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Review Article

The Effect of Denture Cleansers on the Hardness of Denture Base Resins, Polyamides and Copolymers

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Abstract

Denture wearers are strongly urged to practice regular oral and denture hygiene to maintain good oral and general health. Denture cleansing by chemical agents is an easily practiced method that requires simply the immersion of the denture in a commercially available solution according to the manufacturer's instructions. However, these agents must be effective in removing the biofilm without adversely affecting the mechanical properties of the prosthesis.

Aim: To study the effect of over the counter denture cleansers on the hardness of six widely used denture base materials.

Materials and Methods: Six types of denture base materials were tested (GC unifast self-cure resin. GC major heat-cure resin. Deflex thermo injected acrylic, Vertex self-polymerizing resin, IvoBase copolymer and IvoBase Hybrid copolymer). Immersing was conducted using three chemical cleansing agents: a. Effervescent Sodium Bicarbonate denture cleanser, b. Mono-dose Sodium Sulfate Peroxide sachets and c. denture cleansing Sodium Chloride. Distilled water was used as the control. All samples were immersed twice a day for periods of 1 Day, 1 Week and 1 Month at a temperature of 50ºC and were stored at 37ºC in between. The change in hardness was measured using Vickers hardness tester under a 50N load.

Results: Multi variance analysis revealed high significance $p \leq 0.001$* for solution and resin types, immersion time and the interaction of these factors on surface hardness.

Conclusion: The hardness of resin material is significantly altered by immersion time and the disinfectant solution tested as well as by the type of resin.

Keywords: *Denture Cleansing; Denture Base Materials; Hardness; Polyamide*

Literature Review

Poly-methylmethacrylate (PMMA) resin has been the material of choice for the fabrication of removable dentures due to its numerous advantages including optimal aesthetics, biocompatibility, favourable physical and chemical properties as well as ease of fabrication and repair. However, PMMA resin suffers from an inherent disadvantage which is the allergic hypersensitivity reaction of some patients and technicians to the material. This is due to the continuous leaching out of the methylmethacrylate monomer (MMA) which also results in compromising the mechanical properties of the resin [1].

Recently, thermoplastic resin polymers (nylons or polyamides) became a popular alternative to PMMA resin due to its attributes including its hypoallergenic nature and favourable properties (both chemical and physical). Nylons have a flexible nature which offers stress breaking design to removable partial dentures as well as enhanced aesthetics [2]. Furthermore, Polyamide denture base materials have an important advantages of reflecting the colour of gingival and oral tissue as a result of their high light transparency. These attributes makes polyamides a suitable material especially in patients with MMA allergy, bruxism as well as in cases with thin mucosa and excessive bone resorption [3].

Currently many thermoplastic systems are commercially available such as proflex, flexiplast and Bio-dentaplastas as well as flexite [4].

It is vital for denture wearers to maintain good oral and denture hygiene, preferably by using a soft non-abrasive brush to clean the denture. This is crucial for sustaining oral health and preventing undesirable effects including bad breath, unpleasant staining as well as biofilm formation and calculus build-up on the prosthesis which may give rise to pathological conditions including angular cheilitis and denture stomatitis [5]. Furthermore, denture plaque is a predisposing factor for more serious conditions including bacterial endocarditis, gastrointestinal infection and chronic respiratory tract infection in the elderly [6,7]. Thus, it is crucial to practice regular and daily denture disinfection using either the mechanical or the chemical technique. The disinfection technique should be effective without adversely affecting the properties of prostheses [8] and the disinfecting agent must be compatible with the material used in the construction of the prostheses to prevent adverse effects [9].

Where manual dexterity might limit the effectiveness of physical cleansing by manual brushing as in the elderly, a viable alternative is chemical cleansing by immersion of the prosthesis in commercially available solutions twice a day. This is a simple routine task that can prevent bacterial colonization of microorganisms such as *Candida albicans* and *Candida glabrata*, which are responsible for oral conditions such as denture stomatitis and Halitosis [10]. Commercially available denture cleansers can be grouped as alkaline peroxides, alkaline hypochlorites and dilute organic or inorganic acids [11]. While alkaline peroxides are believed to be effective on newly formed plaque and stains, long period of immersion is required for these to be affective. Alkaline hypochlorites are disinfectants against fungal and bacterial growth as well as on stains, mucin, and other organic substances. Acid cleansers must be used with caution due to their corrosive nature and should not be used on daily basis [12]. Most commercially available disinfectants are composed of sodium hypochlorite and alkaline peroxides [13], sodium bicarbonates [14], and those containing diluted acids (organic or inorganic) [11]. Peroxides are usually supplied as effervescent tablets and hydrogen peroxide solutions is formed upon dissolving in water [15]. The main disadvantage of peroxide cleansers is the long immersion periods required for effective cleansing [16].

