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## Position paper

# Clinical application of removable partial dentures using thermoplastic resin. Part II: Material properties and clinical features of non-metal clasp dentures



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<http://dx.doi.org/10.1016/j.jpor.2014.03.002>

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## ARTICLE INFO

### Article history:

Received 16 December 2013

Accepted 18 March 2014

Available online 18 April 2014

### Keywords:

Removable partial denture

Thermoplastic resin

Non-metal clasp denture

Resin clasp

Position paper

## ABSTRACT

This position paper reviews physical and mechanical properties of thermoplastic resin used for non-metal clasp dentures, and describes feature of each thermoplastic resin in clinical application of non-metal clasp dentures and complications based on clinical experience of expert panels. Since products of thermoplastic resin have great variability in physical and mechanical properties, clinicians should utilize them with careful consideration of the specific properties of each product. In general, thermoplastic resin has lower color-stability and higher risk for fracture than polymethyl methacrylate. Additionally, the surface of thermoplastic resin becomes roughened more easily than polymethyl methacrylate. Studies related to material properties of thermoplastic resin, treatment efficacy and follow-up are insufficient to provide definitive conclusions at this time. Therefore, this position paper should be revised based on future studies and a clinical guideline should be provided.

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## 1. Introduction

The Japan Prosthodontic Society proposed a definition and naming standard for removable partial dentures (RPDs) using thermoplastic resin, and presented guidelines for their clinical application in 2013. This is the secondary publication of the position paper published in the official journal of the Japan Prosthodontic Society [1]. In the first part, a definition of non-metal clasp dentures (NMCDs), indications/contraindications and advantages/disadvantages in clinical use were described [2]. This second part presents the mechanical properties of thermoplastic resin, clinical application and maintenance of these materials.

## 2. Mechanical properties of thermoplastic resins used for NMCDs

Regarding the materials used for NMCDs, 14 products made from five types of thermoplastic resin (polyamides, polyesters, polycarbonates, acrylics, and polypropylenes) have been approved for dental use in Japan as of 2012 (Table 1). In 2009, the Japanese Society for Dental Materials and Devices responded to a request from the Japan Prosthodontic Society to evaluate the material properties of elastic thermoplastic resins, but tested only three of the materials used in NMCDs: Valplast<sup>®</sup>, EstheShot<sup>®</sup>, and Reigning Resin<sup>®</sup> [3]. Since then, numerous new materials have been developed by 2012, but these have yet to undergo complete physical evaluation.

The mechanical properties of NMCDs that have been evaluated include flexural strength [3–11], flexural modulus [3–11], bonding strength [3,11–14], absorbency [3,7,8,15,16], abrasion [3,17,18], surface hardness [7,19–21], resistance to impact [9–11], color stability [3,8,15,22], and fit [16,23–25]. However, it is not always possible to compare all these materials objectively, due not only to the large number of different materials but also to the diversity of clinically appropriate testing methods and variations in results between different testing institutions. Values for flexural properties published by various manufacturers are listed in Tables 2 and 3, but for some materials those values were very different from the data obtained in scientific studies, and there are still many materials that have not even been evaluated. Different polyamides may also differ greatly in their flexural properties, indicating the need for objective evaluation of all the different materials under the same conditions. It must be mentioned that clinical use has taken precedence, and materials are being subjectively evaluated by clinical experience.

This Position Paper summarizes the properties of materials from among the various mechanical properties that have been reported to date, but this information may require revision in future as new materials and new assessment methods are developed. Even materials of the same basic type may differ in physical attributes and properties. In this paper, we list the physical attributes and mechanical properties of different materials in the form of criteria for their selection for clinical use (Tables 2–4).

**Table 1 – Thermoplastic resins available for non-metal clasp dentures in Japan (December 2012).**

Generic name	Product name	Manufacturer
Polyamide	Bioplast	High Dental Japan
	Valplast	UNIVAL
	Flex Star V	Nippon Dental Supply
	BIO TONE	HIGH-DENTAL JAPAN
	Lucitone FRS	DENTSPLY International
Polyester	EstheShot Bright	i-Cast
	EstheShot	i-Cast
Polycarbonate	Reigning N	Toushinyoukou
	Reigning	Toushinyoukou
	JET CARBO-S	HIGH-DENTAL JAPAN
	JET CARBO RESIN	HIGH-DENTAL JAPAN
Acrylic resin	ACRY TONE	HIGH-DENTAL JAPAN
Polypropylene	UNIGUM	WELDENZ

### 2.1. Polyamides

The most important property of polyamides is their resistance to fracture, but their physical attributes vary, with Bioplast<sup>®</sup> possessing the lowest flexural strength and flexural modulus, and Ultimate<sup>®</sup> the highest. Differences in flexural strength and flexural modulus are often used as selection criteria when deciding which material to use in terms of tooth contour level. However, impact resistance may vary greatly between different materials irrespective of flexural strength and flexural modulus [9,10]. As polyamides do not bond to self-curing resins [3], repair and relining is difficult and must be done in a laboratory, but a number of methods are currently being tried out [6,15]. Although materials vary in terms of absorbency, Lucitone FRS<sup>®</sup> absorbs a greater amount than acrylic resins (Acron, GC, Tokyo) [8]. The change in color after immersion in curry was greater for Valplast<sup>®</sup> and Lucitone FRS<sup>®</sup> compared with acrylic resins [3,8]. Although few studies have addressed fitting accuracy, Valplast<sup>®</sup> undergoes high thermal contraction, and caution is therefore required in patients with multiple missing teeth [23]. At this point, the only information on the physical attributes and mechanical properties of Ultimate<sup>®</sup> is that provided by the manufacturer, and its verification by other institutions is therefore required.

### 2.2. Polyesters

There are two types of polyester material, both of which are relatively new. EstheShot<sup>®</sup> exceeds the requirements of the ISO standards for denture base resins in terms of both flexural strength and flexural modulus [3,7–10]. Its impact resistance is low, however, meaning that it entails a high risk of fracture [9,10]. According to the manufacturer's published figures, EstheShot Bright<sup>®</sup> has a flexural modulus of 1490 MPa, close to that of polyamides, making it softer yet with an impact resistance eight times greater than that of EstheShot<sup>®</sup> (Table 4). One important characteristic of polyesters is that they bond well to self-curing resins [3,15]. This means that repair, adding lost teeth, and relining can be performed at the chairside. EstheShot<sup>®</sup> exhibits lower absorbency than acrylic resins, and the color change after immersion in curry is greater [3,8]. The

