Characteristics of denture thermoplastic resins for non-metal clasp dentures

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Six thermoplastic resins and conventional acrylic resin were examined to characterize their mechanical and physical properties, water sorption, solubility, flexural strength, modulus of elasticity, tensile strength and color stability. Thermoplastic resins for non-metal clasp dentures exhibiting low water sorption and solubility offer hygienic advantages. Since they have a low modulus of elasticity and are easily manipulated, these materials make it possible for larger undercuts to be used for retention compared to acrylic resin. Not all of the thermoplastic resins tested fractured after the bending test in contrast to the conventional denture base resin, which fractured when tested beyond its proportional limit. It was also found that clinically noticeable staining may occur on the polyamide resins and polyethylene terephthalate resins.

Keywords: Non-metal clasp dentures, Thermoplastic resins, Mechanical and chemical properties

INTRODUCTION

Most dental patients of all ages prefer to avoid the use of metal in dental treatment because of their desire for a bright, white smile. Due to such increased esthetic expectations, non-metal clasp dentures using thermoplastic resins have recently become a treatment option for patients. Several types of non-metal clasp dentures are available, all with the advantages of superior esthetics and the reduced potential for allergic reactions to metals. Additional advantages of these dentures are their flexibility and highly elastic nature, which decrease the stress on abutment teeth. After investigations into these types of materials were published, clinicians in Europe and the United States began using them for various clinical procedures, such as for orthodontic appliances and temporary dentures after implant placement instead of conventional dentures.

However, the present concern about these materials is that there is insufficient scientific evidence regarding the properties of the thermoplastic resins due to the small number of studies, as well as a lack of studies comparing the various clasp materials. Even though the indications and contraindications for the use of thermoplastic resins have never been clearly defined, some practitioners have already begun using them based on their preferences and clinical experience.

The purpose of this study was to characterize the mechanical and physical properties of most of the currently commercially available thermoplastic resins for non-metal clasp dentures for the aid in determining the clinical suitability of thermoplastic resins. An evaluation of some mechanical and physical properties, i.e., flexural strength, tensile strength, contact angle, water sorption, and color stability was conducted using conventional acrylic resin as a control.

MATERIALS AND METHODS

Thermoplastic resins

As shown in Table 1, the following three types of commercially available thermoplastic resins were tested in this study: Polyamide (PA-type) resins [Valplast (VAL), Lucitone® FRSTM (LTF) and Flexite® supreme (FLS)], Polycarbonate (PC-type) resins [Reigning (RP) and Jet Carbo Resin (JCR)], and Polyethylene terephthalate (PET-type) resin [Estheshot (EST)]. The chemical structure of polyamide, polycarbonate and polyethylene terephthalate was shown in Fig. 1. As a control, polymethyl methacrylate (PMMA) [Acron (AC)] specimens were prepared.

All the materials tested were in the shade of “pink” due to its common use in removable prosthetic practice, although each material has its own shade system. All the materials used in this study were Type 3 denture base resins: thermoplastic blank or powder as defined in ISO 20795-1: 2008, Dentistry-based Polymers-Part 1: Denture base polymer.

Fabrication of specimens

Metal molds and/or wax patterns were prepared in the desired shape for each sample. For water sorption test, flexural test for VAL, LTF, AC, metal molds were used to manufacture the specimens, and wax patterns were produced for other specimens. The samples were fabricated by the manufacturers or the manufacturers' recommended laboratories. Table 2 shows heating temperature, heating time, injection pressure, the temperature of the flask. The fabricated samples were reshaped with abrasive paper for each test. The AC specimens were fabricated in the conventional manner, i.e., polymerization in a water bath at 70°C for 90 min and 100°C for 30 min.
Flexural test
The testing of the flexural properties was performed in accordance with ISO standard 1567: 2005. The samples were wet polished using 600-grit waterproof abrasive paper as described in ISO standard 21948: 2001. Six specimens (64×10×2.5 mm) were made for each group. They were stored for 50±2 hours in distilled water at 37±2°C using an incubator. According to the method described in the ISO standard, each specimen was mounted on a universal testing machine (Instron 5565, Instron Japan, Kawasaki, Japan), and the load at deflection or fracture of specimens was recorded by applying the load. While dental materials testing should ideally be conducted under humid conditions in order to simulate the oral environment, due to the limitations of our testing equipment, the test was performed under normal room conditions immediately after the specimens were removed from the water at 37±2°C. Three-point bending tests were carried out with a distance of 50 mm between the two supporting points and a crosshead speed of 5 mm/min. The formulas found in the ISO standard were used to calculate the flexural strength and modulus of elasticity:

