

RESEARCH AND EDUCATION

Effects of nonaldehyde immersion disinfection on the mechanical properties of flexible denture materials



Alex Leo Sequeira, BDS, MDS,^a Aparna I. Narayan, BDS, MDS,^b and Vinu Thomas George, BDS, MDS^c

The disinfection of dentures is important to avoid infectious disease transmission. However, some methods of disinfection can alter the mechanical properties of the denture materials and affect clinical function.¹⁻⁴ Flexible polyamide removable partial dentures are an alternative to conventional polymethylmethacrylate prostheses as they can be fabricated in thinner sections and their translucency leads to improved esthetics.⁵ The reduced bulk and weight of the prosthesis increases patient comfort and acceptance of the denture.⁵ Flexible polyamide dentures are available as monomer-free products, allowing their use in patients with hypersensitivity.⁶

An additional advantage is the flexibility of polyamide resin denture bases because undercuts are engaged and used to retain the prosthesis.⁷

As handling dentures after removal from the oral cavity is associated with a risk of infectious organism transmission, dentures must be disinfected before delivery or when transferred to a dental laboratory. The British Dental Association Advisory Service recommends the use of sodium hypochlorite with 10 000 parts per million (ppm) of available chlorine for the disinfection of prostheses.⁸

ABSTRACT

Statement of problem. Variation in the baseline mechanical properties of polyamide thermoplastic polymers used in the fabrication of prosthetic dental appliances and the effects of nonaldehyde disinfectants on the mechanical properties of these polymers are unclear.

Purpose. The purpose of this in vitro study was to compare the flexural and impact strengths of 2 flexible denture materials (Valplast and Sunflex) and evaluate the effect of 24-hour immersion in nonaldehyde disinfectant (Perform) on their flexural and impact strengths.

Material and methods. Of 48 specimens of Valplast and Sunflex, half were immersed in nonaldehyde disinfectant solution containing the active ingredient 2% peroxymonosulfate for 24 hours. Flexural and impact strengths were measured using a universal testing machine. The Student *t* test with Bonferroni correction was used ($\alpha=.008$).

Results. For the Valplast group, the mean \pm standard deviation flexural strength was 27.8 \pm 0.57 MPa, and the impact strength was 3.5 \pm 0.98 kJ/m². For the Sunflex group, the mean flexural strength was 57.4 \pm 4.09 MPa, and the impact strength was 6.0 \pm 3.11 kJ/m². Sunflex showed greater flexural strength ($P<.001$) and impact strength ($P=.001$) than Valplast. A significant increase in the impact strength ($P<.001$) but not in the flexural strength of Valplast was observed after exposure to the disinfectant solution. Immersion disinfection had no significant effect on the strength of Sunflex.

Conclusions. The flexural and impact strengths of Sunflex were significantly greater than those of Valplast. Immersion disinfection with peroxymonosulfate had no significant effect on Sunflex but increased the impact strength of Valplast. (*J Prosthet Dent* 2019;121:843-7)

Perform (Schülke & Mayr GmbH), a disinfectant based on reactive oxygen instead of aldehyde, has also been recommended.⁹ It is supplied in granular form with potassium peroxymonosulfate as its active ingredient. This aldehyde-free product is claimed to be both biodegradable and effective for reducing *Candida* levels on flexible dentures.¹⁰ Its use in dentistry includes the disinfection of impressions, as well as of dentures, dental equipment, and prosthetic materials (<https://www.schuelke.com/gb-en/products/perform-ID.php>). Valplast recommends the use of the proprietary denture cleanser

^aPrivate practice, Axiss Dental, ITPL, Whitefield, Bangalore, Karnataka, India.

^bAssociate Professor, Department of Prosthodontics and Crown & Bridge, Manipal College of Dental Sciences, Manipal Academy of Higher Education, Manipal, India.

^cAssociate Dean, Manipal College of Dental Sciences, Department of Prosthodontics and Crown & Bridge, Manipal Academy of Higher Education, Manipal, India.

