Evaluation of flexural strength and color stability of different denture base materials including flexible material after using different denture cleansers

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INTRODUCTION

The loss of teeth is a matter of concern to majority of the people and their replacement by artificial substitutes, such as removable prostheses which are fabricated using acrylic resin- and nylon-based plastic (polyamide) denture base materials.

Abstract

Aims: Present study aimed at evaluating the colour stability and flexural strength of flexible denture base materials (Valplast) and Polymethyl methacrylate (PMMA) denture base material (Meliodent) processed by two different methods (Injection moulding and compression moulding) after immersing them in three different denture cleansers with acidic, basic and neutral PH.

Methods and Materials: Total 120 specimens (65 × 10 × 3 mm³), 40 specimens of each material (Valplast, Meliodent compression moulding and injection moulding) were immersed in denture cleansers having different PH; Valclean (Acidic), Clinsodent (Basic) and Polident (Neutral) as well as Distilled Water. Color changes were measured with a spectrophotometer after 1 month, 3 months and 6 months of immersion cycle. A flexural 3-point bending test was carried out by using an Instron universal testing machine after 6 months of soaking. Data were analyzed using SPSS software

Results: Maximum effect on colour stability was noted with Clinsodent followed by Valclean. Least color changes were observed after immersion in Polident. Colour difference was increased significantly as the immersion time increased. For both Meliodent and Nylon resins, statistically significant change in flexural strength occurred with immersion in all denture cleansers. Clinsodent has greater effect as compared to Valclean and Polident.

Conclusions: Polident and Valclean can be safely used as denture cleanser for both nylon and acrylic resin denture base materials as far as colour stability and flexural strength both are concerned.

Key Words: Acrylic resin, basic and neutral pH, denture cleansers with acidic, flexural strength and color stability, nylon denture base materials
Maintenance of good oral hygiene is important and the
immersion of prosthesis in a disinfecting solution for
an appropriate time is a convenient method to prevent
contamination. Repeated exposure to various disinfectants
may affect the properties of denture base resins such as color
stability and flexural strength.[1]

Although there are numerous studies[2,3] carried out to evaluate
the effect of denture cleanser on different physical properties of
poly methyl methacrylate acid (PMMA) denture base materials,
there is a knowledge gap regarding the effects of three kinds
of denture cleansers (acidic, alkaline, neutral) on two different
denture base materials using different processing technique.
Thus, the present study was carried out to evaluate the effect
of denture cleanser on color stability and flexural strength of
flexible denture base materials and acrylic resin processed by
two different methods (injection molding and compression
molding) at different time intervals.

SUBJECTS AND METHODS

Study materials

| Material Type | Processing method |
|---------------|------------------|
| Meliodent PMMA | Compression-molded technique, heat-cured polymerization at 70°C for 90 min and at 100°C for 30 min Injection-molded technique, heat-cured polymerization for 35 min at 100°C under 6 bar air pressure |
| Valplast Nylon | Injection-molded technique, preheated in the furnace for 8 min at 248.8–265.5°C under 5 bars for 3 min |

PMMA: Poly methyl methacrylate acid

Denture cleansers

| Denture cleansers | Composition | pH |
|-------------------|-------------|----|
| Valclean          | Sodium, potassium, sulfur, magnesium | Acidic |
| Polident          | Sodium bicarbonate, citric acid, sodium carbonate, potassium monopersulfate, sodium perborate, sodium benzoate, sodium lauryl sulfoacetate | Neutral |
| Clinsodent        | Sodium perborate | Basic |

Methods

The rectangular specimens were made from the heat
cure denture base resin (Meliodent) and flexible
denture base material (Valplast) with dimensions of
65 mm × 10 mm × 3 mm using stainless steel dies
complying with the ADA specification number 12
for denture base polymers[4] [Figure 1]. This enables
the specimens to be tested for flexural strength on a
three-point bending apparatus (Universal Instron Testing Machine). Meliodent was subjected to compression and injection molding. Totally, 120 specimens were prepared: 40 from Meliodent (Compression Molding), 40 from Meliodent (injection molding), and 40 from Valplast.