**Table 2 – Flexural strength of thermoplastic resins used for non-metal clasp dentures.**

Generic name	Product name	Flexural strength (MPa)				
		Manufacturer data	Takahashi [3]	Takabayashi [8]	Hamanaka [9,11] <sup>c</sup>	Katsumata [6] <sup>d</sup>
Polyamide	Bioplast	27 ± 10				
	Valplast	78–98 <sup>a</sup>	27–42	35–41	13.7 ± 0.8	
	Flex Star V	30>				
	BIO TONE	57 ± 10				
	Lucitone FRS	60–65		70–78	22.3 ± 0.9	83.6 ± 3.3
	Ultimate	60 <sup>b</sup>				
Polyester	EstheShot Bright	61.1			24.2 ± 0.7	
	EstheShot	76	65–70	85–92	30.4 ± 2.1	
Polycarbonate	Reigning N	65>				
	Reigning	76.8	70–80	88–95	29.6 ± 1.0	
	JET CARBO-S	80 ± 10				
	JET CARBO RESIN	85 ± 10		90–100		
Acrylic resin	ACRY TONE	48			17.3 ± 0.5	
Polypropylene	UNIGUM	65–130				

For reference: Acrylic resin (ACRON, GC) 90.7 MPa (manufacturer data), 90–110 MPa [8], 38.2 MPa [9,11].  
<sup>a</sup> Converted to MPa.  
<sup>b</sup> Tensile test.  
<sup>c</sup> Proportional limit.  
<sup>d</sup> Maximum value (elastic limit).

**Table 3 – Elastic modulus of thermoplastic resins used for non-metal clasp dentures.**

Generic name	Product name	Elastic modulus (MPa)				
		Manufacturer data	Takahashi [3]	Takabayashi [8]	Hamanaka [9,11] <sup>c</sup>	Katsumata [6]
Polyamide	Bioplast	540 ± 50				
	Valplast	1471–1765 <sup>a</sup>	800–1400	826 ± 111	1045 ± 110	
	Flex Star V	650>				
	BIO TONE	1340 ± 50				
	Lucitone FRS	1330–1360		1639 ± 88	1450 ± 50	1380 ± 70
	Ultimate	1600 <sup>b</sup>				
Polyester	EstheShot Bright	1493			1590 ± 21	
	EstheShot	2069	2000–2200	2826 ± 193	1980 ± 80	
Polycarbonate	Reigning N	2000>				
	Reigning	2126	2300–2400	2701 ± 120	2190 ± 110	
	JET CARBO-S	2110 ± 50				
	JET CARBO RESIN	2380 ± 50		3097 ± 234		
Acrylic resin	ACRY TONE	1360			1355 ± 39	
Polypropylene	UNIGUM	2400–6000				

For reference: Acrylic resin (ACRON, GC) 2805 MPa (manufacturer data), 2917 MPa [8], 2770 MPa [9,11].  
<sup>a</sup> Converted to MPa.  
<sup>b</sup> Tensile test.  
<sup>c</sup> Proportional limit.  
<sup>d</sup> Maximum value (elastic limit).

fitting accuracy of EstheShot<sup>®</sup> is the best of all the different types of resins [23].

### 2.3. Polycarbonates

Polycarbonates have been produced by improving the thermoplastic resins originally approved under health insurance for use in NMCDs. Their flexural strength and flexural moduli are both higher than those of polyamides and polyesters

[3,7–10]. According to the manufacturer's published figures, JET CARBO-S<sup>®</sup> and Reigning N<sup>®</sup> have lower elastic moduli than JET CARBO RESIN<sup>®</sup> and Reigning<sup>®</sup>, and can be used even in patients with a large undercut. Although no references on fracture risk are available, Reigning<sup>®</sup> has high impact resistance [7,9,10]. Reports of actual fractures provide a clinically appropriate evaluation of physical properties. Although their fit is poorer than EstheShot<sup>®</sup>, it is better than Valplast<sup>®</sup> [23]. Their bonding to self-curing resins is around

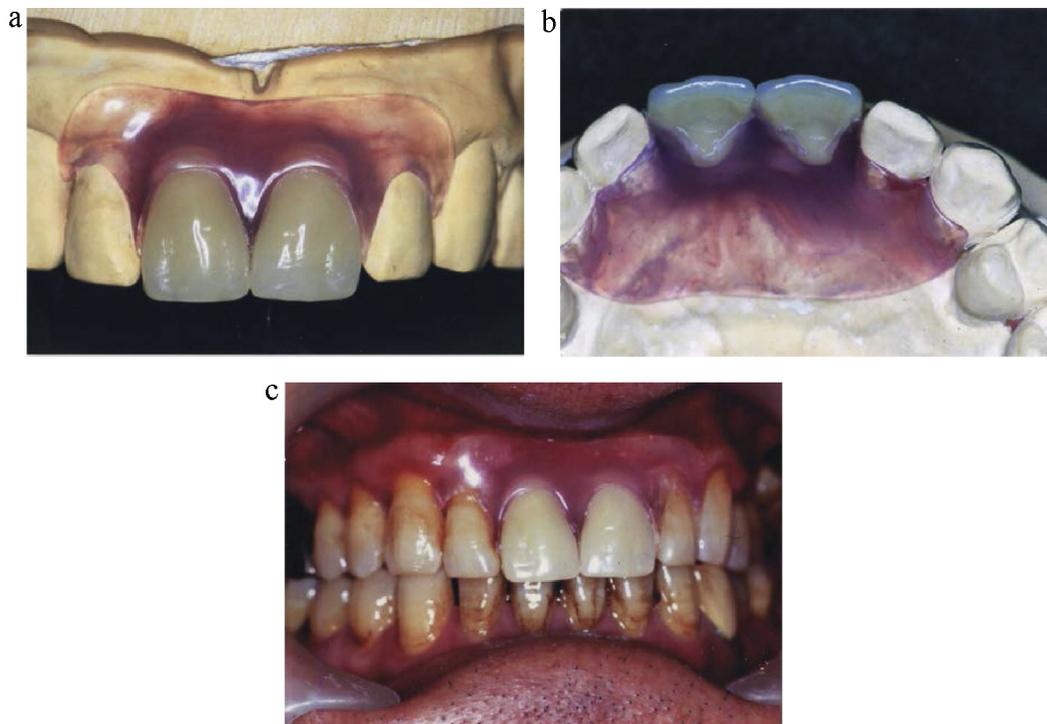
**Table 4 – Physical and mechanical properties of thermoplastic resins used for non-metal clasp dentures.**