\[
\text{Modulus of elasticity } (E) = \frac{FL^3}{4ybd^3} \\
\text{Flexural strength } (S) = \frac{3PL}{2bd^2} \\
P: \text{load, } L: \text{length, } y: \text{deflection}
\]

Table 1 Materials used in this study

<table>
<thead>
<tr>
<th>Abbreviation</th>
<th>Type</th>
<th>Color</th>
<th>Lot</th>
<th>Manufacturer</th>
</tr>
</thead>
<tbody>
<tr>
<td>Valplast®</td>
<td>VAL</td>
<td>PA</td>
<td>Original pink</td>
<td>070933</td>
</tr>
<tr>
<td>Lucitone®FRSTM</td>
<td>LTF</td>
<td>PA</td>
<td>Original pink</td>
<td>070611A</td>
</tr>
<tr>
<td>Flexite® supreme</td>
<td>FLS</td>
<td>PA</td>
<td>LT pink</td>
<td>L5A</td>
</tr>
<tr>
<td>Reigning</td>
<td>RP</td>
<td>PC</td>
<td>RP-01 Clear pink</td>
<td>COC28T</td>
</tr>
<tr>
<td>Jet Carbo Resin</td>
<td>JCR</td>
<td>PC</td>
<td># 7a Real pink</td>
<td>0809107</td>
</tr>
<tr>
<td>EstheShot</td>
<td>EST</td>
<td>PET</td>
<td># 8 Live pink</td>
<td>IJA</td>
</tr>
<tr>
<td>Acron</td>
<td>AC</td>
<td>PMMA</td>
<td>Pear pink</td>
<td>070471</td>
</tr>
</tbody>
</table>

Table 2 Molding conditions for six thermoplastic resins

<table>
<thead>
<tr>
<th>Abbreviation</th>
<th>Heat temperature (°C)</th>
<th>Heat time (min)</th>
<th>Pressure (MPa)</th>
<th>Flask temperature (°C)</th>
</tr>
</thead>
<tbody>
<tr>
<td>VAL</td>
<td>288</td>
<td>9:30-12:30</td>
<td>1.0</td>
<td>100</td>
</tr>
<tr>
<td>LTF</td>
<td>302</td>
<td>17</td>
<td>0.5</td>
<td>60</td>
</tr>
<tr>
<td>FLS</td>
<td>270</td>
<td>15-35</td>
<td>7.8</td>
<td>70</td>
</tr>
<tr>
<td>RP</td>
<td>320</td>
<td>20</td>
<td>22.5</td>
<td>120</td>
</tr>
<tr>
<td>JCR</td>
<td>320</td>
<td>15</td>
<td>0.7</td>
<td>130</td>
</tr>
<tr>
<td>EST</td>
<td>240</td>
<td>30</td>
<td>1.0</td>
<td>40</td>
</tr>
</tbody>
</table>

Fig. 1 Chemical formulas of non-metal clasp denture base materials.
The contact angle with respect to the double-distilled water was measured using a Contact Angle Meter (CA-

Fig. 2   Dimensions of specimens for tensile testing.  \( L_0 \)  Gauge length 12±0.5 mm,  \( L \)  Initial distance between grips 40±1 mm,  \( l_1 \)  Length of narrow parallel-sided portion 16±1 mm,  \( l_2 \)  Overall length 60±2 mm,  \( b_1 \)  Width of narrow parallel-sided portion 3±0.2 mm,  \( b_2 \)  Width at ends 12±1 mm,  \( r \)  Large radius 12±1 mm, and  \( h \)  Thickness 2±0.2 mm.