An ideal denture cleanser should be readily available, effective, affordable, non-abrasive and simple to use. There are numerous reports on the detrimental effect of denture cleansers on the physical properties of acrylic resin [17], as daily use of such solutions can affect the colour, surface roughness, flexural strength and the hardness of resins [18]. Furthermore, of unsuitable cleansers may result in weakening of the denture with time [19,20]. Investigators suggest that the effect of denture cleansers varies according to its type, immersion duration and the type of resin [14]. Recent reports suggest that denture cleansers adversely affect the hardness of denture base acrylic resin which should be considered when instructing patients on denture hygiene [21]. However, there have been many advances in the biomaterials including resins method of polymerisation and composition rendering the need for further investigation on the effect of denture cleansers on these new generation resins.

The current report examined the effect of various commercially available denture cleansers on the hardness of polyamides denture base materials as well as conventional resins.

Materials and Methods

Samples Preparation

The hardness of six various types of denture base materials (Table 1) was tested by preparing 40 disc shaped specimens of each material. A total of 240 discs were fabricated each measuring 6 mm in diameter and 3mm in thickness. The resin discs were constructed according to the manufacturer's instructions employing the lost wax technique where applicable (Dental wax; Lordell trading, New South Wales, Australia).

	Denture base resin	Manufacturer
1	Vertex Castavaria	Joh. V. Oldenbarneveltlaan, 62 3705 HJ, Zeist, the Netherlands
2	GC unifast cold-cured PMMA resin	GC Dental Prod. Corp. 2-285, Torimatsu, Kasugai, Aichi, Japan
3	GC Major heat cured PMMA resin	Prodotti Dentari, S.p.A via Einaudi 23 – 10024, Moncalieri (TO) Italy
4	Acrilato Deflex Thermo Injected Acrylic	Sitio de Montevideo 2381 Lanus (Zip Code) 1824 Bs.As. City Argentine
5	IvoBase Hybrid PMMA	Ivoclar Vivadent, AG FL-9494, Schaan / Liechtenstein
6	IvoBase High impact PMMA copolymer	Ivoclar Vivadent, AG FL-9494, Schaan / Liechtenstein

Table 1*: Denture resins used to prepare samples.*

Immersion protocol

All samples were immersed twice daily starting at baseline, then at 1 day, 1 week and 1 month periods according to the manufacturer's instruction for each cleansing agent. The control was immersion in distilled water. Following each immersion cycle, the samples were rinsed with tap water and then stored in distilled water in an incubator at 37ºC.

Denture cleansers tested

Samples were immersed in 3 different types of readily available denture cleansers twice daily (Table 2).

	Material	Manufacturer	Immersion Protocol	Composition
a	Effervescent Denture Cleanser	E.U for Tesco Stores Ltd. Cheshunt EN8 95L, U.K Tesco 2006. SC4388	Immersion at 50ºC for 3 minutes twice a day.	Sodium Bicarbonate, Citric Acid, Sodium Carbonate Peroxide, Potassium Monopersulfate, Sodium Carbonate, Sodium Sulfate, PEG 90, PEG 150, Aroma, Tetramethylenediamine, Sulfamic acid, Sodium Cocoyl Isethionate, C16-C18 Fatty Alcohol Ethoxylate, CI 73015.
b	Steradent	Reckitt Benckiser Healthcare (UK) Limited, Dansom Lane, Hull HU8 7DS UK	Immersion at 50ºC for 1 minute twice a day	Sodium Sulfate, Sodium Carbonate Peroxide, Sodium Bicarbonate, Sodium Carbonate, Citric Acid, Sulfamic Acid, Sodium Cocoyl Isethionate, Maltodextrin, Aroma, Arabic gum, Glucose, Sodium Chloride, Ci 42090.
c	Smile Denture Cleansing Powder	The boots Company LPC Nottingham England	Immersion at 50ºC for 10 minutes twice a day.	Sodium Chloride, Sodium Carbonate, Sodium Carbonate Peroxide, Trisodium phosphate, Parfum, Sodium dodecyl benzene sulfonate, CI 45430.