Generic name	Acrylic resin	Polyamide			Polyester		Polycarbonate		Acrylic resin
Product name	ACRON [3,8,17]	Valplast [3,8,17]	Lucitone FRS [5,6,23,25,29]	Ultimate	EstheShot [7,8]	EstheShot Bright [11,14]	Reigning [3,5–7,30]	Reigning N [3,7,8,25,33]	ACRY TONE [11]
Relative weight (density) (g/cm <sup>3</sup> ) [27]	1.16–1.20	1.04	1.02	1.06 <sup>a</sup>	1.12			1.20 <sup>a</sup>	1.15 <sup>a</sup>
Injection molding conditions (°C)	–	288	240	280 <sup>a</sup>	230–240 <sup>a</sup>	270–290 <sup>a</sup>		300–340 <sup>a</sup>	260–270 <sup>a</sup>
Glass transition point (°C)		50	155	155 <sup>a</sup>	67 <sup>a</sup>	113 <sup>a</sup>		150	
Mold shrinkage (%)				0.8 <sup>a</sup>				0.6	0.4–0.7 <sup>a</sup>
Tensile strength (MPa)	90	60	70	60 <sup>a</sup>	45.5		57–76	56	
Solubility (µg/mm <sup>3</sup> )	0.3 <sup>a</sup>	2	0		0 <sup>a</sup>	0 <sup>a</sup>		<1.6 <sup>a</sup>	0.3 <sup>a</sup>
Water absorption (µg/mm <sup>3</sup> )	22.9 <sup>a</sup>	17	28–30		10.7 <sup>a</sup>	6.4 <sup>a</sup>			22 <sup>a</sup>
Absorption coefficient water (%)				1.5 <sup>a</sup>	0.303		0.24–0.31	0.23–0.29 <sup>a</sup>	
Resilience (J)					3.16		5.12		
Rockwell hardness (HRM)					21.8		59.9	56.7 <sup>a</sup>	
Izod impact strength (kJ/m)							14.0	88.0 <sup>a</sup>	5.2 <sup>a</sup>
Charpy impact strength (kJ/m <sup>2</sup> ) [9,11]	1.1	6.9	30.2	NB <sup>a</sup>	4.1 (10 <sup>a</sup> )	65.3 (80 <sup>a</sup> )	21.3		6.5
Surface roughness (µm)	0.9	0.24	0.21						
Shear bond strength with acrylic resin (MPa) [11,14]	12.6	2.5	3.3		17.5	11.7	12.3		17.1
Shear bond strength with acrylic resin (surface treatment <sup>b</sup> ) (MPa) [14]		16.5	19.6		23.5		24.1		

NB: not broken.

<sup>a</sup> Manufacturer data.

<sup>b</sup> Silica coating + 4-META/MMA-TBB.



**Fig. 1 – A non-metal clasp denture without metal framework replacing missing maxillary bilateral frontal teeth (Valplast®). (a) Labial view on working cast, (b) palatal view on working cast, and (c) intraoral labial view with the denture.**

the same level as that of acrylic resins [3]. JET CARBO RESIN® and Reigning® have lower absorbency than acrylic resins [3,8]. The color change of Reigning® after immersion in curry is around the same as or less than that of acrylic resins [3,8].

#### 2.4. Acrylic resin

ACRY TONE® is the only acrylic resin currently used for NMCDs. This product uses an acrylic resin that is much softer than the thermoplastic resins (ACRY SHOT® and ACRY JET®), which are approved for use under health insurance, but information on its physical attributes is limited [24].

#### 2.5. Polypropylenes

This type of thermoplastic resin has only recently been approved for use in denture bases. According to its manufacturer, UNIGUM® may be useful as a multi-purpose repair material, but no detailed reference information is available.

### 3. Characteristics of thermoplastic resins used for NMCDs

#### 3.1. Polyamides

##### 3.1.1. Valplast®

Valplast® is a polyamide resin developed from a type of nylon material, with 99.9% of its content consisting of poly-lauractam (nylon 12, chemical formula  $\{CO(OH)_2_{11}NH\}_n$ ). It has a lower elastic modulus than acrylic resins, whereas its flexural

strength and flexural modulus are only approximately one third as high. It is thus soft, easily deformable, and elastic. Its high amount of flexion means it is unlikely to fracture; however, denture bases will not break even if a large occlusal force or stress is applied. Its excellent elasticity means it can be used even in abutment teeth with a large undercut. It is only available in a single color, but as this is semitransparent pink it easily blends in with the color of the gums, giving it the esthetic advantage that the border between base and gums is difficult to distinguish [26]. It can be used to make thinner denture bases than those possible with acrylic resins [26], and is also of lower specific gravity [27], minimizing discomfort when dentures are worn. It is useful for spare dentures, or for dentures worn only when going out. It possesses sufficient strength and elasticity not to fracture even under the application of maximum stress [3]. Colorless and odorless, it has no risk of allergy, and is highly resistant to both acids and alkalis. There is almost no change in its surface roughness even after immersion in glutaraldehyde or sodium hypochlorite. It may also be used to provide retention when inserting a denture base into the undercut of the residual ridge.

Its disadvantages include the fact that its surface is easily damaged [26], and that the polished surface gradually loses its luster after dentures have been inserted, becoming rougher and darker. These can be improved somewhat by repolishing at a laboratory used to dealing with Valplast®. It is extremely difficult to grind and polish [26], and its retentive capacity is also difficult to adjust. As its surface roughness is greater than that of acrylic resins, it is susceptible to plaque adhesion and coloration. One of the foods that causes the greatest change in color is curry [3,8]. When Valplast® is used to cover a wide

area, its fit becomes poor. Because it warps under a small amount of stress, patients with large numbers of missing teeth and large denture base may tend to feel rocking of their dentures and have difficulty in sensing the degree of bite. As it does not bond to acrylic resins, reline and repair are difficult to carry out at the chairside [26,28]. This problem has reportedly been addressed by methods such as the use of resin repair materials or treating the surface with 4-META/MMA-TBB resin after sandblasting to enable bonding to acrylic resins [13].

Valplast<sup>®</sup> is the most suitable for NMCDs in patients with intermediary defect of 1–2 incisors that require only a retentive area and a denture base, without a major connector (Fig. 1). It may also be used for patients with intermediary defect of molars (requiring a metal rest). The low elastic modulus of Valplast<sup>®</sup> means that dentures are lacking in rigidity, but this can be obtained by using it in combination with a metal framework, expanding its indications [29].

### 3.1.2. Lucitone FRS<sup>®</sup>

Lucitone FRS<sup>®</sup> is a polyamide resin with excellent stability, esthetic appearance, and functionality made from a high-grade microcrystalline polyamide (Trogamid CX7323). It is characterized by its softness compared with polyester resins and polycarbonate resins. This softness means it provides an outstanding fit that is unlikely to cause pain, and also makes it less likely to break if dropped. It is a little harder than Valplast<sup>®</sup>, another polyamide resin, which gives it greater durability. Its fit is also good, and it is highly resistant to abrasion, making it easy to polish and grind, and it has the further advantage of being resistant to stains and dental calculus.

