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Effect of Some Curing Methods on Acrylic Maxillary Denture Base Fit

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Abstract - *The aim of this study was to investigate the fit of acrylic maxillary denture bases processed by the methods of microwave, quick-wet-heat, slow-wet-heat, and self curing. Forty stone-casts were obtained using a mould of an undercut-free acrylic resin master cast of an edentulous maxilla. Standard acrylic replicas patterns sealed on casts and randomized to four groups (10 in each) were used to make denture bases using different processing methods for each of the four groups. The resultant discrepancy of fit between the denture base and the casts were measured using a silicone wafer. Varying fit discrepancies both within and between denture base groups was observed. The proportional fit-loss in the palatal region was significantly greater than the sulcular areas for all materials tested ($p<0.05$). The fit-loss observed was greater in microwave-cured bases than for other materials examined. Careful selection of appropriate denture base materials and processing technique is important when providing complete dentures for edentulous patients.*

KEY WORDS: Acrylic resin processing methods, Processing changes, Denture base-fit.

INTRODUCTION

Polymethylmethacrylate (PMMA) / acrylic resin is extremely popular in the construction of contemporary removable prostheses, with up to 98% of conventional removable partial and complete dentures being made in this material[1]. Intraoral retention of acrylic complete dentures is dependent on a number of factors including adhesion, cohesion, surface tension and viscosity that are facilitated through a saliva film at the denture- tissue interface[2-4]. However, for a denture to resist displacement forces exerted on it during function, it is important that its intaglio, muscular and occlusal surfaces have been appropriately fashioned[5]. This will allow the denture base to be sufficiently retentive to resist, amongst others, non-vertical denture displacing forces as occur during mastication. Notwithstanding both theoretical and practical investigations[2-4], little agreement has been reached on the nature of the factors that contribute to complete denture retention. However, it would appear that a well-fitting denture base is important[4]. This allows a thin film of saliva to lie between the well-fitting denture base and the underlying denture bearing tissues. Assuming completion of an appropriate master impression, satisfactory cast pouring and fabrication of an accurate wax pattern, any subsequent ill-fit/ poor adaptation of the subsequently completed denture base would most likely be related to changes in the acrylic resin that occur during its curing. Although it has been previously noted the dimensional change in acrylic resin is related to the selected processing technique, the exact amount of that occurs in each individual method is unclear[6-12]. It is likely that apart from the volumetric contraction occurring during the conversion of monomer to polymer, there are other factors involved in this dimensional change, including the inherent variations in the composition of acrylic resin as well as denture processing methods that bring dimensional changes with consequent inadequate fit of the denture base[13-16].

Patient-based clinical studies have indicated that the technical quality of completed dentures is not always correlated to patient satisfaction, but better-fitting prostheses have been shown to be associated with improved nutritional and quality of life outcomes among edentulous patients[17,18]. Of the possible denture base-cast fitting discrepancy measurement techniques available[19-56], the use of the method of a wafer of impression material for the assessment of the fit/adaptation of the denture base is relatively simple, straightforward and inexpensive to perform. This technique has recently been validated and used for the assessment of the fit of full coverage crowns[56]. Other previously used measurement methods employed feeler gauges, direct measurement of the gap between cast and base, Moiré topogram and others subjective and invasive cast-base sectioning methods. These and other more sophisticated techniques[6,15,27,30,35,36,44-51] are not only complex nature but lack universal applicability and problems which can confound results, such as the need for sectioning the casts and denture bases as well as the inherent movement of the denture base during measurements.

While an ever-increasing range of new materials and techniques now exist for fabrication of denture bases, it is important to investigate the suitability of these for the rehabilitation of the edentulous patient. Therefore, the aim of this study is to compare the fit of maxillary acrylic complete denture bases produced using commonly-used curing methods, such as microwave, quick-wet-heat, slow-wet-heat, and self curing.