\( b \): width of specimens,  \( d \): thickness of specimens,  
\( P \): the load at fracture (N)

(The maximum load value was used for testing the flexural strength of the thermoplastic resins.)

**Tensile strength test**

The tensile strength tests were conducted according to ISO 527: 1993 Plastic – Determination of tensile properties\(^{18,19}\) and JIS· K7113\(^{20}\), K6920\(^{21,22}\) and T6501\(^{23}\). Flat dumbbell-shaped specimens (16±1 mm long, 3±0.2 mm wide, and 2±0.2 mm thick at the parallel segment, Fig. 2) were used for tensile strength tests. The measurements were performed with universal testing machine (Instron 5565, Instron Japan) with a 50 mm grip-to-grip distance and 5 kN load cell at 25°C. The ISO and JIS standards do not include guidelines for the measurement of tensile strengths under wet conditions. In the present study, therefore, tensile testing was performed under dry conditions as the first step of the series of experiments.

The ISO and JIS standards include a wide range of tensile strength testing speeds. Since the purpose of our test was to measure tensile stress, it would have been ideal to set the testing speed at 50 mm/min±10%, which is the minimum speed in the JIS standard. Because the area of the parallel segment in the fabricated specimen was two-thirds of the standard, the testing speed was set at 30 mm/min, i.e., two-thirds of 50 mm/min as a proportional reduction. Based on the stress-strain curve, the strength for the maximum stress was obtained to measure the tensile strength.

**Contact angle**

The contact angle with respect to the double-distilled water was measured using a Contact Angle Meter (CA-

**Water sorption test**

The water sorption test was conducted in accordance with ISO Specification No. 1567: 2005\(^{24}\). The samples were wet-polished with 100-grit up to 1200-grit waterproof abrasive paper to produce three disk specimens (50±1 mm dia., 0.5±0.1 mm thick) for each group. Each specimen was then stored in a 100 ml round sample container with 35 g of silica gel (Tokaigel Blue, Tokai Chemical Industry, Toyoda, Japan) for desiccation purposes. Desiccation was repeated until mass changes decreased the weight to 0.2 mg or less as a constant weight. The mass \( (m_0) \) of each specimen was measured using an electronic balance (Shimadzu, Tokyo, Japan). The specimens were then immersed for seven days in distilled water at 37±2°C using an incubator (Yamato Scientific, Tokyo, Japan). They were removed from the water, wiped with a cleaning tissue (Kimwipe S-200, Nihon Seishi Cresia, Tokyo, Japan), and the mass of each specimen was measured 60 seconds after removal from the water (designated as \( m_1 \)). Desiccation of the specimens was performed again in the round sample container with silica gel, and then the mass at a constant weight \( (m_2) \) was measured. The water sorption of each specimen was calculated using the formula:

\[
W_{sp} = \frac{(m_1-m_2)}{V}
\]

\( W_{sp} \): water sorption (µg/mm\(^3\)), \( V \): volume (mm\(^3\))

The diameter of the specimens was obtained from the mean of three different points. The mean thickness was found by measuring the thickness at four equidistant points on the circumference and the thickness at the center of the specimen (total of five points). The volume of each specimen \( (V) \) was calculated using the mean values for diameter and thickness. Testing was repeated three times.