However, Lucitone FRS<sup>®</sup> also has the disadvantages that fracture may occur in some patients if the denture base is too thin, and that it lacks color stability [15,22]. The design of the labiobuccal side must also be taken into account in order to strengthen its retentive capacity [30]. As it also becomes looser with long-term use, it is a good idea to overcome this loosening with a buccolingual connection such as a metal rest or wire (Fig. 2). Its greatest disadvantage is that it does not bond to self-curing resins, making repair and reline difficult, and methods using special equipment have been described. Artificial teeth also fall out easily, and adequate mechanical retention holes must therefore be provided. Although its indications can be expanded by using it in combination with a metal rest, it is most suitable for patients with only a few missing teeth in areas where little force is applied to the retentive area, including areas where esthetics is important, such as the incisors and premolars.

### 3.1.3. Ultimate<sup>®</sup>

Ultimate<sup>®</sup> is a denture base material with properties similar to those of the polyamide resins, Valplast<sup>®</sup> and Lucitone FRS<sup>®</sup>. As it is a new material, little is known about it, and few laboratories are able to handle it. Ultimate<sup>®</sup> is a soft material with a low elastic modulus that is characterized by high durability. It can be used to make thin, light bases that are comfortable when worn. In terms of design, its hardness can be increased by the use of a metal rest or metal major connector, and wires should preferably be incorporated into the structure to prevent breakage of the resin clasp and enable



**Fig. 2 – A non-metal clasp denture connecting a metal rest and buccal-medial/lingual resin clasps with a wrought wire on maxillary left first premolar (Lucitone FRS<sup>®</sup>).**

readjustment of its retentive capacity. The use of such designs improves its hardness and expands its indications. Care is required when it is used in patients with inadequate clearance who have problems with the support or strength of artificial teeth, or those with a shallow oral vestibule (<10 mm).

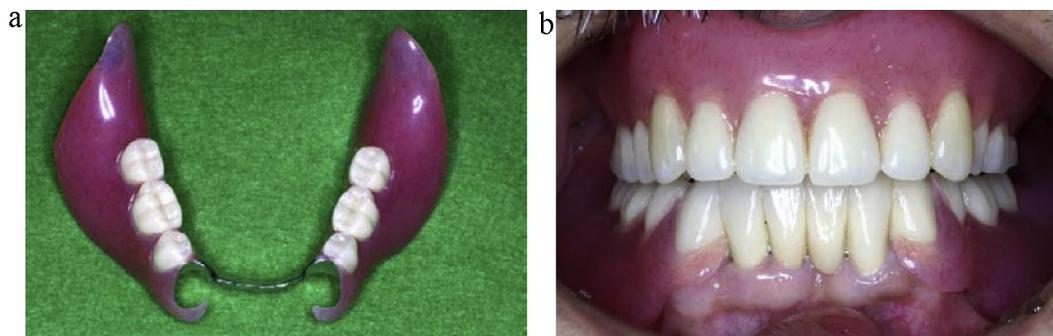
One general problem with polyamide resins is that they lose color or become discolored over time. Ultimate<sup>®</sup> is believed to change color to a lesser extent than Valplast<sup>®</sup> and Lucitone FRS<sup>®</sup> after dentures have been inserted, although this varies between individuals and depends on denture management.

As Ultimate<sup>®</sup> is also a polyamide resin, it is difficult to carry out repairs or relining with self-curing resins at the chairside. Ultimate<sup>®</sup> can be reinjected, however, to enable indirect relining, addition of teeth, and repair of the resin clasp. Ultimate<sup>®</sup> can also be used to repair and reline NMCDs made of Lucitone FRS<sup>®</sup>.

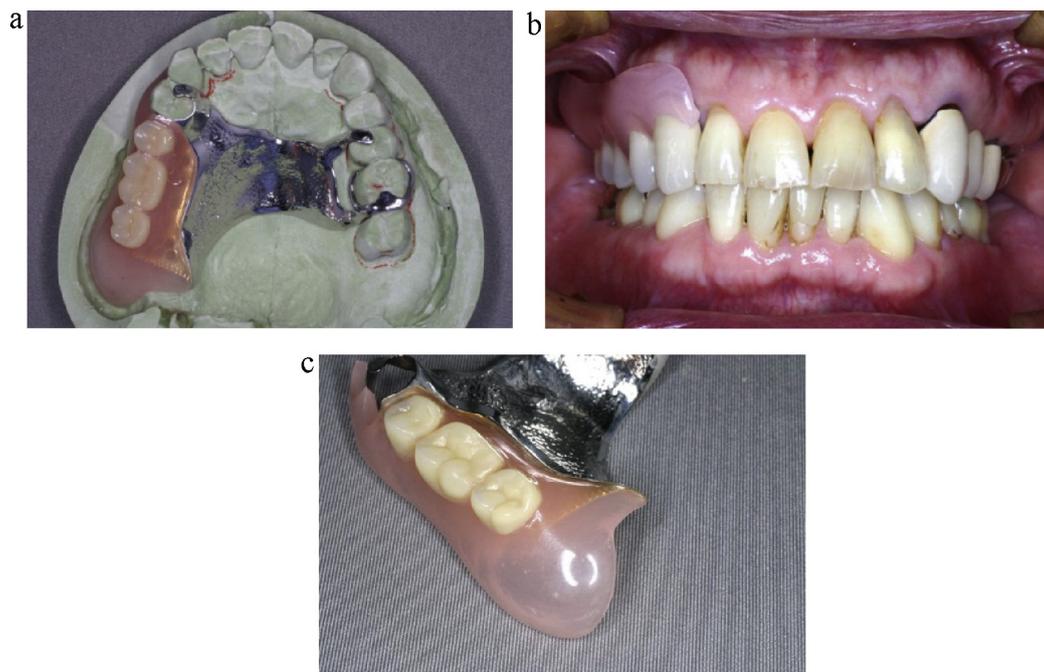
## 3.2. Polyesters (EstheShot<sup>®</sup>, EstheShot Bright<sup>®</sup>)

EstheShot<sup>®</sup> is a polyester resin that has polyethylene terephthalate copolymer, well known as the material used to make plastic bottles, as its main ingredient (Fig. 3). EstheShot Bright<sup>®</sup> has a lower flexural modulus than EstheShot<sup>®</sup>, and has been developed as a novel polyester resin that combines strength and flexibility (Fig. 4). The package insert lists polyester copolymer as the main ingredient of EstheShot Bright<sup>®</sup>. Both have outstanding safety, esthetic appearance, and functionality. There have been few studies on the physical properties of EstheShot Bright<sup>®</sup>, but various physical properties of EstheShot<sup>®</sup> have been reported (Table 4) [7,8].

