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FRACTURE RESISTANCE OF RELINED MICROWAVE-CURED HIGH IMPACT VERSUS CONVENTIONAL HEAT-CURED ACRYLIC RESIN MANDIBULAR DENTURE BASES: AN IN VITRO STUDY

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ABSTRACT

Aim: This in vitro study aimed at comparing the fracture resistance of microwave-cured high impact and conventional heat-cured acrylic resin mandibular denture bases, whether relined by a resilient liner or not.

Materials and methods: Conventional heat-cured (C) and high impact microwave-cured (H) acrylic resins were used in the fabrication of 24 mandibular denture bases divided into 4 groups (n=6). Half of these bases were 4 mm in thickness to be used unrelined (CU and HU), the other half was prepared in reduced thickness (2 mm thick) to be relined (CR and HR) with addition silicon resilient liner (R). The denture bases were loaded in compression at the canine-premolar areas bilaterally until failure, using a universal testing machine. Data on fracture resistance (N), work of fracture (J) and deflection at fracture (mm), were analyzed by Kruskal-Wallis and Dunn's test ($P \leq 0.05$).

Results: Among the unrelined (CU and HU) and the relined (CR and HR) bases, there were insignificant differences regarding the fracture resistance and the work of fracture median values. Fractures/cracks were repeatedly observed either unilaterally or bilaterally at the premolar regions of the bases. The CU bases exhibited the statistically lowest significant median deflection value at fracture compared to all other denture bases which were insignificantly different from each other.

Conclusions: Relining of mandibular denture bases with resilient liners reduced their fracture resistance, work of fracture and increased their amount of deflection at fracture regardless to the type of the denture base material. Economically, conventional acrylic resin denture base material is still the material of choice for dentures that would require relining with resilient liners.

Key word: Fracture resistance, Resilient denture liners, Microwave-cured, High impact acrylic resins, Mandibular dentures.

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INTRODUCTION

Sometimes patient comfort cannot be achieved using hard acrylic denture bases because of the advanced resorption of the residual alveolar ridge and the relatively non-resilient mucosa[1]. For such situations, the application of resilient liners to the denture base enable stress to be absorbed, thereby, reducing the load on the supporting tissues [2, 3]. The load is distributed over the denture bearing area by preventing localized areas of stress concentration[2-5]. Several materials are available for use as resilient denture liners, for example, silicone, acrylic resin and fluoroethylene type that offer a wide range of viscoelastic properties [2, 6-8].

The predicted growth in the number of edentulous patients implies that the possibility of clinicians encountering edentulous patients with complications related to their complete dentures may increase in the future [9]. Unfortunately, edentulous patients are unable to change the inherent characteristics of the mucosa. Currently however, there are two possibilities for changing the acquired chronic disorder of these edentulous patients with atrophic and thin mucosa. The first is treatment with implants [10-13] while the second is treatment with permanent resilient denture liners [14]. Implant treatment is not a practical solution for all edentulous patients due to medical, psychological or financial constraints, whereas treatments with permanent resilient denture liners provide few restrictions for edentulous patients. However, fracture of acrylic resin denture bases is a continuing problem in prosthodontics especially in relined dentures [15-17]. Although patients have welcomed soft-lined complete dentures, early fracture is one of the main reasons for their denture failure [18].

Recently, modified high impact microwave-cured acrylic resin denture base (Diamond D) has been introduced in the dental market. This material exhibits high impact resistance, exceptional flexural strength and high total fracture work. Furthermore, it has a homogenous dough stage, which facilitates packing procedures [19]. It is claimed to provide the dental professionals with a lighter, more comfortable fitting and even thinner dentures than other acrylic denture, while still maintaining its mechanical properties [19].

Hence, it was decided to conduct this in vitro study to compare the fracture resistance of microwave-cured high impact (Diamond D) and conventional heat-cured (Acrotstone) acrylic resins mandibular denture bases, whether relined by a resilient liner or not. The null hypothesis of the current study was that the fracture resistance of the high impact microwave-cured mandibular denture base would be non-significantly different than those of the conventional heat-cured ones weather relined or not.