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MATERIALS AND METHODS

Fabrication of Acrylic Resin Denture Bases

A stone cast was produced (New Plastone, GC Corp, Tokyo, Japan) using a commercially available rubber mould of an edentulous maxilla. Undercuts were removed from this cast on setting, however, the labial and buccal frenae were left intact to act as anatomical landmarks and to facilitate accurate location of bases later in the experiment. A silicone mould was made of this stone cast, from which an acrylic resin test cast was produced. This was immersed in water for 7 days, after which it was duplicated through a silicone mould contained in a rigid plastic casting ring to allow production of forty identical replica stone casts for this experiment. To produce each of the replica stone casts identically, the silicone mould was left unused for a period of 2 hours to allow its complete recovery before it was poured again. On each replica stone cast a 3mm thick denture base was patterned in modeling wax. These were sealed to their casts and invested in a metal denture flask using a quick setting hard dental stone (Plastone Fast-Set, GC Corp, Tokyo, Japan) and alginate based separating agent (Acrosep, GC Corp, Tokyo, Japan). The wax-pattern was boiled out, and each stone mould and denture flask facilitated the production of a clear acrylic resin replica patterns with the same standard thickness to fit each of the 40 test stone casts.

The transparent resin patterns were sealed to their stone casts. After necessary soaking, they were then assigned to 4 groups of 10 casts each according to the following curing techniques:

Group 1 for processing by the microwave curing (MC) methods;

Group 2 for processing by quick-wet-curing (QWC);

Group 3 for processing by slow-wet-curing (SWC);

Group 4 by processing by self-curing (SC).

Details of individual products used for each group are reported in Table 1. All the resins used were those commercially supplied as polymer powder and monomer liquid systems that are routinely used in the dental laboratory of the hospital for fabricating acrylic dentures. The sealed acrylic bases and casts were invested using suitable denture flasks: 'FRP' (fibre-reinforced plastic flasks) for Group 1, and metal denture flasks for Groups 2-4. Following setting of the investment material, the resin bases were removed. Each mould was then carefully packed with the test acrylic resin. Using thin soft cellophane film, all the flasks were trial packed three times (with a packing pressure sequence of 10, 10 and 25 $kgcm^{-2,}$ respectively, and removal of resin flash after the first and second trial packing steps). The packed FRP flasks were kept tightly bolted using the polycarbonate bolts, while the packed metal flasks were kept tightly clamped until processed. Upon completion of the packing step, each of the metal flasks was clamped with a metal spring clamp using the spring-clamp-prong device used for the purpose in the departments' laboratory. Details of each curing cycle are reported in Table 1. The completed bases from each group were finished with care to preserve the peripheral outline and contour in relation to the base model. The test denture bases and the resin test master cast were all kept immersed in water for at least 7 days and were removed from the water-bath only when needed for the test procedure.

Assessment of fit of denture bases

For the assessment of the extent of fit and adaptation of the test denture bases to the resin test master cast, a cartridge type hydrophilic polyvinylsiloxane impression material (Examixfine, GC Corp, Tokyo, Japan) was used. A controlled amount (3.5g) of the impression mix was evenly delivered across the intaglio of the test base. No impression adhesive was used. The surrounding environment was controlled at a temperature of 24° C and relative humidity of 55 – 60 %. Initial manual pressure was applied to exude the excess impression mix from the interface and then by transferring to a specially designed loading apparatus (Figure 1). Loading in the apparatus was precise and controlled by applying a 3 Kg preset load to the test base through a custom-fitting adapter made in putty silicone impression material, and was applied for 7 minutes. The exuded set material at the peripheral borders was then precisely cut in a controlled manner using a sharp surgical scalpel blade before carefully removing the test base from the resin test master cast. The resulting thin impression wafer (Figure 2), representing the fit discrepancy of the test denture base during each test processing method, was removed for quantitative assessment and analysis. For each test denture base, the fit discrepancy was recorded 5 times to reduce error (i.e. 5 impression wafers were produced for each mould).