Of total 120 specimens, 40 specimens of each material were
assigned to three different denture cleansers namely, Valclean, Polident, and Clinsodent; 40 specimens were also immersed in
distilled water for control [Figure 2]. As per the manufacturer’s
instruction, specimens were soaked in a respective cleanser. Every
day, specimens were immersed for 12 h in Clinsodent, 5 min
in Valclean, and 3 min in Polident. After immersion in denture
cleanser, the specimens were washed thoroughly with water
and then kept in distilled water until next soaking trial. Regular
immersion was carried out for the duration of 6 months.

Color changes were measured with a spectrophotometer
(CM-3600d Konica Minolta, Japan) [Figure 3]. Colorimetry
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was done after 1-month, 3 months, and 6 months of immersion cycle. The spectrophotometer was calibrated according to the manufacturer’s instructions before each measurement period using the white calibration plate supplied by the manufacturer. The color differences were evaluated using the Commission Internationale de l’Eclairage L*a*b* colorimetric system.[5,6] This system is based on three parameters for defining color: L*, a*, and b*. L* represents lightness, a* represents red-green, and b* represents yellow-blue. The color change (ΔE) of each specimen was calculated as follows:

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

where a* and b* are on the chromatic scale and represent red as +a* and green as -a*, while yellow corresponds to + b* and blue to -b*. Delta L*, Δa*, and Δb* represent the differences measured in L*, a*, and b* values before and after immersion.

The levels of color change (ΔE) have been quantified by the National Bureau of Standards (NBS) with the NBS units of color difference. NBS units are expressed by the following formula:[7]

$$\text{NBS unit} = \Delta E \times 0.92$$

$$S = \frac{3PL}{2bd^2}$$

Readings of flexural strength for all specimens were taken after 6 months of soaking. A flexural three-point bending test was carried out using an Instron universal testing machine (Instron 5500 R) at a crosshead speed of 10 mm/min [Figure 4]. Thickness and width of each specimen were measured with a digital vernier caliper. The specimens were placed on jigs that were 50 mm apart (L) and then loaded at the center until fracture occurred. The flexural strength was measured using a three-point bending test in a universal testing machine.

The flexural strength (S) of each rectangular specimen was calculated from the following equation:

Where, P is the maximum load, L is the distance between the supports (50 mm), b is the specimen width (10 mm), and d is the specimen thickness (3 mm). Mean flexural strengths were calculated in megapascals.

Statistical analysis was carried out using Student’s t-test and analysis of variance (ANOVA). The level of statistical significance was taken as $P < 0.05$.

RESULTS

Values of color change (δE) for specimens of all three denture base materials after immersion in control (distilled water) as well as disinfectant solutions (Polident, Clinsodent, and Valclean) were calculated. To quantify levels of color change ($\Delta E$), NBS units were calculated. NBS units were expressed by multiplying delta E values with 0.92 (NBS unit = $\Delta E \times 0.92$).[7] [Table 1].

Table 2 shows mean values of color change (δE) and NBS Unit of each material after immersion in different denture cleansers and distilled water. The maximum color change was noticed at 6 months for all three groups of specimen after immersing them in Clinsodent. Specimens of Valplast showed the mean color difference of 3.21, 2.77, 5.14, and 3.35 after 6 months of immersion in distilled water (Control), Polident, Clinsodent, and Valclean, respectively [Table 2].

Table 3 illustrates an analysis of color change as computed using NBS. It was found that at an interval of 1-month, all three denture cleansers causes trace change in color of all three denture base materials. As the immersion period increased, the effect of denture cleansers on color stability also increased. Maximum effect on color change was seen after 6 months of immersion. After 3 months, Valplast specimens immersed in Clinsodent showed “Appreciable” color difference, whereas those immersed in Polident and Valclean showed “Noticeable” change in color. Clinsodent had “Appreciable” effect on color change for all the specimens after 6 months of immersion.

Table 1: Critical marks of color difference according to the NBS

| Critical marks of color difference | Textile terms (NBS units) |
|-----------------------------------|--------------------------|
| Trace                             | 0.0-0.05                 |
| Slight                            | 0.5-1.5                  |
| Noticeable                        | 1.5-3.0                  |
| Appreciable                       | 3.0-6.0                  |
| Much                              | 6.0-12.0                 |
| Very much                         | >12.0                    |

NBS: National Bureau of Standards
Findings suggest that among all three cleansers, Clinsodent has the greatest effect on color stability. Results of color changes were similar for compression molding as well as injection molding. This suggests that there is no effect of polymerizing technique as far as color change is concerned.

