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Dimensional Stability of Complete Denture Permanent Acrylic Resin Denture Bases; A Comparison of Dimensions Before and After a Second Curing Cycle.

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Abstract - *The purpose of this study was to measure deformation of mandibular complete denture permanent bases after secondary curing. A cast of a flat mandibular edentulous ridge was duplicated ten times. A wax base was laid on the original cast, two wax sprues were attached and an overcast was made. The overcast was used to produce wax bases similar in outline and thickness on the duplicate casts. These were invested and following manufacturer's instructions ten similar acrylic resin bases were produced. The fitting surface of each denture base was scanned on a contacting scanner with an axis resolution of 1µm and accurate to 25µm. Denture teeth were waxed up on the base on the original master cast, an overcast was made to produce wax ups and tooth positions that were similar in outline and thickness to the original. These were processed, removed from the flasks and excess acrylic resin was removed. The denture bases were rescanned in an identical fashion to the first scanning procedure. Using commercially developed metrology software calibrated colour maps were generated for each denture base that illustrates measurements of differences between pairs of surfaces. Histograms showing distributions of distances between points were constructed. 50% of the points were separated by a mean 50µm or less and that 90% of the points were separated by 160µm or less. The maximum separation was of 380µm. Complete denture permanent bases were not found to distort significantly as a result of being subjected to a second heat curing cycle as part of final processing of dentures.*

KEY WORDS: Denture base, Processing, Deformation, Complete Denture

INTRODUCTION

About 10% of the UK adult population are edentulous [1] although levels of edentulousness are falling, there is no prospect in the foreseeable future of all patients retaining teeth through life; levels of edentulousness of around 6% are predicted for 2038 [1]. A similar situation is seen internationally [2]. Some edentulous patients are becoming more difficult to treat as they may lose their teeth later in life when adaptive capacity is reduced whereas others suffer from severe mandibular residual alveolar ridge resorption which compromises the success of lower dentures. While the McGill Consensus Statement [3] advocates implant supported mandibular complete dentures for all edentulous patients, the reality is that edentulous patients tend to be elderly and are disproportionately drawn from socio-economically deprived strata of society [1]. This means that those who are most prone to becoming edentulous are least able to be able to fund implant supported prostheses. This fact is reflected in the tiny proportion of edentulous patients who have been provided with implant supported complete dentures. Even in Sweden less than 8% of edentulous patients have any type of implant supported prosthesis [4].

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An accurately fitting complete denture base with effective border seal is essential for retention [5,6]. Accurate reproduction of the retruded jaw relationship is crucial to the stability of the mandibular denture base [7], predicts whether complete dentures are worn regularly and for eating [8] and predicts patient satisfaction [9]. Permanent acrylic resin denture bases have been advocated because they allow assessments of retention and stability of the bases at an early stage and facilitate the recording of the retruded jaw relationship as compared with wax, shellac or other temporary denture bases [10]. However, the second heat curing cycle, when denture teeth and pink acrylic are processed onto the permanent bases, has been shown to cause dimensional changes when processed at 100°C that might be of clinical significance [11]. In contrast, when the second process was carried out at 74°C shrinkage from the second cure was found to be so small as to be clinically insignificant. Yeung, Chow and Clark in 1995 measured linear shrinkage of denture bases for both first and second processing cycles using three recognizable reference points and found total linear shrinkage of the base to be less than 1% with 0.2% occurring as a result of the second processing cycle [12].

The possibility that reduced retention of maxillary dentures after second processing might be caused by base distortion was explored by Ellis, Read and Thomason in 2004 [13]. In this study clinicians and patients rated retention of maxillary complete dentures at trial insertion (before second processing with permanent base and teeth in wax) and at

insertion stage (after final processing) and no significant differences were found. However our clinical experience stood in marked contrast to the findings of Ellis, Read and Thomason. To explore the possibility of deformation of acrylic resin as a result of a second processing a small trial of concept was undertaken. Briefly, rectangles of dental wax 3mm thick were laid down on a flat glass slab, invested in a flask, boiled out and processed in heat polymerised clear acrylic resin. These were removed from the flask trimmed and it was found that they had not distorted. No bowing or apparent space was seen between the specimens and the slab. Subsequently, the specimens were secured to the glass slab and 3mm of wax was laid down on top of the acrylic samples. The glass slab with samples attached was invested in a flask, the wax was removed with boiling water and they were then processed in heat polymerised clear acrylic resin. These acrylic specimens were removed from the flask and trimmed. When the specimens were placed on the glass slab, they were found to have a slight but definite bowing of the original acrylic away from the flat glass slab. While this experiment was not directly compatible to the situation found with dual curing of acrylic resin denture bases, it did suggest that deformation of an acrylic resin permanent base as a result of a second heat curing cycle might be a possibility.