To determine the over-all fit discrepancy, as well as at its distribution at various portions and aspects, each of the whole impression wafers and their subsequent sections were weighed 5 times using digital analytical balance (Mittler Weighing Scale to weigh up to a fraction of 0.001g). Using predetermined landmarks and lines crossing the labial frenum, buccal frenum, the central deepest point of the palate and the mid-palatal line, each of the sulcular portions and palatal portions of the wafers were sectioned to represent the buccal (right and left sides), labial, anterior palatal and posterior palatal aspects in each of the test denture bases. Each of these cut specimens of the impression wafers was weighed. Thus each of the 200 impression wafers (50 in each of the 4 groups) was sectioned into portions to represent the proportion of the relative misfit in the described aspects of the test denture bases.

STATISTICAL ANALYSIS

It was hypothesized that all the test processing methods are equally effective in producing denture bases with identical fit and adaptation. Statistical analyses of the data were carried out using SPSS Version 14.0 for Windows (SPSS, Inc., Chicago, IL, USA). One-way analyses of variance (ANOVA) and post hoc Tukey's test were performed. The probability levels of $p< 0.05$ were considered statistically significant. The inter-group variations in data when significant have been shown with connecting asterix (*) in the relevant figures (Figures 3-5).

Table 1. *Acrylic resin products and curing methods used. Each group had 10 test specimens.*

Group	*Curing Method*	*Product*	*Polymer: Monomer Ratio*	*Curing details*
1	Microwave	ACRON MC^{R}, (GC Corp, Tokyo Japan)	100g: 43ml	Cured for 3 minutes at a frequency of 2450 MHz in a 960W output domestic microwave oven (Model EM535T, Sanyo Co, Japan)
2	Quick-wet-heat	ACRON^{R}, (GC Corp, Tokyo Japan)	100g: 43 ml	Flasks immersed in water in an automatic water curing unit (Marathon, Dentronics, Tokyo, Japan). Water heated slowly to reach 100°C in 2 hours, then maintained at 100°C for 48 minutes and then cooled back to room temperature.
3	Slow-wet-heat	ACRON^{R}, (GC Corp, Tokyo Japan)	100g: 43ml	Flasks immersed in water in an automatic water curing unit (Marathon, Dentronics, Tokyo, Japan). Water heated to 70°C and maintained at this temperature for 9 hours and then cooled back to room temperature.
4	Self-curing	Repairsin^{R} (GC Corp, Tokyo Japan)	100g: 50ml	Flasks kept in a hydro-flask with controlled warm water at 45°C under a pressure of 40 Kg.Cm^{-2} for 20 minutes.

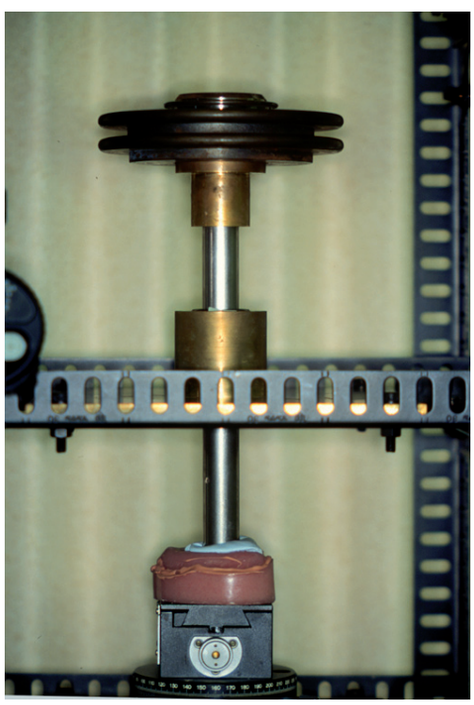

Figure 1. *Apparatus for applying controlled loading to the test-specimens during the recording of fit discrepancy for the test-denture bases.*