Clinical Implications

A denture made of a polyamide material such as Valplast is primarily chosen for its inherent ability to flex and engage undercuts. Disinfection of Valplast resulted in increased impact strength and hence rigidity, which could hamper its successful use.

Val-Clean, which contains potassium peroxymonosulfate as the active ingredient.

Patients are advised to clean their dentures every day and store them in water when not in use. As long-term disinfection and water sorption can alter the mechanical and esthetic properties of the denture base,¹¹ the flexural and impact strengths of flexible denture base materials and the effect of immersion disinfection in peroxymonosulfate aqueous solutions on their mechanical properties must be established.

Thermoplastic polymers are produced by the condensation reaction between a diamine and a dibasic acid.^{12,13} The polyamide-based flexible denture materials retain both elasticity and strength.¹²⁻¹⁴ The inherent flexibility of polyamide nylon dentures provides advantages over conventional polymethylmethacrylate prostheses,^{13,15} such as engagement of undercuts where a conventional denture base would be impossible to insert. An additional property is the material's elastic memory, allowing the prosthesis to revert to its original form after flexing over an undercut. Similar to conventional clasps, flexible dentures use elastic memory to engage undercuts for retention of the prosthesis. Furthermore, the translucent clasps are more esthetically pleasing than conventional metal clasps.

A denture material's impact strength is important in determining its durability¹⁶ and ability to absorb energy during plastic deformation. Both flexural and impact testing are essential to understand the physical and mechanical behavior of a material. The effects of immersion disinfection on the mechanical properties of polymethylmethacrylate have been studied.^{2,3,17} However, evaluations of the mechanical properties of polyamide denture base materials before and after exposure to immersion disinfection with potassium peroxymonosulfate are limited.¹⁸ Some studies have focused on the effectiveness of disinfection on microbial eradication and topographic characteristics.¹⁹ In this study, the hypotheses tested were that the mechanical properties, measured as flexural and impact strengths, of 2 proprietary polyamide denture base materials would be different and that exposure to peroxymonosulfate-based disinfectant would alter their flexural and impact strengths.

MATERIAL AND METHODS

Dental stone mixed according to the manufacturer's instructions was used to invest the respective denture base flasks. The mold was created with a ratio of 100 g of gypsum (Pankaj Enterprises) to 30 mL of water. Metal dies of appropriate dimensions were invested in the gypsum to create a mold space for introducing molten flexible denture material. Specimen dimensions followed standards set by the International Standards Organization²⁰: 64×10×2.5 mm for flexural testing and 80×10×4.0 mm for impact testing. After the gypsum mold had set, wax sprues were attached to the metal dies. The cope of the flask was accurately positioned and filled with gypsum under vibration to prevent air bubbles. The wax was eliminated under boiling water, the flask was opened, and the metal dies were removed. The gypsum mold was heated according to the manufacturer instructions, and the flexible resin material in their respective cartridges was heated in an electric furnace (Dentsply Sirona). Resin material was injected into the mold space using a manual injection unit. The flasks were bench cooled before deflasking and cutting sprues with a carborundum disk. Finishing and polishing were carried out with silicon carbide disks and a polishing lathe.

Denture base specimens were fabricated according to the specified guidelines in relation to dimensions. A 2% (w/v) concentration of disinfectant solution was prepared by dissolving 40 g of Perform powder in 2 L of distilled water. A freshly prepared disinfectant solution was used. Half of the specimens were disinfected for 24 hours in a controlled environment. Specimens were tested within a controlled environment at a temperature of 23 ±2°C while maintaining a relative humidity of 50 ±5% using a humidifier.

A total of 48 specimens were fabricated. Of these, 24 were immersed in a 2% disinfectant solution for 24 hours as the intervention group. The remaining 24 specimens were immersed in distilled water as the control group. In each group, 12 specimens were tested for flexural strength and impact strength after conditioning in a controlled environment. The specimens were placed in a closed room at a temperature of 23 ±2°C. Relative humidity was maintained at 50 ±5% for a minimum of 40 hours.