The aim of this study was to measure any deformation of a mandibular complete denture permanent base that might arise during or immediately after secondary curing, simulating the clinical scenario of dual cured complete denture bases. The null hypothesis was that denture bases do not deform significantly after secondary curing.

METHODS

To investigate the possibility of permanent base deformation as a result of dual heat curing, a cast of a flat mandibular edentulous ridge was chosen. This cast was chosen because the flat ridge offered a form which is the least resistant to deformation, in contrast to the biconcave palatal vault. As the intention was to measure deformation in three dimensions using a coordinate measuring machine, the flat mandibular cast offered a better possibility of demonstrating deformation as a result of dual processing compared to a maxillary cast as suggested by Ellis, Read and Thomason in 2004 [13] where retention was used as an indication for maxillary complete denture accuracy. As mandibular conventional complete dentures are rarely retentive the method described by Ellis, Read and Thomason in 2004 [13] would not be appropriate.

The cast was duplicated ten times using a polyvinyl siloxane duplicating material (Pourable Silicone. Chaperlin & Jacobs Ltd, Sutton, Surrey, U.K.) and Type III dental stone (Kaffir D, British Gypsum, Newark,U.K.). On the original cast a wax base of 1.5mm was laid down and two wax sprues were attached. This was then covered with a polyvinyl siloxane overcast. When set it was transferred to the ten duplicates in turn and molten wax was poured through the sprues and allowed to cool. This produced wax bases that were broadly similar in outline and thickness. These were invested in ten flasks in a similar manner using dental stone. After the stone set, the wax was removed with boiling water, a separating medium applied (cold mould seal) and the moulds were allowed to dry and cool. A single batch of heat curing clear acrylic resin (Selectaplus H/Trevalon Universal Clear. Dentsply International Inc, Milford U.K.) was mixed according to the manufacturers' instructions and at the appropriate stage was placed in all of the flasks. These were all closed at the same time, placed in hydraulic presses and the closing pressure was gradually increased to 3000kPa; when no further excess material was extruded the pressure was released and the flasks were placed in spring loaded processing clamps and tightened to 36Nm torque in order to maintain pressure. The bases were processed overnight in a controlled water bath – (Derotor Multicure, Quale Dental, Worthing UK.) using a cycle of 6 hours at 70˚C with a terminal boil of 2 hours. The permanent bases were allowed to cool completely after processing over two days as recommended by Moturi *et al.* 2005 [14]. They were carefully removed from the flask, excess acrylic resin and any beads resulting from air bubbles below the surface of casts removed. The fitting surfaces were not trimmed or polished in any other way. The bases were stored in water (20°C +/- 3°C) when not being manipulated. This process represents the first curing cycle for the purposes of the experiment.

The fitting surface of each denture base was scanned on a Cyclone® contacting scanner (Renishaw plc, New Mills, Wotton-under-Edge, Gloucestershire, GL12 8JR, United Kingdom) using Tracecut 24a (Renishaw plc, New Mills, Wotton-under-Edge, Gloucestershire, GL12 8JR, United Kingdom) to control the scanning settings. The scans were made on the X axis with a 1 mm diameter ball stylus using a step over distance of 50µm. This scanner has an axis resolution of 1µm and was accurate down to 25µm at the time of measurement The finished scans consisted of a 'point cloud' which represents surface topography.

After the bases were scanned, teeth were waxed up on the base on the original master cast, two wax sprues were attached and a polyvinyl siloxane overcast was made over the teeth and waxwork. This served to transfer the teeth arrangement from the original master cast to the ten baseplates by positioning teeth from the same mould as the original in the silicone overcast and pouring molten wax onto the void. This produced wax ups and tooth positions that were broadly similar in outline and thickness to the original master cast. These were invested in ten flasks in a similar manner using dental stone, the wax removed with boiling water, separated and packed using a single batch of heat curing pink acrylic resin (Selectaplus H Pink Veined, Dentsply International Inc, Milford U.K.) mixed according to manufacturer's instructions; this was repeated for every flask. These were closed in a similar fashion as described previously and then placed in spring loaded processing clamps, as done previously. The bases were processed overnight in a cycle of 6 hours at 70˚C with a terminal boil of 2 hours.