MATERIALS AND METHODS

This in vitro study was reported following the modified Consort guidelines [20]. The product names, batch numbers, code and manufacturers of the investigated materials are listed in table 1.

Sample size calculation

IR (Iman Radi) and DA (Dalia Abdel-Hamid) planned a study comparing the maximum fracture resistance of 2 relined and unrelined denture base materials. Hence, 4 independent groups were required; 3 experimental and one control (unrelined conventional heat-cured acrylic resin). In a study conducted by Seo et al. in 2006 [16], the mean of the maximum fracture load difference between relined and unrelined denture bases was 295 N with standard deviation of 155. Accordingly, 6 samples i.e. denture bases per group with a total sample size of 24 were prepared to be able to reject the null hypothesis that the population means of the relined and the unrelined mandibular denture bases are equal with a power of 0.95. The Type I error probability associated with this test of this null hypothesis was set at 0.05.

TABLE (1) Materials used in the current study

Product	Code	Manufacturers
Acrostone Conventional Heat-Cure Acrylic Resin Denture Base Material	C	Acrostone Dental and Medical supplies, Zone-Salam City-Egypt)
Diamond D® High-Impact Microwave -Cure Acrylic Resin Denture Base Material Liquid batch no. 1013093 Powder batch no. 1013020	H	Keystone Industries GmbH Werner-von-Siemens Str. 14a 78224 Singen -Germany
Mollosil Plus Self-Cure Addition Silicone Soft Reline Material Batch no. 02439	R	DETAX GmbH & Co. KG, Ettlingen, Germany.
Mollosil ® plus Primer Batch no. 02440		
Mollosil® plus Polish Batch no. 02441		

Preparation of mandibular denture bases

Standardization of mandibular denture base thickness

A mandibular completely edentulous stone model was scanned using a lab scanner (Shera Eco-scan7, 3D scanner 1 piece, Werkstoff technologies, GmbH & co., KG, Germany). On the resulting digital model, 2 mandibular denture base designs; relined (R) and unrelined (U), were created to extend to the full vestibular depth of the model, using designing software (Dentalwings Inc., H1V 2N9; Montreal, Quebec, Canada). The thickness of these denture bases was standardized to be 4 mm throughout for the U groups and 2 mm for the R groups. The latter groups required the development of 5 tissue stops, 2 at the retro-molar pad, 2 in the molar and 1 in the midline regions of the bases (Fig. 1).

The borders of the bases were traced and smoothened using the smoothening function of the software. The STL (standard tessellation language) files of the created designs were exported to a 5-axis milling machine (Shera Eco-mill 5x, Shera Werkstoff-Technologie, GmbH & co., KG, Germany). Polymethyl-methacrylate transparent acrylic resin blocks (Wieland PMMA blocks, Tianjin, China stone, China), 98 mm in diameter and 25 mm in height, were required to mill the designed denture bases. The milled bases were constructed to help in obtaining denture bases of standardized thickness for the conventional heat-cured (C groups) and the high impact microwave-cured acrylic resin bases (H groups), whether relined (CR and HR) or not (CU and HU).

Flasking and processing

Conventional flask was used for the construction of the CU and CR groups. Flasking was done by laboratory putty condensation silicone (Labosil shore Protechno 90, dentaltix; Madrid, Spain) in a conventional metal flask to obtain 2 molds, one for the CU (4 mm thickness) and the other for the CR group (2 mm thickness with 5 tissue stops). On the other hand, high impact resin bases, HU and HR groups, required a plastic flask (Technoflask, Keystone Industries GmbH, Germany), which could be used for microwave processing of these bases. Flasking of the bases was done in 2 steps; first by packing a layer of laboratory condensation silicone (Labosil - Silicone Putty, Protechno, Spain) in the fitting surface of the milled transparent R or U base to record tissue stops and preserve integrity of the milled bases and then by immersing the packed base in dental stone plaster class III (On stone, Onpharno lifscience, Indiamart, India) mixed and poured in the die of the flask (Fig. 2). After securing the counterdie to the die of the flask, the flasking and packing procedures were continued in the conventional manner according to the manufacturer instructions of each material. For the CU and CR groups, the bases were processed conventionally in a long curing cycle (70^{0}C for 7 hours, then boiling for 1 hour). Processing of HR and HU was done in a microwave oven (500 -700 Watt, LG Neochef, MJ3965ACS, LG Electronics, Seoul, Korea) for 9 minutes as recommended by the manufacturer. The bases were not finished to avoid reducing their thicknesses and were then evaluated for adaptation on the edentulous stone model. The bases were stored in distilled water at 37 °C for 24 hours in the incubator (Cbm. Torre Picenardi (CR), Model 431/V., Italy) before relining.