Shear bond strength tests comparing EstheShot<sup>®</sup> and acrylic resins have shown that this product has higher bond strength than polyamide, polycarbonate, or acetyl resins [3]. This is regarded as the most important advantage of EstheShot<sup>®</sup>, and in practice it can be easily repaired with self-curing resins. Fitting tests also indicated better results than polyamide or polycarbonate resins [23]. In clinical practice, no problems with fitting have been clinically experienced. It has, however, been reported to have lower resilience and Rockwell hardness compared with polycarbonate and polyamide resins [7]. Its low resilience means that it is vulnerable



**Fig. 3 – A non-metal clasp denture with a metal framework using EstheShot®. (a) Polished surface of denture and (b) intraoral view with a mandibular non-metal clasp denture and a maxillary complete denture using a heat-cured acrylic resin.**



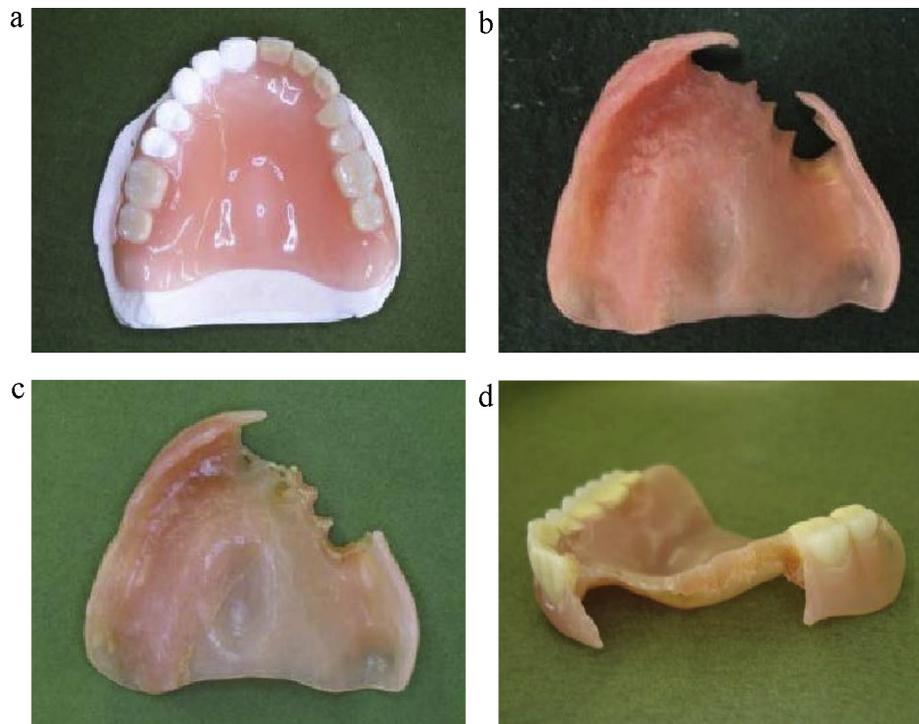
**Fig. 4 – A non-metal clasp denture using EstheShot Bright®. (a) Denture design. Non-metal clasp dentures using EstheShot Bright® as well as EstheShot® should follow the design principles of conventional RPDs. Resin clasps should be used as retainers only for esthetic requirement. (b) Intraoral view with denture. (c) Roughened polished surface and fractures were not observed after 6-month use.**

to fracture, and a few cases of fractured dentures have been reported. Its low hardness also makes it susceptible to abrasion, and the problem of surface roughness with long-term use has also been observed.

There have been few studies of the physical properties of EstheShot Bright®, making an objective comparison impossible, but its basic advantages are probably in line with those of EstheShot®. It is probably correct to assume that EstheShot®'s low flexural modulus has been improved to help prevent fracture. Although it probably also has low hardness, unlike acrylic resins, EstheShot® tends to be somewhat sticky during polishing, and this characteristic does not appear to have been improved significantly during denture adjustment in EstheShot Bright®. In clinical practice, however, it may be slightly easier to polish the denture. There is no obvious surface roughening after

six months, and it has probably been improved in this respect (Fig. 4c), but other issues may become apparent after future long-term follow-up. The package inserts for both materials include a warning to avoid the use of strongly alkaline denture cleaners, as these may cause degradation.

Dentures should have designs that conform to the standard RPD principles, in order to avoid problems such as excessive stress on retainers and denture sinking as much as possible. When used in combination with a framework, the framework plays the leading role in supporting, retaining, and bracing the dentures, and by using resin in the retentive area at sites where good esthetic appearance is required (Figs. 3 and 4a and b), denture movement is kept to a minimum, and the stress imposed by the resin clasp on the abutment teeth is also reduced as a result.



**Fig. 5** – A non-metal clasp denture without metal element used for an immediate denture (Reigning<sup>®</sup>) in a patient with multi-tooth loss. (a) Denture on working cast, (b) denture base view immediate after relining using a cold-cured resin, (c) the relined resin was detached on connecting regions at a year and 7-month after relining, and (d) fracture of resin clasps after 4-year and 3-month use.

### 3.3. Polycarbonates

#### 3.3.1. Reigning Resin<sup>®</sup>

Reigning<sup>®</sup> is a pigment-containing thermoplastic resin used for denture base that has polycarbonate resin as its main ingredient (Fig. 5). Polycarbonate resins are highly reliable, and are conventionally covered by national health insurance in Japan when used as denture base materials. Polycarbonate resin, which is the main ingredient of Reigning<sup>®</sup>, has already been used clinically as a denture material for around 20 years, and dentures made from polycarbonate resin are no different from those made from acrylic resins in terms of factors such as safety, fit, and feel when worn [31]. Reigning<sup>®</sup> has equivalent physical attributes to those of polyester resin, but is characterized by lower water absorbency and better abrasibility than other resins used for NMCDs. This material is also relatively unaffected by denture cleaners.