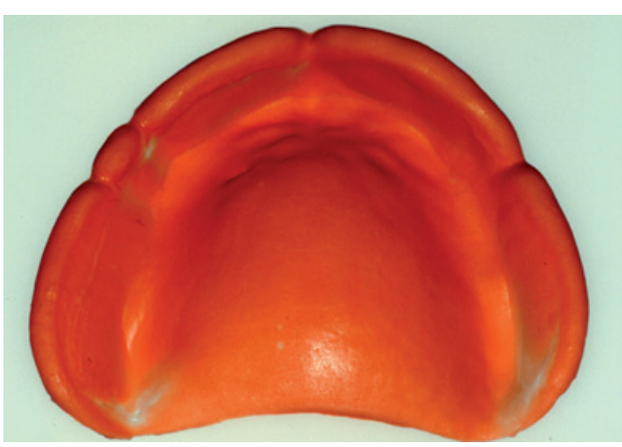

Figure 2. *An impression-wafer of the interface space representing the extent of the fit discrepancy of a test denture base.*

RESULTS

The data collected are presented in Table 2 - 3 and illustrated in Figures 3 - 5. These data and their graphic illustration not only clearly show variations both within and between groups but they also show that upon curing, the test denture bases suffered fit discrepancy irrespective of the processing method used. This was determined from the mass of impression-wafer of the space between the intaglio and tissue surface of the resin master cast and it ranged between 1.6 – 1.8 g (Figure 3). It can also be seen that the values for specimens cured by microwave energy were the highest while those for the bases processed by the quick-wet-heat-curing method were the lowest. Figure 3 shows that the variations from the mean values of fit discrepancy in the denture bases cured by the two water-curing methods and the self-curing methods were significantly lower than those of bases cured by micro-waving ($p<0.05$). Fit discrepancy values seen on the whole labial aspect (left & right) were significantly larger in the bases processed by micro-waving and self-curing. Values relating to the whole anterior palate were significantly larger in bases processed by the slow-wet-heat and self-curing methods. As shown in Figure 5, significantly larger proportional fit-discrepancy values in the posterior palatal segment were seen in denture bases processed by the micro-wave curing method as compared to the others in which the differences were insignificant ($p < 0.05$).

It appeared that none of the curing methods could facilitate the fabrication of denture bases with identical fit qualities. The reason for these could be the inherent compositional variations in the test resin systems as well as the dissimilarities of the test curing methods.

DISCUSSION

While the variety of laboratory techniques and available denture base materials are continually increasing, the challenge for clinicians of making a satisfactory and well-fitting denture base remains. Failure to do so will adversely affect the quality of life of patients and lead to complaints of looseness at the chair-side[18]. Needless time will be expended in modifying the completed denture and expense may be incurred in the provision of relines and other laboratory procedures that may be indicated. While

Table 2. *Extent of fit discrepancy as seen from the mass of impression wafer (g) in denture-bases and their various segments during curing methods. (n =10 specimens in each of the 4 groups) and n = 50 (10 x 5 fit discrepancy recordings).*

Segment	*Denture Base Group*			
	MC *Mean ± SD (%)*	*QWC* *Mean ± SD (%)*	*SWC* *Mean ± SD (%)*	*SC* *Mean ± SD (%)*
Over-all	1.811± 0.192	1.624 ± 0.148	1.729 + 0.194	1.730 ± 0.152
Over-all Labial & Buccal	0.832 ± 0.103 (45.9)	0.720 ± 0.072 (44.3)	0.779 ± 0.076 (45.1)	0.804 ± 0.103 (46.5)
Over-all Palatal	0.976 ± 0.117 (53.9)	0.900 ± 0.100 (55.4)	0.954 ± 0.126 (55.2)	0.921 ± 0.114 (53.2)
Over-all Labial	0.458 ± 0.077 (25.3)	0.397 ± 0.044 (24.4)	0.419 ± 0.058 (24.2)	0.438 ± 0.056 (25.3)
Over-all Buccal	0.374 ± 0.049 (20.7)	0.323 ± 0.043 (19.9)	0.360 ± 0.029 (20.8)	0.377 ± 0.060 (21.8)
Over-all Anterior Palatal	0.408 ± 0.070 (22.5)	0.431 ± 0.074 (26.5)	0.453 ± 0.086 (26.2)	0.443 ± 0.074 (25.6)
Over-all Posterior Palatal	0.564 ± 0.078 (31.8)	0.468 ± 0.055 (28.8)	0.501 ± 0.055 (29.0)	0.487 ± 0.080 (28.2)