The dentures were allowed to cool completely over two days after processing. They were carefully removed from the flask and excess cured acrylic resin was removed. The fitting surfaces were not trimmed or polished in any way. Dentures were stored in water when not being manipulated. This processing of denture teeth and associated pink acrylic resin onto the permanent bases represents the second curing cycle for the purposes of the experiment as the permanent bases were exposed to the processing cycle a second time.

The numbered dentures were relocated on the measuring machine and the fitting surface of each denture was rescanned in an identical fashion to the first scanning procedure. This allowed for comparisons of the fitting surface of each base using commercially developed surface metrology software.

The scans from each denture base before and after secondary curing were registered using UCL Surfaceview. The registration procedure works by searching for areas of conflict and coincidence between the two scans by minimizing distances between each point in each scan using the root mean square principle. This allows comparison of two surfaces which may be slightly dissimilar and identification of the differences between them. A calibrated colour map was generated which illustrates and allows measurements of differences between pairs of surfaces as a function of histograms showing distributions of distances between points.

RESULTS

Distribution of mean difference for the bases as a whole is shown in Figure 1. Distribution of mean difference for each of the bases is shown in Figure 2. The data from Tables 1 and 2 show differences between points on the Y axis and percentages of the regions of interest on the X axis. The ten maps of difference, colour coded for degrees of difference are shown in Figure 1. The scale on these calibrated colour maps is in millimetres.

The data from the Figure shows that at least 50% of the points were separated by a mean 50µm or less and that 90% of the points were separated by 160µm or less. The maximum separation was of 380µm. The images showing maps of differences show that the largest separation of points tended to occur at the periphery of the denture bases. The differences detected for every pair were very similar, i.e. located within the same area for each denture base.

DISCUSSION

The results from this study showed that there were no clinically significant dimensional changes in any of the denture bases. This does not agree with the findings from the initial small experiment. It is possible that the three dimensional nature of the denture bases compared to the flatness of the specimens from the experiment contributed and prevented any major deformation.

The main reason for undertaking this study was to investigate alterations in three dimensions of denture base shape arising from second processing. The similarity in shape of each of the bases after the first curing cycle (base production) to the same bases incorporated in the finished dentures was striking, with over half of the points being within 50µm and 90% being within 160µm. The pattern of distribution of the mean difference between the ten bases is strikingly similar. The areas of good and poor fit are very similarly located for all base/denture map pairs. Furthermore the most inaccurate areas are at the borders where trimming of excess cured acrylic resin or invasion of the marginal base area with small amounts of pink acrylic probably accounts for inaccuracy. It is also possible that measurements made at the edges were affected by using a contacting scanner, it has been documented that these

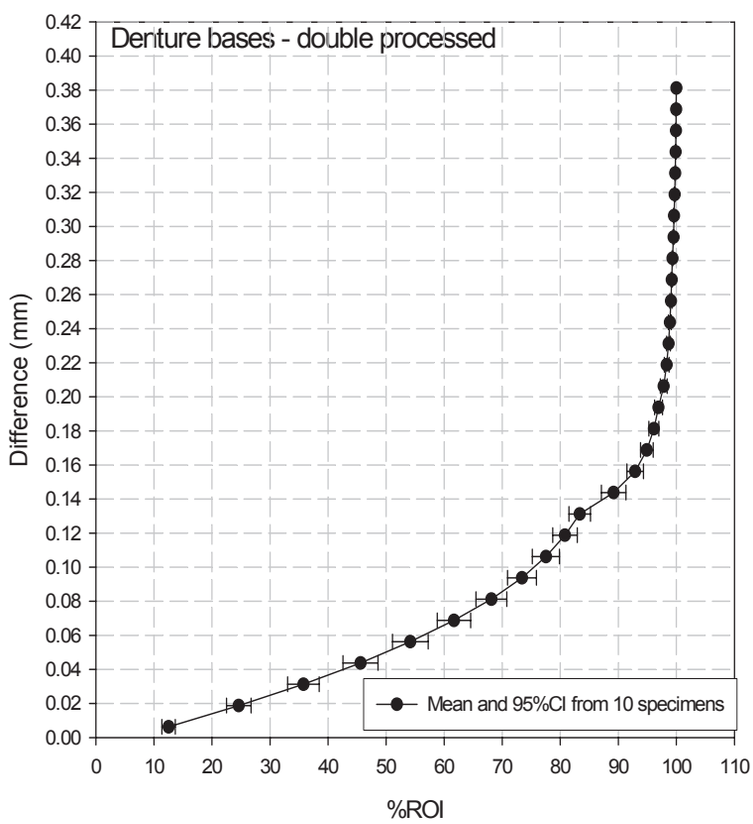

Figure 1. *Distribution of mean difference for all of the bases (ROI:- Region of Interest).*