The denture base specimens for flexural testing were 64×10×2.5 mm in dimension. Flexural testing was carried out according to ISO 178: 2000 specifications.²⁰ Support separation was calculated using a ratio of 16:1 in relation to the width of the specimen. Thus, with a specimen width of 2.5 mm, a 40-mm-span length was set. A preload of 0.1 MPa was applied, and the test speed was set at 1 mm/min. Testing was carried out to 5% deflection as the test material was flexible. The values of flexural strength were recorded in MPa.

Table 1. Comparison of baseline flexural and impact strength between Valplast versus Sunflex groups

| Group | Mean ±SD | P |
|--------------------------------------|------------|-------|
| Flexural strength (MPa) | | |
| Valplast | 27.8 ±0.56 | <.001 |
| Sunflex | 57.4 ±4.09 | |
| Impact strength (kJ/m ²) | | |
| Valplast | 3.4 ±0.98 | .001 |
| Sunflex | 6.0 ±3.11 | |

SD, standard deviation.

The dimension of the specimens for impact testing was 80×10×4 mm. Impact strength testing was performed according to ISO 179-1:2010(E) specifications with a notched Charpy test. This specification describes a method of determining the impact strength of plastics under defined conditions. The specimens were notched using a motorized notch cutter because it was observed that unnotched test specimens did not fracture. A 7.5-J hammer was used for testing with an impact velocity of 3.807 m/s until complete fracture. The values of impact strength were recorded in kJ/m². Flexural and impact testing was performed at a room temperature of 23 ±2°C and relative humidity of 50 ±5%.

The specimens were grouped as follows: group VN (Valplast control), group VD (Valplast exposed to Perform), group SN (Sunflex control), and group SD (Sunflex exposed to Perform). The flexural strength and impact strength of all groups were measured. Impact testing resulted in the complete fracture of every specimen. The primary outcome variables included the flexural and impact strength of Valplast and Sunflex.

The independent sample Student *t* test was performed, and the data were analyzed using a statistical software program (IBM SPSS Statistics, v20; IBM Corp). Bonferroni correction was applied ($\alpha=.008$). As no previous estimates were available for the primary outcome, sample size was not estimated, but a post hoc power calculation was performed.

RESULTS

The mean baseline flexural strength and impact strength of the Valplast group were 27.8 ±0.57 MPa and 3.5 ±0.98 kJ/m², respectively. The corresponding values for the Sunflex group were 57.4 ±4.09 MPa and 6.0 ±3.11 kJ/m² (Table 1). The difference in the mean flexural strength (27.8 ±0.56 MPa versus 57.4 ±4.09 MPa; $P<.001$) and the mean impact strength (3.5 ±0.98 kJ/m² versus 6.9 ±3.11 kJ/m²; $P=.001$) of the Valplast versus the Sunflex group was statistically significant (Tables 2 and 3). A statistically significant increase was found in the impact strength (3.5 ±0.98 kJ/m² versus 4.9 ±0.67 kJ/m²; $P<.001$) but not in the flexural strength of Valplast after exposure to peroxymonosulfate disinfectant solution for 24 hours

Table 2. Comparison of flexural and impact strengths between Perform-nonexposed (control) and Perform-exposed (intervention) Valplast groups

| Groups | Mean ±SD (MPa) | P |
|--------------------------------------|----------------|-------|
| Flexural strength (MPa) | | |
| VN | 27.7 ±0.57 | .015 |
| VD | 28.6 ±1.37 | |
| Impact strength (kJ/m ²) | | |
| VN | 3.5 ±0.98 | <.001 |
| VD | 4.9 ±0.67 | |

SD, standard deviation; VD, Valplast disinfected; VN, Valplast nondisinfected.