Table 2: *Details of all denture cleansers used and immersion protocol.*

Hardness test

Surface hardness was measured (Micromet 6040, Buehler LTD, Illinois 60044. USA) with a testing load of 50N at three points. The mean was calculated as a result of 10 hardness values obtained for each resin type in each immersion cycle.

Statistical Analysis

Three-way analysis of variance was carried out to test the effect of storage time, denture cleaners, materials and their interactions on surface hardness was performed using the Statistical Package for Social Science (SPSS) version 20 (IBM Corp., Armonk, NY).

Results

Figure 1 displays the hardness measured for all tested resins following immersion in solution a (the effervescent Sodium Bicarbonate, Citric Acid) denture cleansing solution. Self-cured, heat-cured and Deflex resins displayed a decrease in hardness at 1 day immersion that was followed by an increase on subsequent immersions. Other resins showed an initial increase in hardness that was either sustained (Vertex) or declined but remained above the hardness value measured at baseline. Similarly, an increase in hardness was recorded following the immersion of Vertex and copolymer resins in solution b (Mono-dose Sodium Sulfate, Sodium Carbonate Peroxide sachets) while the hardness of heat-cure and self-cure resins decreased as displayed in the figure 2. Figure 3 represents the effect of immersion in solution c (Sodium Chloride, Sodium Carbonate powder / solution) where the self-cure resins and vertex displayed an increase in hardness while all other materials showed a decrease in hardness. Figure 4 shows the results of immersion in the control medium (distilled water) where all resins displayed a decrease of hardness.

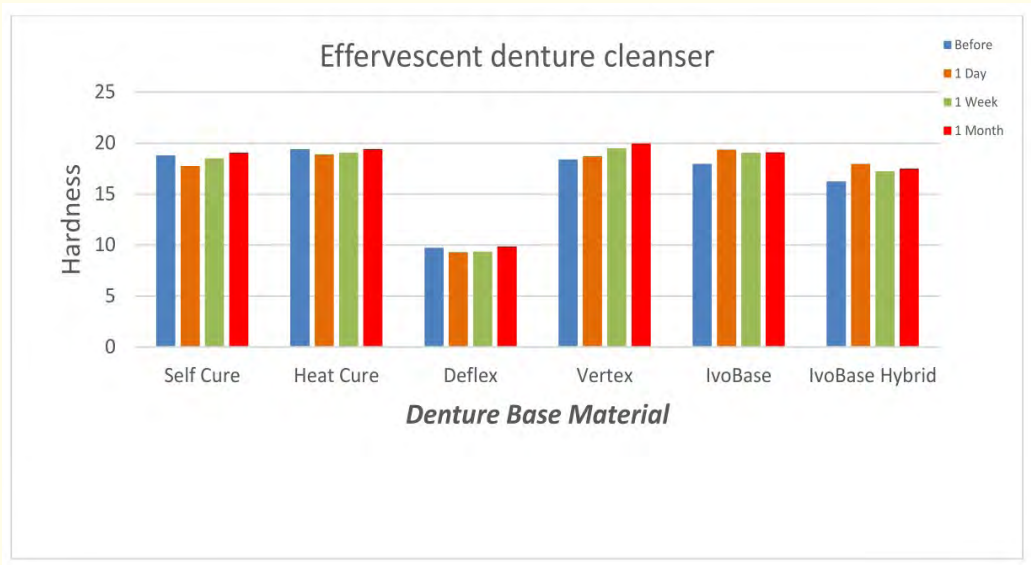

Figure 1: *Hardness in all denture base material following immersion periods of 1 Day, 1 Week and 1 Month in Tesco effervescent denture cleansing solution.*