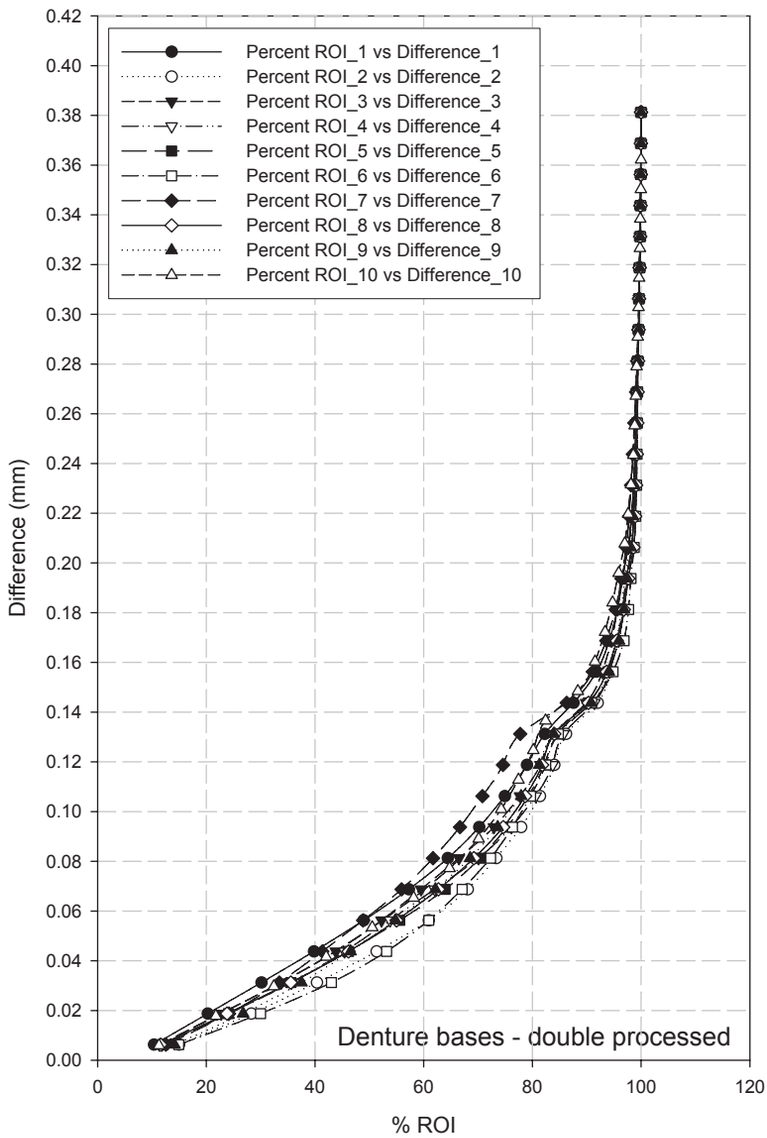

Figure 2. *Distribution of mean difference for each of the bases (ROI:- Region of Interest).*

type of scanners reduce accuracy and precision of measurements as the angle of measurement approaches 60^{O} [14] which would be the case at the edges of the denture bases. These scanners are known to suffer from step over error. This occurs as a result of the way these machines work; height is measured at 50µm centres yielding a cloud of points which is converted into a shape; when the base is rescanned the process is repeated and the two shapes are fitted together to yield a best fit with subtractive analysis to determine mean difference; this process is potentially highly accurate for flat surfaces but where edges occur unless the measuring points are coincident the probe may step over the edge while still being within 50mm of the previous scan producing a very different height. As contact scanners cannot reach undercut areas, any change in angulation of the base between scans would result in different edges being recognised at borders. Examination of Figure 3 shows that all the major errors represented by black areas are to be found at the borders. It is impossible to be sure whether these represent trimming errors, flash overlap of bases, low angle of measurement error, angulation error or step over error. This is also the reason why the error levels for 90% of points are quoted as the remaining 10% will contain these errors. However as none of the bases were smoothed, pumiced or polished it is probable that the amount of change in dimension that happened to the bases in this study was less than might be expected in the clinical situation. Any deformation relating to dual processing would be unaffected.