Table 3. Comparison of flexural and impact strengths between Perform-nonexposed (control) and Perform-exposed (intervention) Sunflex groups

| Groups | Mean ±SD | P |
|--------------------------------------|------------|------|
| Flexural strength (MPa) | | |
| SN | 57.4 ±4.09 | .179 |
| SD | 59.0 ±4.08 | |
| Impact strength (kJ/m ²) | | |
| SN | 6.0 ±3.11 | .499 |
| SD | 6.6 ±3.01 | |

SD, standard deviation; SD, Sunflex disinfected; SN, Sunflex nondisinfected.

(Tables 2 and 3). Immersion disinfection had no significant effect on Sunflex (Table 3). Sunflex had significantly greater baseline flexural and impact strengths when the 2 control groups were compared (Table 1).

DISCUSSION

This study reveals differences in the mechanical properties, measured as flexural and impact strengths, of 2 commonly used denture base materials. The effect of disinfectant exposure on these polyamides was also different. These findings confirm the hypotheses of the present study.

One of the chief requirements of any denture base is adequate mechanical and physical properties. High strength, hardness, toughness, dimensional stability, and low density are all favorable qualities for denture base materials. High impact strength and flexural strength generate a prosthesis that is durable, tough, and more resistant to damage. This is of greater relevance when prostheses are used in high-stress situations.

Immersion disinfection is a critical step in handling any prosthesis and may alter the mechanical properties of polyamides such as Valplast but not Sunflex, as revealed by this study. Dental prostheses brought into a clinic for repair or adjustments are potential reservoirs of pathogens and must be disinfected to prevent disease transmission. Studies on chemical disinfection have used 2% glutaraldehyde, diluted sodium hypochlorite, and chlorine dioxide among others. Other studies have used a 15-second scrub with chlorhexidine, followed by 3 minutes

of contact time with chlorine dioxide to disinfect acrylic resin.^{13,17} However, studies have mainly addressed surface disinfection, without assessing the absorption of fluids by the material. Evidence exists that microbial contamination of acrylic resin prostheses occurs on the superficial surface as well as within the matrix, thus necessitating disinfection throughout the thickness of the material and not solely on its surface.¹⁸ Additional studies of this nature are required to further understand this phenomenon.

The mechanical properties of conventional polymethylmethacrylates deteriorate after immersion disinfection.^{17,18} Comparable studies on nylon denture materials are limited. Immersion disinfection in Perform was tested in the present study because the active constituent, potassium peroxydisulfate, has been reported to be an effective antimicrobial agent.¹⁸ Peroxydisulfate is also the active ingredient in Val-Clean, a commercially available denture cleanser recommended for use with Valplast dentures.

Impact strength has an important influence on the life span of a material and expresses the energy required to fracture the material under impact force. Reasonable impact strength would therefore be beneficial for prostheses expected to encounter high stress. Flexural strength is defined as the material's ability to resist deformation under load and represents the highest stress experienced within the material at its moment of rupture. Both flexural and impact testing are necessary to understand the physical and mechanical behavior of the material.

The authors are unaware of a previous study that has directly compared the baseline flexural and impact strengths of Valplast and Sunflex. The results of the present study revealed significantly greater flexural and impact strengths of the Sunflex material than those of Valplast. This also indicates the greater flexibility of the Valplast material, which has relevant clinical implications. Valplast would be better suited to a situation with deep bony undercuts as insertion and removal would be more comfortable and easier for the patient.

The rigidity of a flexible denture base material (Lucitone FRS) was reported to increase after immersion disinfection in Perform.²¹ However, its flexural yield strength did not change after disinfection. The present study found a similar result with Sunflex; no change in flexural or impact strength was observed after immersion disinfection. However, Valplast increased in impact strength after identical disinfection protocols.

The greater flexibility of Valplast would be a disadvantage if the prosthesis is to replace extensive hard and/or soft tissues. In such procedures, the more rigid Sunflex would have better stability in the oral cavity. Sunflex would therefore have multiple applications in high-stress conditions. Individuals who are at high risk of fracturing

their prosthesis may benefit from this specific denture base material.