Relining of mandibular denture bases

IR, the investigator, relined CR and HR mandibular denture bases by self-cured addition silicone soft reline material (Mollosil plus, Detax, Ettlingen, Germany). The mandibular denture bases to be relined were primed (Mollosil ® plus Primer) where the primer was applied on the bases for 1 minute according to the manufacture instructions. After words, the homogenous mix (catalyst: base ratio of 1: 1) of the reline material was applied on the fitting surface of the denture base and then the base was fit to the vasilinated surface of the stone model. Finger pressure was applied for approximately 30 minutes to ensure contact between the tissue stops and the model. This was essential to provide an even thickness of 2 mm for the reline material, not only within the same denture base, but also for relined denture bases of both groups. After setting of the reline material, the excess was removed with a sharp scalpel. Mollosil® plus polish was then applied to the reline material surface and trimmed borders which was left to dry at room temperature for approximately 5 minutes.

The mandibular bases were placed in 2 plastic bags, coded as A and B for the conventional (CU and CR) and the high impact (HU and HR) acrylic resin bases, respectively. Codes were concealed from DA, the assessor, to avoid reporting bias. IR and DA planned to assess the fracture resistance of the mandibular bases as primary outcome. This is defined as the maximum compressive load in Newton (N) at which fracture occurred. Secondary outcomes were the work of fracture measured in Joule (J) which is defined as the energy needed to produce 2 fractured surfaces [21], and the maximum deflection at fracture which is measured in millimeter (mm).

Fig. (1) Standardization of the thickness of the resilient liner by 5 tissue stops, 2 at the retro-molar pad, 2 in the molar and 1 in the midline regions of the mandibular denture bases that required relining (CR and HR).

Fig. (2) Mold created in the die portion for the high impact microwave-cured mandibular acrylic resin denture bases.

Fracture resistance test

DA tested the fracture resistance, work of fracture and deflection at fracture by subjecting the polished surface of the CR, CU, HR and HU mandibular denture bases to a metallic loading bar at the canine premolar regions bilaterally [22]. Each mandibular base was mounted individually on a computer controlled testing machine (Model 3345; Instron Industrial Products, Norwood, MA, USA) with a load cell of 5 kN (Fig. 3). A compressive load was applied via a metal bar attached to the upper movable compartment of testing machine, which travelled at a cross-head speed of 5mm/min [16]. The maximum load in Newton (N) at which failure occurred, was manifested by an audible crack and confirmed by a sharp drop in the load-deflection curve, recorded by the computer software (Instron, Bluehill Lite Software, MA, USA). The latter also recorded the work of fracture in Joule (J) which explains the mechanical toughness of the mandibular denture bases and was calculated from the enclosed area under the whole load-deflection curve [21]. Additionally, the maximum amount of deflection at fracture in millimeter (mm) was obtained from the load-deflection curve of each tested mandibular denture base (Fig. 4).

Statistical methods

Numerical data were explored for normality by checking the data distribution and using Kolmogorov-Smirnov and Shapiro-Wilk tests. All measurements showed non-normal (non-parametric) distribution. Data were presented as median and inter-quartile range (IQR) values. Kruskal-Wallis test was used to compare between the 4 tested groups (CU, CR, HU, HR) followed by Dunn's test for pair-wise comparisons. The significance level was set at P≤ 0.05. Statistical analysis was performed with IBM (IBM Corporation, NY, USA), SPSS (SPSS, Inc., an IBM Company) Statistics Version 20 for Windows.