MC = Microwave-cured. QWC = Quick-wet-heat-cured. SWC = Slow-wet-heat-cured. SC = Self-cured.
Figures in parentheses refer to proportions (%) of the over-all fit discrepancy in the relevant aspects of the denture bases.

Table 3. *Data for the mean mass (g) of the test denture bases and their analyses. (n = 10).*

Denture Base Group	*Mean ± SD*	*Group Comparison*	*F-Value*	*P - Value*
MC	13.694 ± 0.311	MC - QWC	0.979	0.01
QWC	14.673 ± 0.904	MC - SWC	- 1.007	0.008
SWC	14.701± 1.002	MC - SC	0.344	0.330
SC	13.339 ± 0.615	QWC - SWC	0.028	0.94
		QWC - SC	1.333	0.001
		SWC - SC	1.362	0.001

MC = Microwave-cured, QWC = Quick-wet-heat-cured, Slow-wet-heat-cured (SWC), Sc = Self-cured

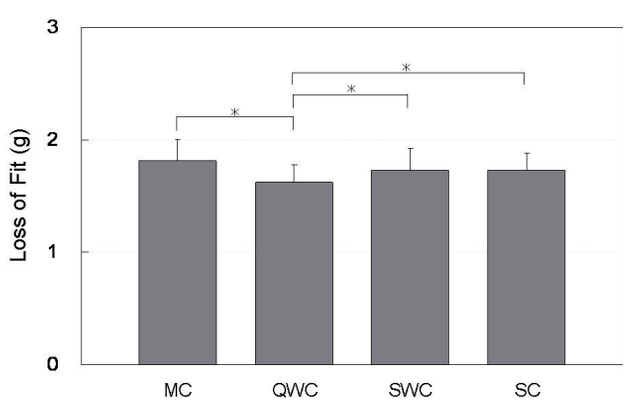

Figure 3. *Mean over-all fit discrepancy (g) in the test-denture-bases. (MC = microwave cured, QWC= Quick-wet-heat-cured, SWC = slow-wet-heat-cured, SC = Self-cured.)*

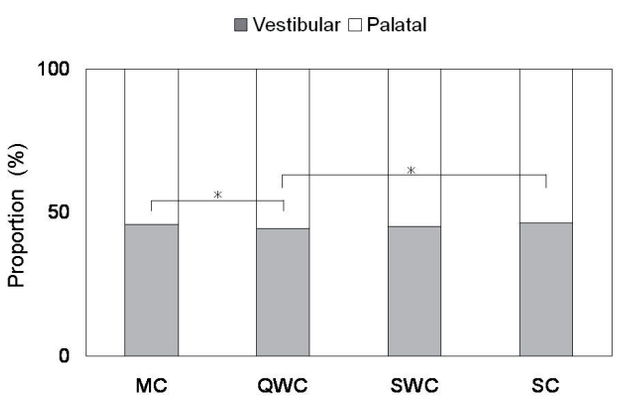

Figure 4. *Proportional Fit discrepancy in the vestibular and palatal aspects. (QWC= Quick-wet-heat-cured, SWC = slow-wet-heat-cured, SC = Self-cured.)*

the range of denture base materials is continually increasing, with claims from manufacturers that newer materials are "faster" (and hence more economical), the quality of care afforded to patients should never be compromised. Similarly the financial advantages obtained via 'false economies' encountered in the utilization of 'faster' materials may be short-lived in the long term. It is noteworthy that within this study not only did the microwave-cured bases exhibit the greatest overall fit discrepancy values, this technique was also associated with the greatest degree of poor fit in the posterior palatal region – a clinically significant area when attempting to optimize complete denture retention via the postdam area.