Results of three-way ANOVA for color change of materials suggested that denture cleansers had statistically significant effect on color change with \( P < 0.001 \). It was found that significant color alteration occurred as the immersion periods increased \( (P < 0.001) \) [Table 4].

Mean values of flexural strength and results of unpaired \( t \)-test for all materials after immersion in control and disinfectant solutions were calculated. Flexural strength of all three materials significantly differs after immersion in control and disinfectant solution with \( P < 0.001 \) [Table 5].

The result of two-way ANOVA for flexural strength suggested that there was statistically significant difference \( (P < 0.001) \) in flexural strength between materials as well as disinfecting and control solutions [Table 6].

Mean values of flexural strength of all three denture base materials after immersion in control and disinfectant solution are illustrated in Figure 5. Lower mean values of flexural strength were noticed for all the specimens after immersion in disinfecting solution as compared to those immersed in control solution.

**DISCUSSION**

The present study has evaluated the effect of three denture cleansers on the color stability and flexural strength of acrylic and flexible materials.
In the study by Shah et al., the effect of denture cleansers on the flexural strength and color stability of denture base materials was investigated. Results showed that as the immersion time increases, the difference in color stability also increases. Similar finding was noted by Hong et al. After 6 months of immersion, Clinsodent had an appreciable effect on color change, whereas Polident had a noticeable effect. Specimen immersed in Valclean showed noticeable and appreciable color change for 3 and 6 months of immersion, respectively.

Among all three cleansers, Clinsodent has the greatest effect on color stability. Similar finding was reported in the study of Hong et al. and Nikawa et al. They have used cleanser having alkaline peroxides. The results of present study are also similar with Goiato et al. who also detected a significant whitening effect with Corega Tabs (alkaline) relative to the other tested cleansing agents. However, Sato et al. did not detect color changes in the acrylic resins with the use of chemical agents. The result found in their research may be due to the short simulation period (30 days) and visual comparisons made by photographs.

Clinsodent is an alkaline peroxide type denture cleanser. Peroxide-type denture cleansers include an effervescent component such as sodium perborate or sodium bicarbonate. When dissolved in water, sodium perborate decomposes to form an alkaline peroxide solution. This peroxide solution subsequently releases oxygen and loosens debris via mechanical means. Therefore, use of these denture cleaners may cause hydrolysis and decomposition of the polymerized acrylic resin itself. These observations may explain why Clinsodent cleanser had a greater influence on color stability than the other denture cleansers. Polident showed the least effect on color change in

Table 5: Descriptive statistics for flexural strength of each specimen after immersion in different denture cleansers and distilled water (control)

| Flexural strength          | Valplast       | Meliodent (compression molding) | Meliodent (injection molding) |
|---------------------------|----------------|--------------------------------|------------------------------|
|                          | Mean±SD        | t (significant)                | Mean±SD                      | t (significant)              | Mean±SD                  | t (significant)              |
| Distilled water (control) | 39.55±0.21     | -                              | 95.80±0.03                   | -                            | 78.69±0.07               | -                            |
| Valclean                  | 38.48±0.13     | 66.7 (<0.01)                   | 82.26±0.13                   | 152.3 (<0.01)                | 71.62±0.16               | 202.8 (<0.01)                |
| Polident                  | 34.58±0.11     | 92.8 (<0.01)                   | 76.69±0.11                   | 534.9 (<0.01)                | 69.34±0.21               | 105.4 (<0.01)                |
| Clinsodent                | 29.57±0.14     | 62.3 (<0.01)                   | 74.37±0.18                   | 241.4 (<0.01)                | 60.21±0.09               | 209.1 (<0.01)                |

SD: Standard deviation

Table 6: Two-way ANOVA for flexural strength of materials

| Source                      | Type III sum of squares | df | Mean square | F         | Significant |
|-----------------------------|-------------------------|----|-------------|-----------|-------------|
| Corrected model             | 16,771.3                | 11 | 1524.7      | 139,770.6 | <0.001      |
| Intercept                   | 138,441.0               | 1  | 138,441.0   | 12,691,310.5 | <0.001      |
| Solution                    | 877.7                   | 3  | 292.6       | 26,820.7  | <0.001      |
| Material                    | 15,284.8                | 2  | 7642.4      | 700,603.5 | <0.001      |
| Solution×material           | 608.8                   | 6  | 101.5       | 9301.2    | <0.001      |
| Error                       | 0.3                     | 24 | 0.0         |           |             |
| Total                       | 155,212.6               | 36 |             |           |             |
| Corrected total             | 16,771.6                | 35 |             |           |             |