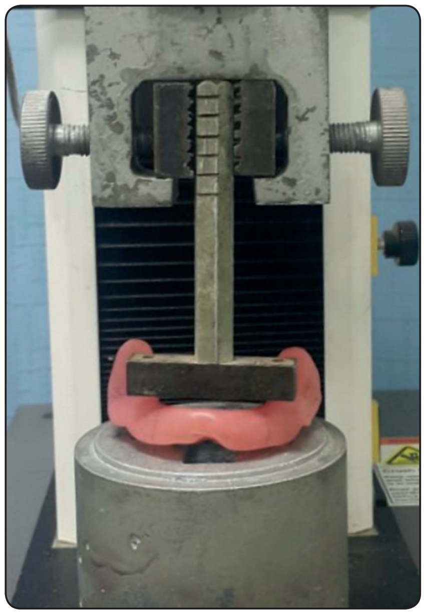

Fig. (3) Mandibular denture base mounted on a computer controlled testing machine subjected to compressive forces on its polished surface by a metallic loading bar at the canine-premolar regions bilaterally.

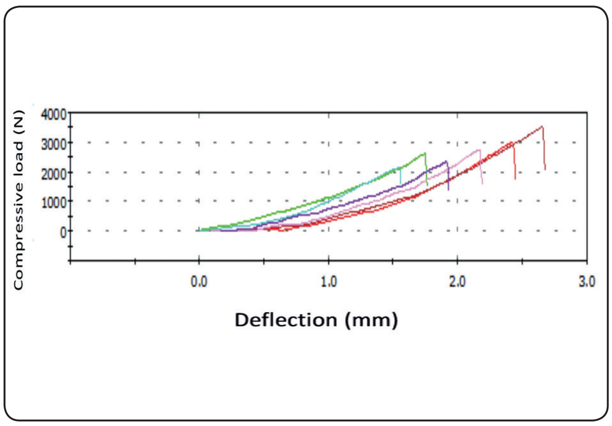

Fig. (4) Representative load-deflection curves of 6 tested mandibular denture bases belonging to the CU group as obtained from the computer controlled testing machine software.

RESULTS

The results of the fracture resistance (N), work of fracture (J) and deflection at fracture (mm) are presented in table (2) and Figs. 5-7, respectively. Regarding the results of the fracture resistance (N), the highest median values were recorded for the HU followed by the CU, HR and finally CR denture bases, which recorded the lowest median values.

Comparison among the 4 tested groups revealed a statistically significant difference between relined and unrelined bases, regardless of the denture base material type; where the relined denture bases possessed significantly lower median fracture resistance values (N) than those of the corresponding unrelined ones. On the other hand, difference in the fracture resistance median values (N) between the denture base materials were only significant for HU and CR groups. Fracture was repeatedly observed either unilaterally or bilaterally at the premolar region, where the loading bar was applied (Figs. 3 and 8A,B) for CU and HU mandibular bases, respectively. On the other hand, the relined denture bases (CR and HR) were cracked without separation of the 2 fractured segments (Figs. 8C and D, respectively).

Regarding the results of the work of fracture (J), the relined denture bases revealed significantly lower median values than those of the unrelined ones, regardless of the denture base material type. However, there were insignificant differences among the relined denture bases (CR and HR) as well as among the unrelined ones (CU and HU).

Finally, the results of the deflection (mm) at fracture revealed that the CU bases exhibited the statistically lowest significant median deflection values at fracture (mm) compared to all other denture bases (CR, HU and HR groups) which were insignificantly different from each other.

TABLE (2) Median, Inter-Quartile Range (IQR) and results of Kruskal-Wallis test for comparison between the fracture resistance (N), work of fracture (J) and deflection at fracture (mm) of the 4 tested groups.