The closeness of fit of the point clouds from the distances between points' scans is surprisingly good. Probably error of less than 500µm is of no clinical significance in the extension of a denture base. Substantial deformation of permanent bases during final processing of complete dentures seems to be ruled out by the findings of this study. The results of this study support the outcomes of previous research [12, 13].

The clinical impression that retention of permanent bases may be lost in final processing could be explained by other causes. These include loss of height or width of peripheral form due to excessive trimming or excessive polishing

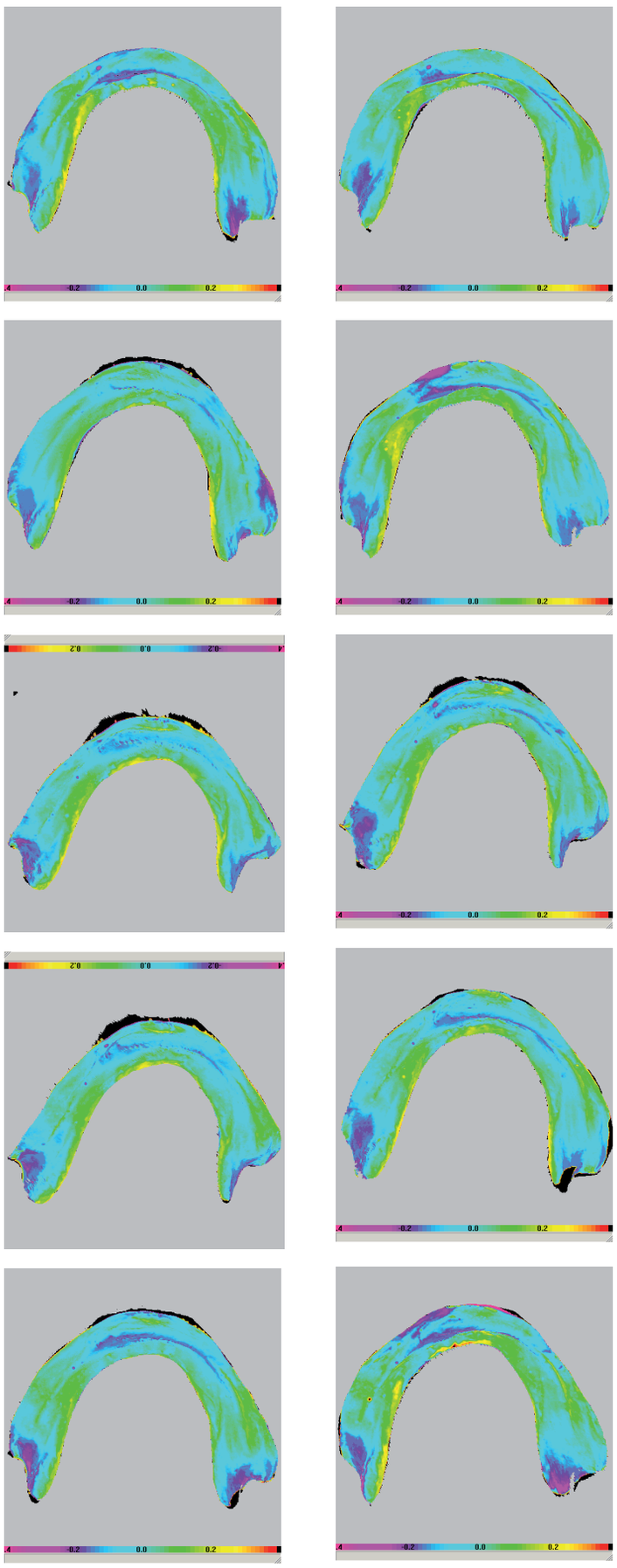

Figure 3. *Maps of difference for second processing for each of the ten dentures, colour coded for degrees of difference in mm (darker colours denote larger separation between points).*

when the final dentures are finished or poor handling or storage. In addition there is convincing evidence that factors other than whether denture bases are subjected to single or double curing techniques, with poor impression technique being a greater concern [16].

In this experiment every effort was made to perform technical procedures in a similar manner for all the specimens to minimize variation between them. The mandibular denture base for a flat mandibular residual alveolar ridge was chosen, as it would be the most deformation prone. For these reasons the level of accuracy achieved is considered to be significant.

CONCLUSIONS

Permanent bases were not found to distort significantly as a result of being subjected to a second heat curing cycle as part of final processing of complete dentures. The results from this study support previously reported findings.

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