**Color stability test**

Five specimens (25×15×2.5±0.1 mm) were used to test the color stability. They were wet-polished with up to 1200-grit abrasive paper. After immersion in distilled water at 37°C for 48 hours, the specimens were dried in desiccators. The specimens were then soaked in a coffee solution (Coffee) (Nescafe\(^{6}\), Nestle, Kobe, Japan, 2 g/100 ml) at 70°C and in a curry solution (Curry) (House\(^{6}\), Higashiosaka, Japan, Kokumaro Curry Chukara, 2.9 g/100 ml) for 60 hours. A color measurement was performed for each specimen before and after soaking based on JIS Z 8730: 2009 (color specification)\(^{24}\) using the CIE1976 \( (L^*a^*b^*) \) color space system. The measurement was conducted under the standard illuminant D65 corresponding to average daylight\(^{24}\). The specimens were washed thoroughly with running water after soaking in the colored...
solutions. After desiccation, the color of the specimens was measured using a spectrophotometer (SE2000 Nippon Denshoku, Tokyo, Japan) against a gray background with a lightness level of 5. The diameter of the measurement window was 6 mm; the illumination and light receiving condition was 0-45°. Measurements were performed at six points for each specimen to obtain a mean value.

In addition, the differences in the $L^*a^*b^*$ values of the five specimens in each group before and after soaking were compared using AC as a control group. The color differences resulting from soaking were calculated using the following equation.

$$
\Delta E^*ab = \sqrt{(\Delta L^*)^2 + (\Delta a^*)^2 + (\Delta b^*)^2}
$$

$$
\Delta L^* = L^*_o - L^*_t
$$

$$
\Delta a^* = a^*_o - a^*_t
$$

$$
\Delta b^* = b^*_o - b^*_t
$$

$L^*_o$, $a^*_o$, $b^*_o$: before soaking

$L^*_t$, $a^*_t$, $b^*_t$: after soaking

The results of each test were statistically analyzed by a one-way analysis of variance (ANOVA) followed by Tukey’s multiple comparisons test at a significance level of $\alpha=0.05$.

**RESULTS**

Figure 3 shows the typical stress versus strain curve each thermoplastic resin and acrylic resin for flexural strength. As shown in the graph, six thermoplastic resins have never fractured though permanent deformation was occurred. Contrary, all of acrylic resin specimens fractured approximately 100 MPa.

The flexural strength of all the resins tested is presented in Fig. 4. Significant differences were observed among all the groups tested except among RP, JCR and EST ($p<0.05$). The modulus of elasticity of each specimen is presented in Table 3. No significant differences were observed between LTF and FLS, RP and EST, AC and EST, and JCR and AC ($p>0.05$); however, there were significant differences among the other materials ($p<0.05$).

Figure 5 shows the typical stress versus strain curve each thermoplastic resin and acrylic resin for tensile strength. AC was broken at an early stage, but other materials showed a ductile deformation. The tensile strengths of each thermoplastic resin with the control are presented in Fig. 6. No significant differences were observed between LTF and FLS, JCR and AC ($p>0.05$).

The contact angles with respect to double-distilled water are listed in Fig. 7. In contrast, there were no significant differences among VAL, FLS and EST ($p>0.05$).

The water sorption values for all the thermoplastic resins are presented in Fig. 8. The water sorption was the highest in LTF and the lowest in RP and JCR; there was a significant difference between the water sorption values of both products ($p<0.05$). Significant
differences were observed among all materials except between LTF and FLS, and JCR and AC ($p<0.05$).

The results of spectrophotometric color measurements are shown in Fig. 9, Tables 4 and 5. The $L^*$ values of all groups except for RP and JCR increased after soaking in the coffee solution, whereas the $a^*$ values increased only in the LTF, JCR, and AC groups. In contrast, the $b^*$ values of all groups increased after soaking in the coffee solution.

When samples were immersed in curry solution, some differences in color stability was recognized compared with coffee solution. Except for RP, the $L^*$ values of all groups increased after soaking in the curry solution. Only JCR and AC showed an increase in the $a^*$ value after soaking. In contrast, the $b^*$ values of all groups except for JCR increased after soaking in the curry solution, showing a remarkable color change in VAL, LTF, FLS, and EST.