	Conventional Unrelined (CU)		**Conventional Relined (CR)**		**High impact Unrelined (HU)**		**High impactRelined (HR)**		***P*-value**
	Median	IQR	Median	IQR	Median	IQR	Median	IQR	
Fracture Resistance (N)	2841.9 ^{AB}	2478.7 – 3332.4	478.6 ^{C}	356.2 – 638.6	3455.6 ^{A}	2993.3 – 3974.8	1031.9 ^{BC}	804.7 – 1082.7	<0.001*
Work of Fracture (J)	0.223 ^{A}	0.213 – 0.268	0.054 ^{B}	0.026 – 0.091	0.199 ^{A}	0.122 – 0.228	0.042 ^{B}	0.032 – 0.053	0.003*
Deflection at Fracture (mm)	2.110 ^{B}	1.649 – 2.609	2.888 ^{A}	2.680 – 3.074	2.770 ^{A}	2.599 – 3.148	2.800 ^{A}	2.375 – 3.125	0.040*

: Significant at P ≤ 0.05, Different superscripts in the same row are statistically significantly different

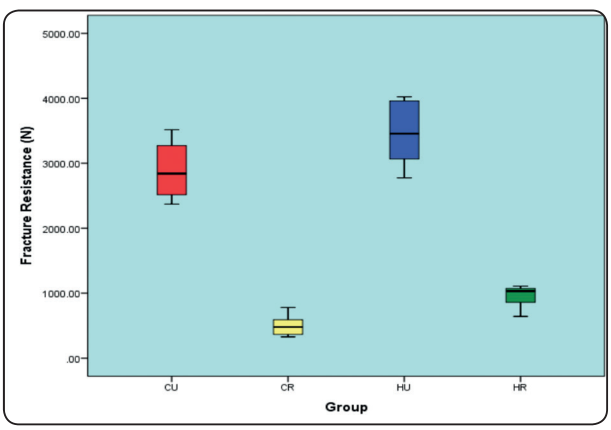

Fig. (5) Box plot representing median values of the fracture resistance (N) in the four groups

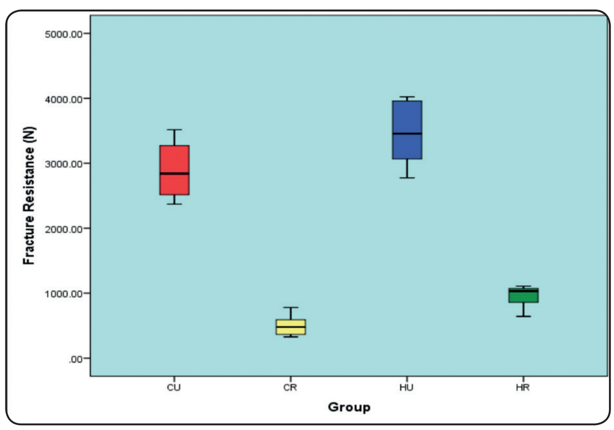

Fig. (6) Box plot representing median values of the work of fracture (J) in the four groups (Circle and star represent outliers)

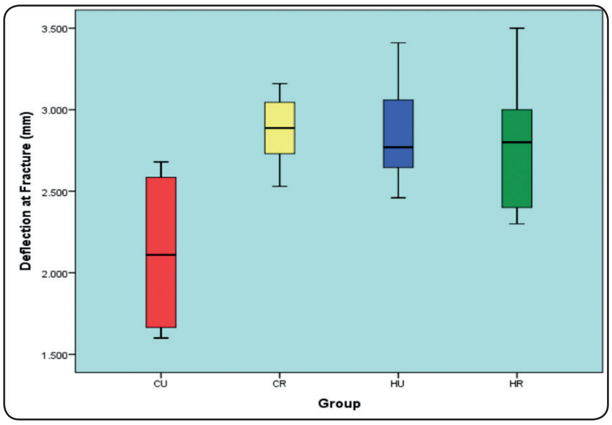

Fig. (7) Box plot representing median values of the deflection at fracture (mm) in the four groups