In this study, we used mass of a silicone wafer rather than length as a measure of fit discrepancy. We justify our method in that is relatively simple, straightforward and inexpensive to perform and has been used in other similar investigations[56]. A difficulty encountered in this study was that of producing test bases to standardized specifications. This was noted in the variation in the weight of the test denture bases in the four groups (range = 13.34 – 14.7g). The data and their analyses in Table 3 show that the mean mass of the silicone wafer recorded for the microwave and self-cured bases were significantly lower than the mean mass for the test bases produced by the other two methods. This variation in mass of test bases may have been

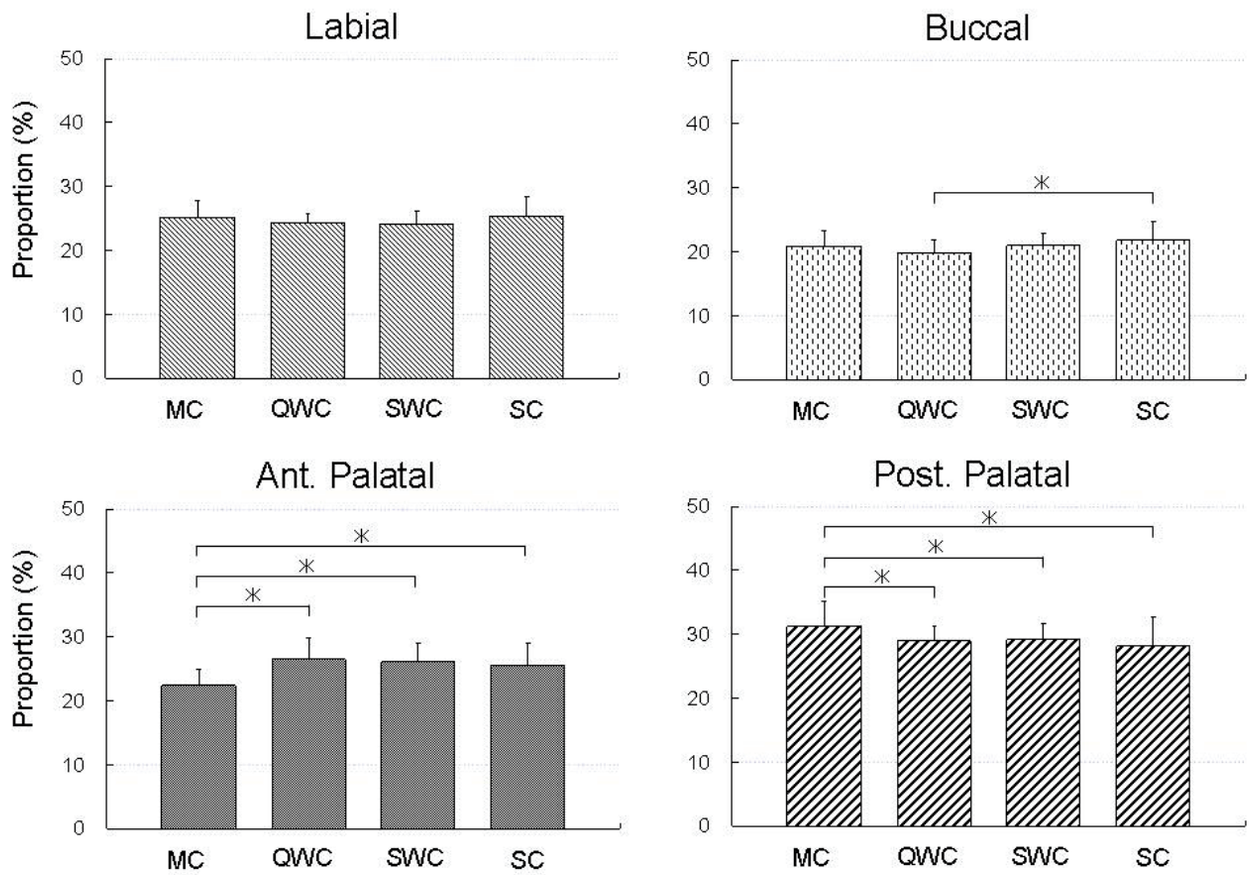

Figure 5. *Proportional fit discrepancy shown as the mass proportions of the labial, buccal and anterior and posterior palatal segments to the weight of the over-all impression wafer. (MC = microwave cured, QWC= Quick-wet-heat-cured, SWC = slow-wet-heat-cured, SC = Self-cured.)*

caused by difficulties encountered in the production of either the acrylic replica pattern or the subsequent denture base. These difficulties may have included that of pressing to the same dimension of the acrylic resin mix when packing the split mould in each flask or due to difficulty involved in finishing these patterns to the same precise specification each time. Other variations could have been encountered in the fabrication of the subsequent test denture bases, including the use different resin materials (with varied ingredients and densities) across the four test groups, variations in the powder: liquid mixing ratios, or by possible variations in the amounts of wax used when sealing the bases to the stone casts, or by the difficulty of repeatedly pressing and packing precisely the moulds in flasks with resin mix. However, the variations in denture base weight could also have occurred due to the early loss of unprocessed monomer or of the subsequent increased leakage/loss of the inevitable residual monomer in the microwave and self-cured test bases as compared to the bases cured by the other methods of wet-heat-curing (either quick or slow) (Table 3). Due to the nature of the materials involved, many of these confounding variables could be encountered irrespective of the level of sophistication of measuring technique used. At the very least, as our experiment was performed under controlled conditions, the results (i.e. masses of impression wafers produced) give a comparative indication of fit discrepancies occurring following the use of selected curing techniques.