In terms of basic design, the support and bracing areas should be made of metal, with Reigning<sup>®</sup> used only for the retentive area. Reigning<sup>®</sup> alone should be used only in patients with missing incisors where the occlusal force is relatively low and in patients who have a strong concern for esthetic appearance; in patients with tight occlusion, a metal structure should be used even for such cases. If Reigning<sup>®</sup> alone is used in cases when the occlusal force load is high and there are a large number of missing teeth with inadequate support, there is a high risk that the resin clasps will fracture (Fig. 5d). If the clasp sits high on the tooth crown and impairs the esthetic appearance with a basic undercut of 0.5 mm,

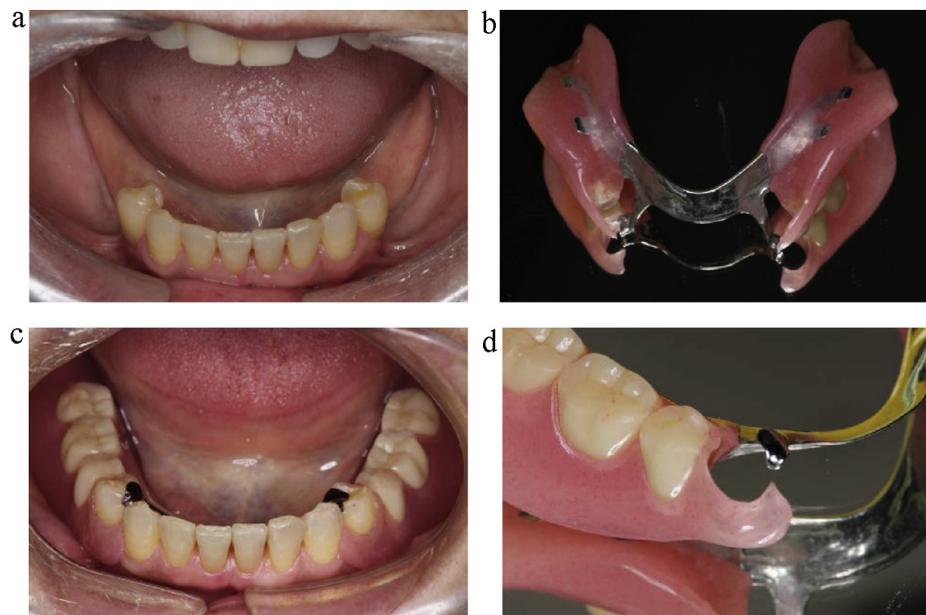
either the abutment tooth should be recontoured or a resin with a lower flexural modulus that can be used with a larger undercut should be selected.

Relining can be performed with self-curing resins, but peeling tends to occur at the bonding site (Fig. 5c). For this reason, its use should be avoided as far as possible in immediate dentures that require relining, as well as immediately following extraction. If the clasp fractures, the area to be repaired is formed in wax and flaked for injection molding to carry out the repair. Special repair materials are also available, and these can be used to deal with partial fractures. The use of artificial teeth made from the same material as Reigning<sup>®</sup> renders special retention unnecessary.

#### 3.3.2. Reigning N<sup>®</sup>

Reigning N<sup>®</sup> was launched as a follow-up to Reigning<sup>®</sup> (Fig. 6). Cases of fracture or cracking over time of Reigning<sup>®</sup> due to excessive internal stress and mechanical stress have been reported [32], but to date there has been no reported fracture of Reigning N<sup>®</sup> under normal conditions of use. This may be because the durability of Reigning N<sup>®</sup> has been doubled (the number of flexures until braking fracture in three-point fatigue testing was increased from 600,000 to 1.2 million times [33]), and its chemical resistance also has been improved.

Reigning N<sup>®</sup> is characterized by a higher elastic modulus compared with polyamide and polyester resins and a higher flexural strength, meaning that dentures made from this material are harder. From a hygiene perspective, its lower



**Fig. 6 – A non-metal clasp denture with a framework (Reigning N<sup>®</sup>). (a) Intraoral view without the denture, (b) basal surface of the denture, (c) intraoral view with the denture, and (d) metal rest and resin clasp.**

water absorbency makes it more hygienic, and the absence of monomer elution means that it tends not to cause irritation or allergic reaction. Compared with other resins, it is also less susceptible to discoloration or color change, with little degradation over time, and its surface is hard and highly resistant to abrasion [3]. It is available as a clear material, and another feature of this resin is that thermal welding can be used to perform two-stage injection molding of a clear resin clasp portion and a clear pink denture base. In terms of the advantage of fabrication, it can be thermally welded to the artificial teeth made of highly impact-resistant polycarbonate resin, meaning that artificial teeth do not fall out even when retention holes are not prepared. It has other advantages; it is more abradable than low-elastic resins, less vulnerable to polishing-induced thermal deformation, contracts little after injection, and is easy to use in combination with metal rests or major connectors (Fig. 6), but it does shrink more than acrylic resins, and its fit is poorer than that of EstheShot<sup>®</sup> [23,25]. Regarding repairs and relines, bonding between Reigning N<sup>®</sup> and self-curing resins is of high shear bond strength [3,14], meaning that chairside repair and relines using self-curing resin are feasible. Its glass transition point is high at over 130 °C [25], and thermal welding during reinjection makes it easy to add teeth or perform repairs.

One point to note during clinical use is that Reigning N<sup>®</sup> has a high elastic modulus, meaning that if it is designed with a similar size of undercut to that used for polyamide or polyester resins its retentive capacity will be exceeded, increasing the load on the abutment teeth and raising the risk of resin clasp fracture. If the survey line is set too high, this may also impair esthetic appearance in the same way as for Reigning<sup>®</sup>.

The greatest disadvantage of NMCDs without metal elements is generally considered to be the weakness of their support [34]. As Reigning N<sup>®</sup> has the highest elastic modulus among thermoplastic resins, a design that provides good

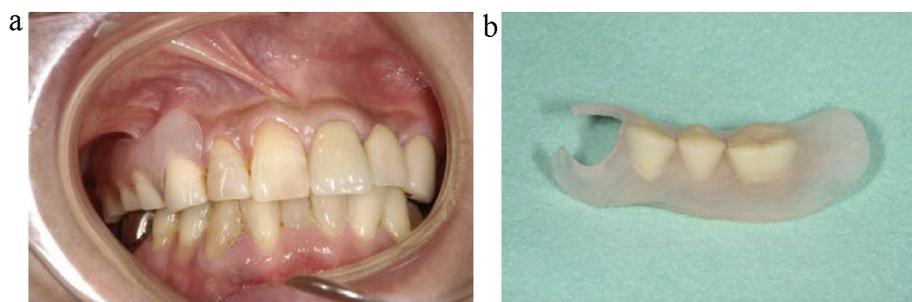
support is feasible, but to prevent fracture of the rest or resin clasp, the support and bracing areas should be made of metal, with Reigning N<sup>®</sup> used only in the retentive area. The procedures for surveying and design of the undercut for the resin clasp follow those for Reigning<sup>®</sup> (a basic undercut of 0.5 mm). As for Reigning<sup>®</sup>, NMCDs using Reigning N<sup>®</sup> alone, rather than a combination with a metal structure, should only be used for patients with missing incisors where the occlusal force is relatively weak and for patients who have a strong concern for esthetic appearance.

#### 4. Maintenance of NMCDs

NMCDs may be made from a variety of materials, and their properties vary depending on the material characteristics as described. A good understanding of these characteristics and the use of appropriate methods are also vital during maintenance of NMCDs.