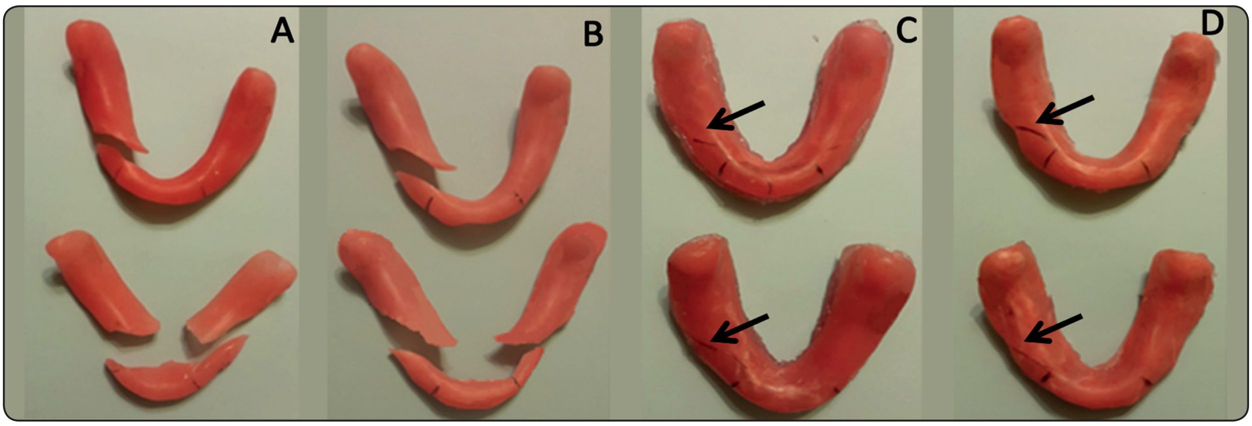

Fig. 8: Representative samples of the prevalent site of failure of the fractured/cracked unrelined (CU and HU) and relined (CR and HR) mandibular denture bases, respectively; A and B: Unilateral and/or bilateral fractures close to the premolar region of the unrelined conventional heat-cured (CU) and high impact microwave-cured bases (HU), respectively. On the other hand, C and D: Unilateral cracking (black arrows) of the relined denture bases (CR and HR), respectively without separation of the 2 fractured segments.

DISCUSSION:

Despite the strong desire of the patients to obtain well-fitting dentures, as well as, clinician's efforts to fabricate satisfactory dentures, there are still edentulous patients who are suffering during eating while wearing their conventional complete dentures. One of the most important reasons for this problem is atrophic and thin mucosa that bears the stress caused by occlusal forces [2-7, 14]. Therefore, resilient denture liners are used for those patients who are unable to tolerate the pressures transmitted by prosthesis to the thin and relatively non-resilient mucosa [6]. However, fracture of relined dentures fracture is a continuing problem in prosthodontics [15-17]. Hence, this in vitro study was conducted to compare the fracture resistance of microwave-cured high impact and conventional heat-cured acrylic resin mandibular denture bases, whether relined by a resilient liner or not. In the present study, we failed to reject the null hypothesis that the fracture resistance of the high impact microwave-cured mandibular denture base would be non-significantly different than those of the conventional heat-cured ones whether relined or not.

It worth mentioning that every effort was made to simulate the clinical conditions; where denture-shaped specimens rather than simple rectangular specimens were used, compressive loading was chosen because it best simulates denture base exposure to masticatory occlusal forces, application of such compressive loads on the polished denture surface rather than the fitting surfaces. In the compressive test, one side of the specimen receives compressive force and the other side of the specimen is exposed to tensile force depending on the loading direction of the testing machine. Consequently, when testing a specimen comprising of 2 materials having different physical properties, mounting direction of the specimen in the testing machine may affect the obtained results. Hence, the fracture properties of a relined specimen evaluated after placing the base resin layer under tension while the resilient relining layer under compression cannot be interpreted as the same as the results measured by placing the specimens in an opposite direction [17]. In the present study, the mandibular denture base was placed under compressive forces while the resilient relining material was placed under tensile forces (Fig. 3) to closely simulate the clinical situation. Additionally, the use of silicon resilient liner in the current study was according to a recent study reported that such material with a 2 mm thickness decreased the maximum and minimum principal stress in the mucosa and in the underlying bone than acrylic resilient liner materials [4].