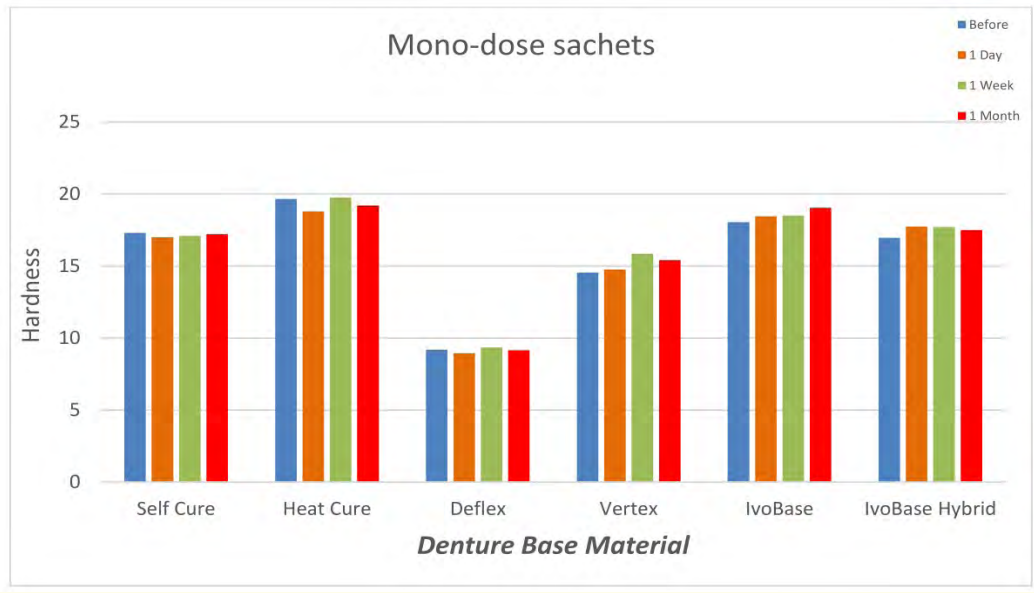

Figure 2: *Hardness change in all denture base material following immersion periods of 1 Day, 1 Week and 1 Month in Steradent mono – dose sachets denture cleansing solution.*

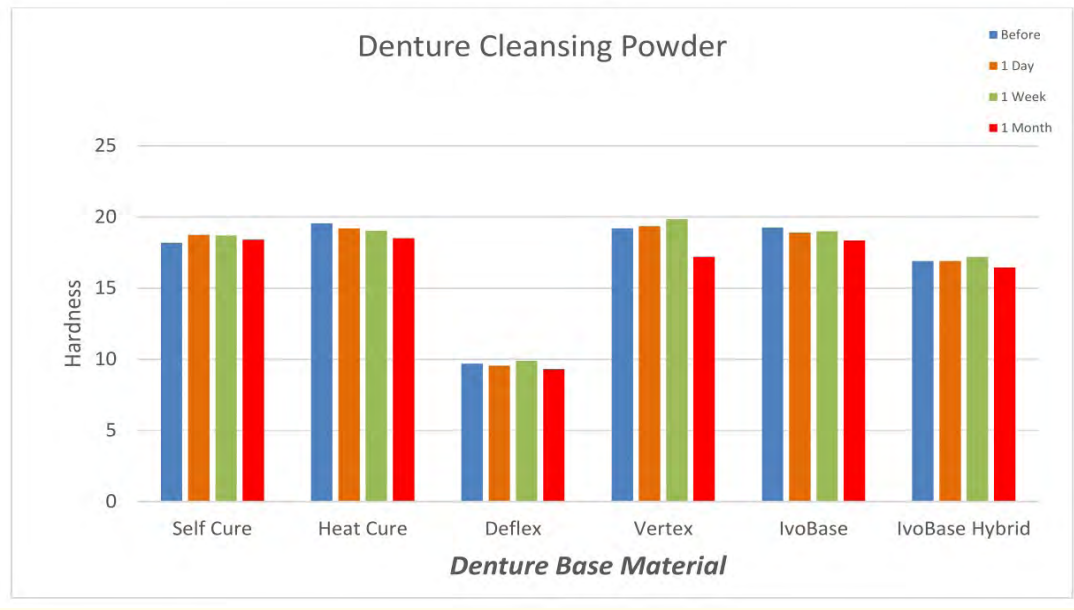

Figure 3: *Hardness change in all denture base material following immersion periods of 1 Day, 1 Week and 1 Month in Boots denture cleansing powder solution.*