The maintenance of NMCDs made from polyamide resins is generally very different from that of RPDs made from heat-curing resins (acrylic resins). NMCDs should not be subjected to mechanical denture cleaning with the stiff bristles found on denture brushes, and brushes made from a soft material must be used instead. As they are easily scratched or deformed, patients must be recalled regularly at shorter intervals. NMCDs made from polyamide resins are difficult to repair or relines using the methods normally used in the clinic for self-curing resins, and usually an impression is taken and sent to a laboratory to undertake repairs by means of reinjection.

The maintenance of NMCDs made from polyester or polycarbonate resins is similar to that used for RPDs made from heat-cured resins rather than NMCDs made from polyamide resins. NMCDs made from polyester or polycarbonate resins can be repaired with self-curing resins at the



**Fig. 7 – Chewing complaint with non-metal clasp denture. (a) Intraoral view with denture and (b) inappropriate denture design.**



**Fig. 8 – Esthetic complaint for resin clasp of non-metal clasp denture.**

chairsides. As high-pH alkaline denture cleaners should not be used for polyester resins, care is required when choosing a denture cleaner.

## 5. Complications of NMCDs

Clinical problems and complications seen in users of NMCDs can be divided into those that appear at the time of insertion and those that appear post-insertion. We discussed their various causes, and indicated precautions that should be taken in clinical application of NMCDs.

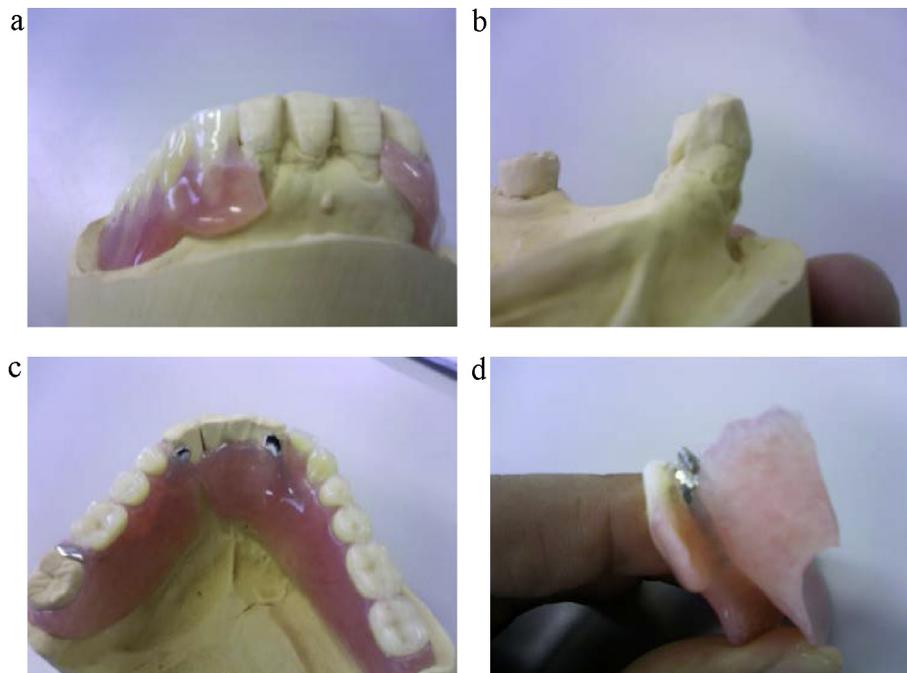
### 5.1. Problems at the time of (or immediately after) insertion

Fig. 7 shows a patient who complained of being unable to chew immediately after dentures were delivered. This was a unilateral free-end missing with four missing teeth, with one direct retainer and three teeth restored. Rather than the material used, the problem was with the RPD design, which did not restrict the denture movement during chewing. The design concept for NMCDs does not differ from that for conventional RPDs with metal clasps. Fig. 8 shows a patient who complained that the dentures were too obvious and she experienced a foreign-body sensation. Three teeth were missing on one side of the jaw, but the NMCDs had a unilateral design and the resin clasp was extended to the right central incisor. There were also problems with the morphology of the residual ridge, and the position of the tooth cervical

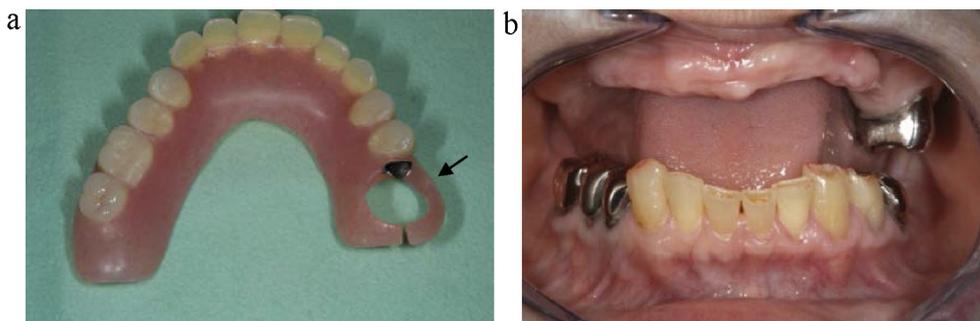
area was bilaterally asymmetrical in order to secure the width of the resin clasp. As the dentist insisted on a unilateral denture design, it seems that esthetics was compromised and the foreign body sensation increased.

### 5.2. Complications some time post-insertion

Fig. 9 shows a patient in whom the resin clasp and the major connector had fractured. There were problems with tooth crown morphology, denture design, and technical errors in laboratory procedures. If a softer material that was less vulnerable to fracture had been used, the dentures would have deformed, resulting in pain to the mucosa of the residual ridge, residual ridge resorption, and changes in occlusal position. A stable RPD requires a design that takes adequate support, retention, and rigid connection. Fig. 10 shows a patient in whom the resin clasp on the buccal side had cracked. In patients with Eichner class C1 occlusion, denture movement acts directly on the resin clasp. As a result, even if a metal framework is used as the major connector, the resin clasp will break or its retentive capacity is reduced. NMCDs should therefore not be used in such patients. Fig. 11 shows a patient with inflammation of the gingiva covered by the resin clasp. This was considered to be the result of the dentures having sunk due to the absence of adequate support by a metal rest. The bracing effect of a resin clasp is far less than that of a metal clasp, and a metal rest that provides adequate support is required. Fig. 12 shows a patient with a mobile mandibular right first premolar. Three teeth were used as abutment teeth for two missing teeth, but without a metal rest the load imposed by the horizontal rotation of the dentures fell entirely on the first premolar abutment tooth, causing mobility of the abutment tooth. Denture movement must be taken into account when designing NMCDs as well as conventional RPDs with metal clasps. Fig. 13 shows a patient in whom an artificial tooth had fallen out. Whatever the type of resin, it is always essential to provide mechanical retention for artificial teeth to improve bonding between artificial teeth and thermoplastic resins. The maxillary incisors in particular are susceptible to load applied in the labial direction, and care is imperative. Fig. 14 shows a patient with a crack on the occlusal surface of an artificial tooth at the rest. If the resin clasp expands widely in the shoulder area during insertion and removal, cracks may easily appear at the boundary between the metal rest and the resin. For teeth with a large undercut, it may therefore be necessary to consider recontouring of the abutment tooth or using a less elastic resin. Cracks also tend to occur in artificial