ANOVA: Analysis of variance

Figure 4: Instron testing machine for measurement of flexural strength

Figure 5: Mean values of flexural strength for each material after immersion in disinfectant and control solution

Specimen prepared from flexible denture base materials showed more color change as compared to acrylic resins. After 1-month of immersion, a slight change in color was noted in the specimens in all three cleansers. After 3 months and 6 months of immersion, Clinsodent had an appreciable effect on color change, whereas Polident had a noticeable effect. Specimen immersed in Valclean showed noticeable and appreciable color change for 3 and 6 months of immersion, respectively.

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the present study. Similar results were observed by Khronghatai and Widhaya. Being a neutral cleanser, Polident has a lesser effect on color stability. Polident contains sodium perborate, other acidic ingredients like citric acid nullify its bleaching effect. Specimen immersed in Valclean showed a minor change in color because it is acidic type of cleanser which has no peroxide content. Similar finding was noted by Hong et al. who used ZTC-acid type of cleanser.

As compared to Meliodent denture base material, Valplast has more tendencies for color change after immersion in denture cleansers. Valplast is flexible denture base material which contains a greater amount of reagents such as benzyl peroxide. This reagent remains after polymerization and may alter the material’s color. Clinsodent had the greatest effect on color stability of Valplast from the initial period of immersion, so for disinfecting the Valplast, the use of Clinsodent should be avoided. Polident and Valclean have a lesser effect on color stability of Valplast. Denture cleansers without alkaline content can be safely used for Valplast.

Results of color changes are similar for Meliodent compression molding as well as injection molding. Findings suggest that there is no effect of polymerizing technique as far as color change is concerned. The result of three-way ANOVA for color change of materials showed that there is a significant effect of the length of the immersion period on color stability. Therefore, denture base resin should not be exposed to a denture cleanser for a long period of time.

In this study, it was observed that denture cleansers decreased the flexural strength denture base resin in comparison with water immersion. Similar findings were reported in a study carried out by Peracini et al. Robinson et al., and Arab et al. also showed a reduction in flexural strength of acrylic resins when exposed to peroxides and hypochlorite. In the present study, the maximum reduction in flexural strength occurred for specimens immersed in Clinsodent, whereas Valclean and Polident show similar results. Findings of the present study showed that the flexural strength of Valplast denture base resin was lower as compared to Meliodent. All the PMMA samples fractured during the test while none of the nylon specimens fractured. Hence, the lower flexural strength exhibited by polyamide nylon was because of its lesser rigidity than the PMMA resin polymer samples. The result of this study was in agreement with those of Stafford et al. and Yunus et al. in that nylon was found to be more flexible than PMMA denture base polymers.

The present study is in vitro that did not completely simulate clinical behavior. To overcome these limitations, an in vivo study wherein the properties like water sorption and its correlation on dimensional change can also be considered and evaluated in vivo, wherein the denture will constantly be in contact with saliva and mucosa.

CONCLUSION

Within the parameters of the present study, designs, and material tests, the following conclusions were made:

- For both PMMA and nylon resins, color difference was increased as the immersion time increased which was significant statistically
- Maximum effect on color stability was noted with Clinsodent followed by Valclean. Least effect on color stability was observed after immersion in Polident
- For Valplast resin, the appreciable effect of Clinsodent on color change was noted within a short duration of immersion. Polident and Valclean did have effect on color change of Valplast, but change became evident after longer duration of immersion
- Statistically insignificant effect of processing method was noticed on color stability of denture base resin
- For both PMMA and nylon resins, statistically significant change in flexural strength occurred with immersion in all denture cleansers. Clinsodent has a greater effect as compared to Valclean and Polident.

Polident and Valclean can be safely used as denture cleanser for both nylon and acrylic resin denture base materials as far as color stability and flexural strength both are concerned. Clinsodent should be used with caution.

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Conflicts of interest
There are no conflicts of interest.

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