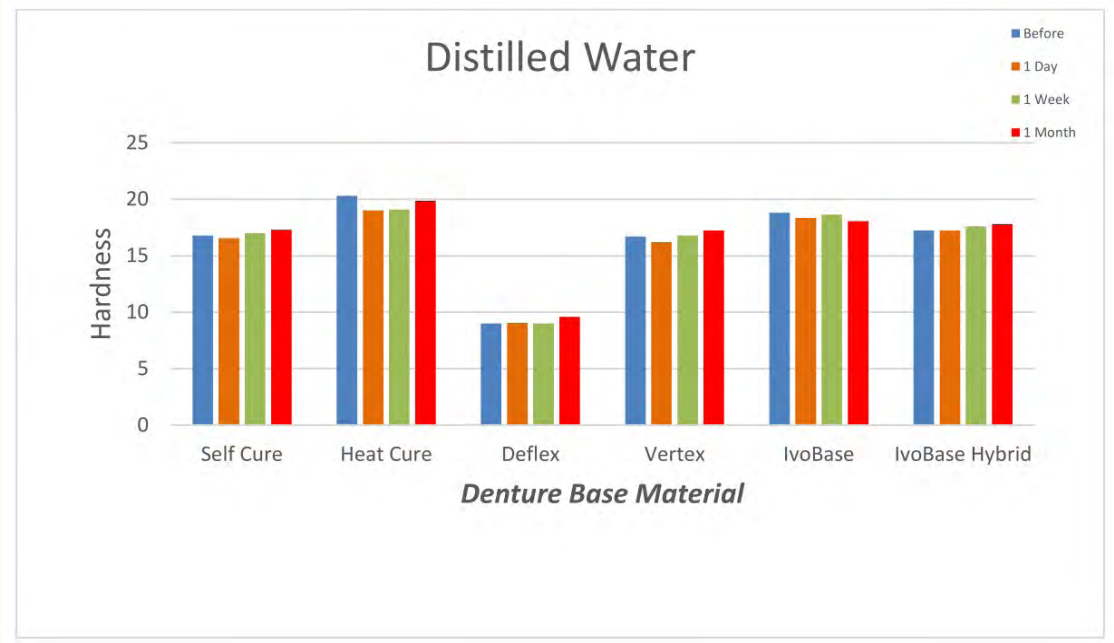

Figure 4: *Hardness change in all denture base material following immersion periods of 1 Day, 1 Week and 1 Month in Distilled Water.*

The least measured hardness values even at baseline, was that of Deflex injection moulding resins. Three-way analysis of variance for the effect of group, material, time and their interactions on surface hardness revealed high significance between test groups $p \leq 0.001$*.

Discussion

The findings of the current study suggest that the immersion of all tested denture base resins in various denture cleansers can significantly affect the hardness of the resin. This is effected by the chemical nature of the denture cleansers, the immersion time as well as the resin type.

The findings indicate that the hardness of all PMMA resins tested was decreased following immersion regardless of the immersion solution type or immersion time. This may be due to leaching out of the monomer from the PMMA matrix and/or the diffusion of molecules from the cleansing solution and into the PMMA resin through the formation of side group chains. Both of the above would result in the softening of the resin.

The polymerization process of conventional PMMA resins occurs by free addition thus resulting in the presence of free radicals as well as partial cross linked polymer chains containing high levels of residual monomer. This is believed to have an adverse effect on some of the mechanical properties of the resin including the hardness due to diffusion of the monomer from the polymer and simultaneous water sorption by diffusion into the resin, a plasticizing effect which reduces the inter-chain forces allowing easy deformation and significant reduction in the hardness of PMMA acrylic resins under load during hardness tests following immersion in sodium perborate [9].

Some reports suggest that the use of hot water in the preparation of denture cleansers containing hydrogen peroxide may result in the conversion of the oxygen to free oxygen radicals which may cause a chemical softening of the resin [10].

Conventional PMMA resins were reported to have higher hardness values at baseline compared to polyamides which was attributed to the higher fibrous content of polyamide resins and lower modulus of elasticity. Irrespective of the solution used, it was reported that the hardness of both polyamide and PMMA resins decreased following repeated immersions of 15 min at 50°C for 20 days. However, the decrease in hardness was less overtime for the thermoplastic polyamide resins and high-impact copolymer polyamides than it was for the conventional PMMA resin. This may be a consequence of the condensation polymerization of nylons that results in an aliphatic chain free from cross linking with a complex crystalline structure that does not allow the penetration of other molecules into the nylon matrix [14,22]. This may explain the findings of the current investigation and the increase in hardness of polyamides and copolymers following immersion in all solutions except in solution c (sodium chloride).

