyethylene terephthalate, the annealing setting was at 110°C for 10 min [10]. The annealing setting may influence the fitting accuracy and the mechanical properties of thermoplastic resins. Furthermore, in NMCDs, the denture base, as well as the retentive part of the retainers (resin clasps), are made of thermoplastic resins. Further investigations are necessary to confirm whether annealing improves the fitting accuracy of resin clasps on abutment teeth and influences the retentive capacity of NMCDs.

## Conclusions

Despite the limitations of this study, it was concluded that the fitting accuracy of thermoplastic resins (ES, ES-B and LF) were adequate for incorporating a metal framework into NMCDs. Further, in terms of fitting accuracy, high-expansion stone should be used for the duplicated cast when using RN, per the manufacturer's guidance. Last, we recommend the annealing of the three thermoplastic resins, to improve the fitting accuracy of NMCDs constructed from ES-B, LF or RN.

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**Declaration of interest:** The authors report no conflicts of interest. The authors alone are responsible for the content and writing of the paper.

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