Fig. 5 Stress-strain curves of non-metal clasp denture base materials for tensile strength in this study.

Fig. 6 Tensile strength of non-metal clasp denture base materials in this study. Horizontal brackets indicate groups that are not significantly different ($p>0.05$).

Fig. 7 Contact angle of non-metal clasp denture base materials against water in this study. Horizontal brackets indicate groups that are not significantly different ($p>0.05$).

Fig. 8 Water sorption of non-metal clasp denture base materials in this study. Horizontal brackets indicate groups that are not significantly different ($p>0.05$).

Fig. 9 Changes of $\Delta E^*_{ab}$ values of non-metal clasp denture base materials in coffee and curry solutions.
Regarding $\Delta E^*_{ab}$, VAL and FLS indicated higher values ($\Delta E^*_{ab}$) compared to RP and JCR in the coffee solution. Similarly, VAL, FLS and EST demonstrated greater values in the curry solutions than did RP and JCR. RP and JCR notably exhibited smaller values than the control (AC).

**DISCUSSION**

In the present study, we evaluated some mechanical and physical properties, *i.e.*, flexural strength, tensile strength, contact angle, water sorption, and color stability, of non-metal clasp denture materials and investigated the possibility for clinical application of non-metal clasp denture materials.

The six non-metal clasp denture materials did not fracture after flexural strength testing; however, the AC samples fractured when tested beyond the proportional limit. All of the unfractured materials exhibited white opacified plastic deformation in the load application area. In this study, the maximum stress was set to fracture points and maximum loading (yield) points in AC and thermoplastic resins, respectively.

According to the ISO standard, Type 3 denture base materials require more than 65 MPa of flexural strength and a modulus of elasticity of 2,000 MPa. Therefore, our results indicated that the PMMA, PC and PET types correlated with the standard values, but the PA types did not. PA types did not have aromatic ring in the structure. Therefore, it is speculated that the penetration of water molecules into the polymer

$\begin{array}{cccccccc}
\text{coffee solution} & \text{VAL} & \text{LTF} & \text{FLS} & \text{RP} & \text{JCR} & \text{EST} & \text{AC} \\
\hline
L^* & \text{before soaking} & 38.6 & 38.8 & 37.2 & 36.7 & 34.9 & 38.0 & 41.6 \\
& SD & 0.1 & 0.5 & 1.0 & 1.8 & 1.7 & 0.6 & 0.7 \\
& \text{after soaking} & 43.9 & 44.4 & 46.4 & 35.1 & 34.7 & 41.3 & 47.7 \\
& SD & 0.6 & 0.5 & 1.1 & 1.4 & 0.5 & 0.7 & 1.1 \\

a^* & \text{before soaking} & 11.3 & 12.2 & 8.7 & 7.4 & 10.5 & 9.9 & 7.6 \\
& SD & 0.3 & 0.1 & 0.8 & 0.3 & 1.3 & 0.7 & 0.1 \\
& \text{after soaking} & 10.8 & 14.8 & 6.6 & 6.8 & 10.8 & 9.2 & 8.6 \\
& SD & 0.4 & 0.6 & 0.3 & 0.4 & 0.3 & 0.3 & 0.4 \\

b^* & \text{before soaking} & 3.3 & 4.9 & 4.5 & 0.7 & 3.2 & -1.9 & 4.1 \\
& SD & 0.7 & 0.3 & 0.4 & 0.2 & 0.8 & 0.6 & 0.1 \\
& \text{after soaking} & 13.3 & 7.6 & 6.0 & 2.5 & 3.4 & 1.9 & 5.3 \\
& SD & 2.4 & 0.3 & 0.8 & 0.4 & 0.5 & 0.6 & 0.7 \\
\hline
\end{array}$