A recent report investigated the effect of disinfectants on the hardness of heat cured PMMA resin before and after 15, 30, 60 and 90 days immersion in various disinfectant solutions: (1% sodium hypochlorite, 2% alkaline glutaraldehyde or 4% chlorhexidine gluconate) at room temperature for 10 minutes with distilled water as a control. A significant decrease in hardness was seen in all samples irrespective of the disinfectant used. The least effect on hardness was measured with 4% chlorhexidine gluconate while 2% alkaline glutaraldehyde had the highest effect on the hardness [23]. Others have reported the adverse effect of oxalic acid and tartaric acid denture cleansers on the hardness, flexural strength and flexibility of traditional heat cures acrylic resin base material but not that of nylon [22].

The method of polymerization and its relation to denture cleansing was reported in a study to evaluate the effect of 1% hypochlorite denture cleansers on heat-polymerized and microwave-polymerized acrylic resins, the mechanical properties tested following immersion times of 15 and 183 days were hardness and flexural strength. The results showed that hypochlorite caused a decrease in flexural following 183 days and a significant decrease in the hardness of both resins [24]. These finding are in agreement with the current study where immersion in sodium chloride solution c resulted in the reduction in the hardness of heat polymerized acrylic resin as well as copolymers and polyamides alike.

The effect of 2% glutaraldehyde, 0.5% sodium hypochlorite and 0.4% chlorhexidine gluconate cleansing solutions on conventional heat cured acrylic denture base resin and Trevalon were reported. The specimens were immersed at baseline (control), 30 min, 2 hr, 10 hr, 24 hr, 48 hr, 7 days and 14 days. Initially there was no significant effect on the surface hardness of all samples after immersion for up to 24 hrs. however, longer immersion in chlorhexidine gluconate resulted in greater reduction of the surface hardness than sodium hypochlorite and glutaraldehyde with the least effect induced by immersion in glutaraldehyde [25].

When comparing mechanical and chemical cleansing methods it was concluded that the chemical composition of the disinfectant used even for short immersion duration was more critical as opposed to the method of cleansing [21].

Contradicting reports to the above were published stating no statistically significant difference in the micro-hardness of resin when using cleansers containing chlorhexidine, sodium perborate and sodium hypochlorite [11,26]. However, these studies looked at the effect of a single prolonged immersion process that was not repeated which does not replicate the patient's daily routine of denture cleaning.

In a systematic review of the literature it was found that all studies reported surface alteration of resin ensuing chemical disinfection. The present-day literature indicates positive correlation between alteration in surface roughness when using sodium perborate compared to less changes with chlorhexidine digluconate and glutaraldehyde. The authors concluded that more research is needed [27]. However prolonged immersion of up to 10 hours in 2.4% glutaraldehyde resulted in reduced hardness of the resin [28].

Chemical disinfection was reported to adversely affect other physical properties of denture base resin including a decrease in the flexural strength of heat-polymerizing acrylic resin following immersion in sodium hypochlorite but not with alkaline peroxide [29].

A recent study examined the effect of prolonged immersion on three denture base resin materials (conventional heat cure resin, a high impact resin, and the polyamide denture base resin). Samples were immersed for 180 days in two commercially available denture cleansers (sodium perborate and sodium hypochlorite). The maximum change in hardness was measured in the conventional heat cure PMMA when immersed in sodium perborate. The authors concluded that the type of resin as well as the type of denture cleanser and its concentration, in addition to the duration of immersion should all be taken in consideration as they can affect the hardness and other properties of the resin [30]. These are similar to the finding of the current study which highlights that possible adverse effect of commonly used denture cleansers on the physical and mechanical properties of denture base resins. The recent introduction of microwaves as an alternative method of disinfection recommends the use of microwave disinfection in dry conditions as significant dimensional changes were noted following microwaving in wet environment. Furthermore, the effects of microwave disinfection on properties including the hardness of denture teeth and are still controversial [31].

Conclusion

Within the limitations of the current study, findings suggest that conventional chemical cleansing can adversely affect the surface hardness of conventional PMMA resin as well as the new generation of polyamides and copolymers. Further investigation is needed to establish the effect of longer immersion times as well as effect of denture cleansing on other properties such as surface roughness and flexural strength.

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