Based on the findings, the disinfection of Valplast with peroxydisulfate increased its impact strength and, in theory, rigidity. Future clinical trials are needed to assess whether the rigidity is adequate to remain stable over the denture bearing area and/or implant abutments. Studies addressing variable immersion exposure time, repeated exposure, analysis of the material composition, and the effect of disinfectant exposure on other flexible denture materials may provide further clinically relevant insights.

CONCLUSIONS

Based on the findings of this in vitro study, the following conclusions were drawn:

1. The flexural and impact strengths of Sunflex were significantly greater than those of Valplast.
2. Immersion disinfection with peroxydisulfate had no significant effect on Sunflex but increased the impact strength of Valplast.
3. These findings are relevant in selecting the most appropriate denture base material in dental practice.

REFERENCES

1. Vojdani M, Giti R. Polyamide as a denture base material: a literature review. *J Dent Shiraz* 2015;16:1-9.
2. Ali IL, Yunus N, Abu-Hassan MI. Hardness, flexural strength and flexural modulus comparisons of three differently cured denture base systems. *J Prosthodont* 2008;17:545-9.
3. Pavarina AC, Machado AL, Giampaolo ET, Vergani CE. Effects of chemical disinfectants on the transverse strength of denture base acrylic resins. *J Oral Rehabil* 2003;30:1085-9.
4. Kurt A, Erkose-Genc G, Uzun M, Sari T, Isik-Ozol G. The effect of cleaning solution on a denture base material: elimination of *Candida albicans* and alteration of physical properties. *J Prosthodont* 2018;27:577-83.
5. Singh JP, Dhiman RK, Bedi RPS, Girish SH. Flexible denture base material: a viable alternative to conventional acrylic denture base material. *Contemp Clin Dent* 2011;2:313-7.
6. Stafford GD, Huggett R, MacGregor AR, Graham J. The use of nylon as a denture-base material. *J Dent* 1986;14:18-22.
7. Lowe LG. Flexible denture flanges for patients exhibiting undercut tuberosities and reduced width of the buccal vestibule: a clinical report. *J Prosthet Dent* 2004;92:128-31.
8. British Dental Association Advisory Service. Infection control in dentistry. *Br Dent Assoc News Suppl* 1996;181:12. Available at: http://www.virox.com/files_docs/content/pdf/msds/bda-cross-infection.pdf. Accessed February 2003.
9. Taylor RL, Wright PS, Maryan C. Disinfection procedures: their effect on the dimensional accuracy and surface quality of irreversible hydrocolloid impression materials and gypsum casts. *Dent Mater* 2002;18:103-10.
10. de Freitas Fernandes FS, Pereira-Cenci T, da Silva WJ, Filho AP, Straioto FG, Del Bel Cury AA. Efficacy of denture cleansers on *Candida* spp. biofilm formed on polyamide and polymethyl methacrylate resins. *J Prosthet Dent* 2011;105:51-8.
11. Porwal A, Khandelwal M, Punia V, Sharma V. Effect of denture cleansers on color stability, surface roughness, and hardness of different denture base resins. *J Indian Prosthodont Soc* 2017;17:61-7.
12. Ucar Y, Akova T, Aysan I. Mechanical properties of polyamide versus different PMMA denture base materials. *J Prosthodont* 2012;21:173-6.
13. Soygun K, Bolayir G, Boztug A. Mechanical and thermal properties of polyamide versus reinforced PMMA denture base materials. *J Adv Prosthodont* 2013;5:153-60.
14. Phoenix RD, Mansueto MA, Ackerman NA, Jones RE. Evaluation of mechanical and thermal properties of commonly used dental base resins. *J Prosthodont* 2004;13:17-27.