$\begin{array}{cccccccc}
\text{curry solution} & \text{VAL} & \text{LTF} & \text{FLS} & \text{RP} & \text{JCR} & \text{EST} & \text{AC} \\
\hline
L^* & \text{before soaking} & 37.0 & 38.3 & 38.3 & 38.4 & 34.1 & 39.3 & 41.6 \\
& SD & 0.1 & 0.3 & 1.1 & 2.0 & 1.6 & 1.7 & 0.7 \\
& \text{after soaking} & 40.9 & 43.4 & 40.6 & 36.0 & 34.4 & 40.4 & 47.5 \\
& SD & 5.4 & 0.1 & 1.2 & 1.7 & 1.6 & 1.2 & 0.6 \\

a^* & \text{before soaking} & 12.4 & 13.8 & 8.5 & 6.9 & 10.5 & 9.4 & 7.6 \\
& SD & 0.5 & 1.4 & 0.4 & 0.4 & 1.1 & 0.7 & 0.1 \\
& \text{after soaking} & 3.9 & 13.2 & -0.3 & 6.7 & 10.9 & 0.8 & 8.4 \\
& SD & 1.6 & 2.3 & 0.2 & 0.5 & 1.4 & 2.5 & 0.6 \\

b^* & \text{before soaking} & 3.4 & 4.9 & 4.3 & 0.5 & 3.6 & -1.9 & 4.1 \\
& SD & 0.3 & 0.3 & 0.5 & 0.3 & 0.6 & 0.3 & 0.1 \\
& \text{after soaking} & 30.1 & 19.5 & 28.7 & 2.5 & 3.5 & 21.8 & 8.5 \\
& SD & 1.2 & 2.5 & 0.7 & 0.1 & 0.4 & 6.5 & 41.1 \\
\end{array}$
structure influenced the flexural strength of PA types.

Since thermoplastic resins are used clinically in the oral cavity, the testing environment in the present study is considered to be valid. Our findings revealed that, although the rigidity of non-metal clasp denture materials is low, they are extremely tough in comparison with acrylic resin\(^{25-27}\).

The advantage of non-metal clasp dentures is their flexibility, providing retention through the use of undercuts on the remaining teeth, thus alleviating denture pain due to excessive local pressure. Given this unique characteristic, evaluation methods specifically for non-metal clasp denture materials need to be established as a complement to the ISO standards. However, the denture should be carefully designed since displacement of soft tissue would be greater by denture flexibility.

All the materials tested fractured during the tensile strength test. The opaque areas may be explained as the result of the process of necking, in which the cross-sectional area of the specimen is reduced under tensile loading. Necking was observed on the entire parallel segment of the dumbbell-type VAL, LTF, FLS, and RP specimens\(^{3}\) (Fig. 10).

Unfortunately, components of non-metal clasp dentures are not clear in the present study. The molecular weight, fiber alignment will influence the mechanical properties of non-metal clasp denture. Acrylic resin does not have fiber structure. Such differences may exhibit plastic deformation and necking without fracture even after exceeding the proportional limits. The detailed study for the structural analysis of non-metal clasp denture should be needed as a next series of the experiments.

The maximum ISO standard values of water sorption and for Type 3 denture base materials are 32 \(\mu\)g/mm\(^2\), respectively. All of the materials tested in the present study were included in this standard except for LTF\(^{15}\).

Acrylic resins such as AC show superior characteristics in various aspects; however, their saturated absorption rate is relatively high. Hayashi et al. suggested that, since the contact angles between the PC-type resin and water is high with low surface free energy, their water repellency is also high, resulting in lower water sorption values\(^8\). In the present study, PC would be hydrophobic property because it demonstrated greater contact angle and strong correlation between contact angle and water sorption was observed. In contrast, PA and PET indicated less contact angle, hydrophilic property would be confirmed. Polymers with a high water sorption tendency may have been used during the fabrication of LTF. There was no significant difference between the water sorption levels of LTF and AC.

LTF showed the highest water sorption. This was due to the greater degree of hydrophobicity supported by the contact angle measurements. However, AC showed greater amount of water sorption compared with PC or PET types, although the lowest contact angle against water. It is presumed that the differences of molecular weight or cross-linking agents will influence the water sorption of AC.