Generally, within each material (C and H), the relined mandibular denture bases (CR and HR) recorded statistically lower fracture resistance (N) and work of fracture (J) than their corresponding unrelined mandibular denture bases (CU and HU, respectively). One reason for this phenomenon was that the original denture base was thinned out (~2 mm) to provide adequate thickness for the resilient liner (~2mm). Several studies have indicated that the strength of relined specimens depends mainly on the bulk strength of the denture base materials, the composition of the reline materials, and the ability of the 2 polymers to bond to each other [17, 23-25]. Furthermore, the distribution of stress within a specimen can be affected by factors such as specimen shape, thickness, mode of loading as well as the elastic modulus of the polymeric materials [16]. Adhesion of two different materials (rigid acrylic resin denture base and resilient silicon liners) of different modulus of elasticity could produce a negative effect on the overall mechanical response of the mandibular denture bases under compressive forces [15, 17]. In other words, the similar behavior of the 2 denture base materials whether relined or not (conventional and high impact acrylic resins) suggests that the thickness of the denture base has a more prominent effect on the fracture resistance and the work of fracture rather than the type of the denture base materials itself.

This has been supported by the fracture pattern of the tested denture bases (Figs. 8A-D) where, both the unrelined mandibular denture bases (CU and HU) revealed the same fracture pattern (2 or 3 parts) unilaterally or bilaterally at the site of load application (Figs. 8A and B, respectively). On the other hand, the relined mandibular denture bases (CR and HR) revealed similar fracture patterns, where cracking of the denture base was observed with the absence of separation of the fractured parts due to the adhesive effect of the resilient reline material (Figs.8C and B, respectively).

In spite of the absences of the statistical significance differences between the values of the fracture resistance (N) and the work of fracture (J) of the conventional and high impact acrylic denture bases whether relined or not, there might be a clinical importance owing to the statistically lowest significant amount of defection at fracture (mm) for the CU denture bases (Table 2 and Figs. 5-7). These findings could be explained in accordance with the compositional differences between the high impact strength acrylic resins and the conventional types. High impact acrylic resins are formulated with rubber reinforcing agent. The rubber particles are usually grafted to methyl methacrylate matrix. These rubber inclusions stop cracks that develop from propagating, thereby giving rise to a high degree of fracture resistance. However, they also lower the flexural modulus and fatigue failure because of the increased deflections [26-30]. These finding are in agreement with the higher amount of deflection at fracture possessed by the HU and HR groups as compared with that of the CU group which are supported with previous studies [27, 28]. Furthermore, the nonsignificant differences between the amounts of deflection at fracture (mm) of the CR, HU and HR bases confirmed the important effect of the reduction of the denture base thickness (CR and HR) in combination with the reduced elastic modulus offered by the rubber inclusions in high impact acrylic resin even in the unrelined groups (HU bases). Clinically, the increase in the amount of denture base deflection would promote the chances for denture base fracture under masticatory forces.

As addressed earlier, efforts have been done to simulate the clinical situation. However, loading was performed on the bases without cast or model support, which could decrease the clinical simulation. Nevertheless, this was essential, since fracture was nearly impossible in the presence of the cast support. Presence of saliva, cyclic, lateral and oblique loading might yield different results. Therefore, trails to include these factors are recommended in further investigations.

CONCLUSIONS

Within the limitations of this study, it can be concluded that relining of mandibular denture base with resilient liners reduced its fracture resistance, work of fracture and increased its amount of deflection at fracture regardless to the type of the denture base material. Economically, conventional heat-cured acrylic resin denture base material is still the material of choice for dentures that would require relining with resilient liners.

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