**Fig. 9 – Fracture of non-metal clasp denture. (a) Fracture of resin clasp, (b) unfavorable cervical form of abutment tooth and excessive undercut of residual ridge, (c) fracture of major connector, and (d) thickness of the major connector is not sufficient (provided by i-CAST Co, Ltd.).**



**Fig. 10 – Fracture of resin clasp. (a) Fracture of buccal resin clasp (indicated with arrow) and (b) occlusal relation overloading resin clasp.**

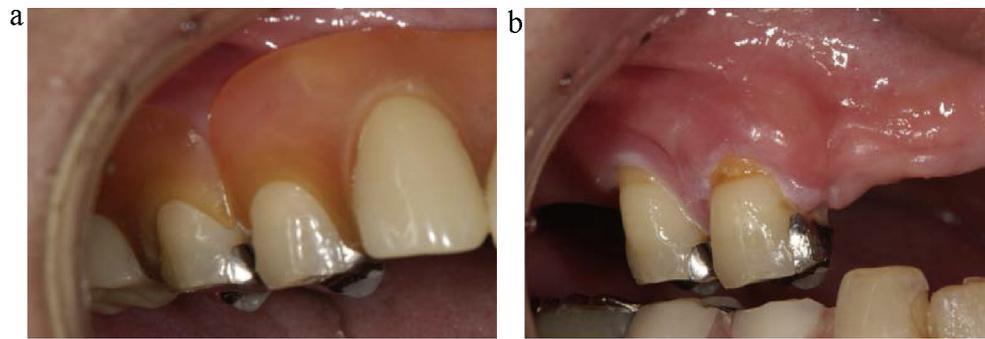
teeth if clearance is inadequate. Dentures may also sink if the support by the rest is insufficient, and this may cause the resin clasp to open during chewing, causing it to fracture. Care is required in patients with defects in which clearance with the opposing tooth is insufficient. Although the wearing period varies, it is not uncommon to see problems such as discoloration, loss of color, and surface roughening. If these complications are due to the properties of the resins itself, it would be difficult for the practitioner to deal with, but the use of a denture cleaner and a soft toothbrush is recommended.

These problems may occur either immediately after denture insertion or some time later. They include some cases in which NMCDs should not be used, but most of the problems can be avoided if care is taken with denture design and laboratory procedure. It goes without saying that full consideration of the design principles for conventional RPDs is required in prosthetic treatment, even with NMCDs. We have

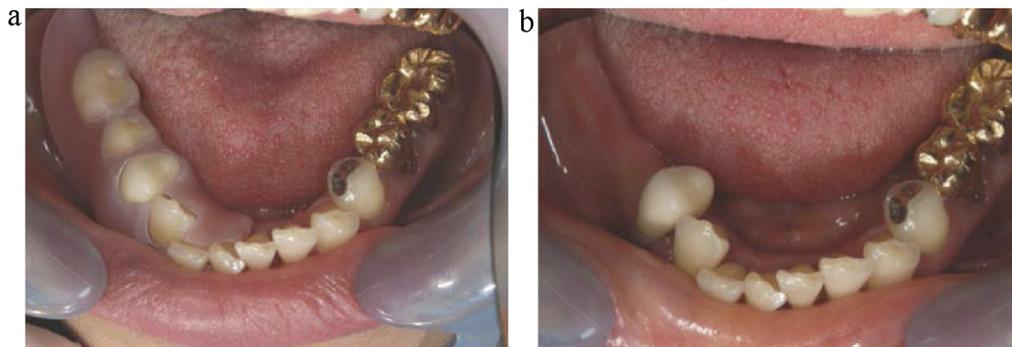
only been able to obtain information on a small proportion of materials. As their characteristics vary, it is important to use them after obtaining as much objective information as possible from scientific papers, workshops, and other sources. The future development of improved materials is required. In this Position Paper, we are unable to make any statements on peeling or discoloration at the finish line between each type of thermoplastic resin and its framework due to the lack of information, and future studies on this point are required.

## **6. Limitations of this Position Paper and future prospects**

The information regarding the use of the dentures described in this Position Paper, their durability, and other matters discussed here are opinions based on the clinical experience



**Fig. 11** – Influence of resin clasp on gingival tissue. (a) Resin clasp without metal rest and (b) compression and inflammation of marginal gingiva of abutment tooth due to depression of denture base.



**Fig. 12** – A non-metal clasp denture that overloads abutment teeth. (a) Intraoral view with a denture and (b) a terminal abutment tooth (mandibular right first premolar) presenting severe mobility.



**Fig. 13** – Detachment of an artificial frontal tooth from denture base.



**Fig. 14** – Fracture of artificial first molar on occlusal surface.

of the Expert Panel, and are not based on evidence obtained from clinical studies. For materials that have recently been approved, they may also be based only on short-term follow-up. The Expert Panel is not well informed on all the types of thermoplastic resin that are currently approved in use for NMCDs in Japan. This Position Paper therefore does not include details of the clinical use of some materials. Taking full note of these limitations, we hope that this Position Paper may be of some assistance in the prosthetic treatment of partially edentulous patients.

Current information on the physical and mechanical properties of thermoplastic resins is inadequate, and further basic studies in view of clinical application are required in the

future. There have also been almost no clinical trials of the treatment effect of NMCDs and follow-up studies. Meticulously designed clinical studies are desirable. The collection of evidence from such clinical studies will verify the validity of the principles indicated in this Position Paper, which should be revised into guidelines in the future. As new materials with improved mechanical properties are developed, the principles of the clinical use of NMCDs may be modified. Patients have high expectations of NMCDs, and as both demand and supply are expected to increase, continued update of information to both patients and healthcare providers (dentists, dental hygienists, and dental technicians) is important to ensure the appropriate clinical application of NMCDs.

## Acknowledgements

We would like to express our gratitude to Dr. Ippei Hamanaka and Dr. Yutaka Takahashi of the Division of Removable Prosthodontics, Fukuoka Dental College, who provided reference materials and data during preparation of this Position Paper.

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