Among the non-metal clasp denture materials, PA tended to have inherently high water sorption values. As mention above, this phenomenon is explained by the water absorption occurring among the molecular chains due to the high hydrophilicity of the numerous amide bonds forming the main chains of the polyamide resin. It is also thought that the higher the amide group concentration, the greater the water sorption. Therefore, it has been suggested that the amide group concentration in the PA-type denture base materials could be adjusted to a level as low as that in popular industrial materials such as nylon 6 or 66. Such an adjustment would result in strong hydrogen bonding between amide groups and a reduction in attachment areas for water molecules; therefore, the amount of water sorption in PA would decrease to the same level as nylon 6 or 66.

All of the materials tested fell within the range of
the standard and had lower water sorption than conventional acrylic resin. These results indicate that a majority of the thermoplastic resins for non-metal clasp dentures have a hygienic nature that reduces the accumulation of plaque and promotes the smooth movement of the oral soft tissue.

Patients today are demanding excellent esthetics besides good function in their dentures. In the present study, we investigated the clinical application of thermoplastic resins with emphasis on the esthetic aspects relative to conventional denture resins. Black tea, green tea and red wine were considered as soaking solutions, but coffee and curry were selected because of their stainability and amount of consumption by the public.

$L^*$, $a^*$, and $b^*$ indicate lightness, red-green, and yellow-blue, respectively. In both the coffee and curry solutions, the $L^*$ values tended to increase after soaking, whereas the $a^*$ values tended to decrease. In all the materials, the $b^*$ values increased after soaking. All the materials tested had Δ$E^*ab$ values of 5 or more, except for two PC-type materials. VAL and FLS showed considerable color change after soaking in the coffee solution, as did the three PA- and PET-type materials in the curry solution. According to reports from Ueda et al., staining occurs due to the physical penetration of pigments between the molecular lattices or the adsorption of pigments on the surface of specimens.

All the materials tested contain chromophores (>C=O), which are known to be easily polarized. The PA-type materials also contain auxochromes (>N-) which, in combination with chromophores and free radicals in solution, may result in staining. Furthermore, color measurements can be affected by surface reflections, inside diffusion and absorption in the specimens, and the background.

Compared with the control value of Δ$E^*ab$ of AC (coffee: 6.4, curry: 7.5), VAL (11.4) and FLS (9.5) showed a greater amount of color change after soaking in the coffee solution. The PA- and PET-type specimens changed their color approximately two to four times more than did AC in the curry solution. Visible color changes were observed in RP and JCR in the curry solution. On the other hand, PA and PET showed a greater color change compared to AC, especially in the curry solution, indicating that the color stability of these materials needs to be improved.

As conclusions, it is found that each material for non-metal clasp dentures possesses widely differing properties. In addition, dentists have never been provided with appropriate guidelines for designing and using these dentures though the manufacturers introduce the simple denture designs. Therefore, the selection of thermoplastic resin and designs adapted to each clinical case must be achieved only after completely understanding the properties of each material.

CONCLUSIONS

After conducting water sorption, solubility, flexural strength, modulus of elasticity, tensile strength and color stability tests to reveal the mechanical and physical properties of six thermoplastic resins and conventional acrylic resin, the following conclusions can be drawn:

1. Although the flexural strength and modulus of elasticity were relatively low in the thermoplastic resins, they demonstrated great toughness and strong resistance to fracture.

2. The tensile strength test suggested that thermoplastic resins can withstand stress through a considerable degree of deflection, indicating that they have sufficient longevity for repeated insertion and removal from the oral cavity.

3. The water sorption values of all the tested materials met the ISO standard for Type 3 denture base materials, indicating that thermoplastic resins are stable and hygienic materials.

4. The color stability of PC was the same as that of acrylic resin. However, PA and PET exhibited staining after soaking, particularly in the curry solution, suggesting that the color stability needs to be improved in these materials.

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