Due to the range of methods and procedures available for recording cast-base adaptation discrepancy through an impression film, a variety of results have been reported in the literature: some being similar to these results, while others are not[7, 12, 23, 33, 41-42, 49, 53-55]. For example, Barco *et al.*[53] recorded lower values of fit loss in case of maxillary denture bases without teeth as compared to those with teeth. They also observed substantial improvement in the fit of both bases without and those with artificial teeth after relining them. In contrast, a similar study by Mainieri *et al.*[12] found that the mean weight of impression wafers was 2.69g – much greater than the 1.6-1.8g range noted in this study. While Mainieri's study indicates a large fit-discrepancy, this may be due to their choice of silicone material, which was different to material used in this study[12]. Mainieri's study continued to reline the test bases, after which a gap of 1.9 g weight remained[12]. This discrepancy is much closer to that being reported in this study; likely explanations for the range of value reported may include the use of a different impression material for recording of fit discrepancy, a dissimilar polymer: monomer ratio, quantity of resin and size, form, area and volume difference in denture bases, differing processing methods with reference to heating methods, timings and temperatures, and non consideration of subjecting the test specimens to the process of water-sorption. The mean mass values recorded by Takamata *et al.*[33] are similar to those recorded in the present study, despite the use of a dissimilar master cast and an uncontrolled method for recording the extent

of fit with the impression material. Further, the findings of that study should be interpreted with caution as the impression was confined mainly to the palatal part of the denture bases as they did not remove undercuts from the labial and buccal aspects of their test master cast.

Future work is indicated on patient satisfaction with alternative denture base materials, or those which have been produced using alternative techniques as considered in this study. While this data indicates that discrepancies are encountered with the fit of certain materials/techniques, further clinical studies could assess patient satisfaction and tolerance of dentures made in this way. In this way, the quality of clinical care offered to patients can be enhanced for the future.

CONCLUSIONS

Within the limitations of this study, it was found that the fit-discrepancy of microwaved cured bases was increased in comparison to other materials/ techniques considered. While these materials offer many advantages, including ease of fabrication and cost effectiveness, more research is indicated. Such work could include clinical-based studies to evaluate patient satisfaction and longevity of such-fabricated prostheses.

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