15. Abhay PN, Karishma S. Comparative evaluation of impact and flexural strength of four commercially available flexible denture base materials: an in vitro study. *J Indian Prosthodont Soc* 2013;13:499-508.
16. Uzun G, Hersek N, Tincer T. Effect of five woven fiber reinforcements on the impact and transverse strength of a denture base resin. *J Prosthet Dent* 1999;81:616-20.
17. Chau VB, Saunders TR, Pimsler M, Elfring DR. In-depth disinfection of acrylic resins. *J Prosthet Dent* 1995;74:309-13.
18. Durkan R, Ayaz EA, Bagis B, Gurbuz A, Ozturk N, Korkmaz FM. Comparative effects of denture cleansers on physical properties of polyamide and polymethyl methacrylate base polymers. *Dent Mater J* 2013;32:367-75.
19. Da Silva FC, Kimpara ET, Macini MN, Balducci I, Jorge AO, Koga-Ito CY. Effectiveness of six different disinfectants on removing five microbial species and effects on the topographic characteristics of acrylic resin. *J Prosthodont* 2008;17:627-33.
20. International Standards Association. ISO1567 specifications for denture base polymers, ISO 20795-1:2013. Available at: <https://www.iso.org/standard/62277.html>.
21. Yunus N, Rashid AA, Azmi LL, Abu-Hassan MI. Some flexural properties of a nylon denture base polymer. *J Oral Rehabil* 2005;32:65-71.

Corresponding author:

Dr Aparna I. Narayan
Associate Dean
Manipal College of Dental Sciences
Department of Prosthodontics and Crown & Bridge
Manipal Academy of Higher Education
Manipal, Karnataka
INDIA

Acknowledgments

The authors thank Konkan Speciality Polyproducts Pvt Ltd for the testing facility, DentCare Dental Lab Pvt Ltd and Schülke & Mayr Pvt Ltd for materials, and Dr RP Sequeira for assistance in preparing this manuscript.

Copyright © 2018 by the Editorial Council for *The Journal of Prosthetic Dentistry*.
<https://doi.org/10.1016/j.prosdent.2018.08.006>

Noteworthy Abstracts of the Current Literature

Influence of residual thermal stresses on the edge chipping resistance of PFM and veneered zirconia structures: Experimental and FEA study

Tanaka CB, Ballester RY, De Souza GM, Zhang Y, Meira JBC

Dent Mater 2019;35:344-55

Objective. Chipping fractures of the veneering porcelain are frequently reported for veneered all-ceramic crowns. In the present study, the edge chipping test is used to measure the toughness and the edge chipping resistance of veneered zirconia and porcelain-fused-to-metal (PFM). The aim is to describe an edge chipping method developed with the use of a universal testing machine and to verify the accuracy of this method to determine the influence of residual thermal stresses on the chipping fracture resistance of veneering porcelain. A finite element analysis (FEA) was used to study the residual stress profiles within the veneering porcelain.

Methods. Veneered zirconia and PFM bar specimens were subjected to either a fast or a slow cooling protocol. The chipping resistances were measured using the edge chipping method. The load was applied in two different directions, in which the Vickers indenter was placed in the veneering porcelain either parallel or perpendicular to the veneer/framework interface. The mean edge chipping resistance (R_{eA}) and fracture toughness (K_C) values were analysed. R_{eA} was calculated by dividing the critical force to cause the chip by the edge distance. K_C was given by a fracture analysis that correlates the critical chipping load (F_C) regarding edge distance (d) and material toughness via $K_C = F_C / (\beta d^{1.5})$.

Results. The R_{eA} revealed similar values ($p > 0.005$) of chipping resistance for loads applied in the parallel direction regardless of framework material and cooling protocol. For loads applied in the perpendicular direction to the veneer/framework interface, the most chip resistant materials were slow cooled veneered zirconia (251.0N/mm) and the PFM fast cooled (190.1N/mm). K_C values are similar to that for monolithic porcelain (0.9MPa. \sqrt{m}), with slightly higher values (1.2MPa. \sqrt{m}) for thermally stressed PFM fast cooled and veneered zirconia slow cooled groups.

Significance. The developed and reported edge chipping method allows for the precise alignment of the indenter in any predetermined distance from the edge. The edge chipping method could be useful in determining the different states of residual thermal stresses on the veneering porcelain.

Reprinted with permission of The Academy of Dental Materials.