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Dimensional Change of Heat-Cured Acrylic Resin Dentures with Three Different Cooling Regimes Following a Standard Curing Cycle

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Abstract - The aim of the study was to compare dimensional changes in poly(methylmethacrylate) complete denture bases resulting from three different cooling regimens following a standard heating cycle. Changes in three separate dimensions were measured on ten dentures within each cooling regimen after curing, and before and after removing the denture from the cast using a computer imaging system. No consistent differences occurred as a result of removing the denture from the cast. The results indicated that there was greater change in dimension of dentures with the quenching cooling method than with either overnight cooling in the water bath or bench cooling. This was particularly evident after removal from the cast after curing ($p<0.001$). It is concluded that slow cooling results in less dimensional change.

Key words: Poly(methylmethacrylate), Denture construction, Denture Technology

INTRODUCTION

The need for dimensional accuracy and stability is *sine qua non* for materials used in restorative dentistry. Close mucosal contact between the denture base and the mucosa is an important factor in retention of the complete denture base[1]. However, dimensional changes due to polymerisation shrinkage are inevitable in heat processed poly(methylmethacrylate) denture base materials[2]. To some extent these changes may be compensated for by water sorption. In addition to polymerisation shrinkage there is also thermal shrinkage as the processed denture cools in the flask. The complex shape of a complete denture does not allow it to shrink equally in all directions and due to the resistance of the gypsum investing material, stresses are set up in the denture. These stresses may be released once the denture has been deflasked and removed from the cast on which it was processed[3]. The extent of distortion due to these stresses will depend on a number of factors such as the shape and size of the denture, the type of separating medium used, the rate of heat application, the temperature at which polymerisation was achieved, the rate of cooling and the treatment the denture received during finishing and polishing[4].

Previous studies have investigated the effects of long and short curing cycles and generally longer cycles have produced the most dimensionally stable dentures[5]. However, comparatively little work has been done on the effect of different cooling regimes on the dimensional accuracy of heat cured poly(methylmethacrylate) dentures. Chen *et al.*[6], showed an increase in the molar-to-molar dimensional change of acrylic resin dentures when cooled rapidly by quenching. To reduce internal stress and the dimensional changes in dentures, it has been recommended that the flask should be cooled slowly by bench or overnight cooling in the water bath[7].

Wong *et al.*[8], as part of an investigation of the degree of water saturation of dentures processed by wet or dry heat, measured the dimensional change in three groups of dentures. The first group were processed in an air oven and allowed to cool in the oven; the second group were processed in a water bath and allowed to cool in the water bath and the third group were processed in a water bath and allowed to cool in air. The dry heat cured samples shrank less than the wet heat cured samples that had been allowed to cool in the water bath and the air cooled samples showed most shrinkage.

Manufacturers generally suggest short curing cycles and rarely suggest cooling regimes. The purpose of this study was to compare dimensional change following three different cooling regimes following a standard curing cycle.

MATERIALS AND METHODS

Three experiments were carried out in which the same processing technique, but different cooling methods were used. Linear dimensional changes, of three groups of ten maxillary dentures each, were determined before and after removing the denture from the cast. The first group were cooled by quenching, the second group were cooled in the water bath and the third group were cooled in air on the bench.

Standardised wax denture patterns were made according to the method used by Wong *et al.*[8] and Keenan *et al.*[9]. Thirty casts were made from a standardized silicone mould with yellow stone mixed with the ratio of 100g powder per 30ml water. A sheet of modelling wax was

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adapted to the palate extending 1cm below the crest of the ridge and the sulcus border was filled with wax. Another sheet of wax was adapted over the whole of the cast. Maxillary acrylic resin teeth were set up over the wax baseplate in flat plane occlusion. Two wax sprues were attached in the tuberosity regions. The wax surface was contoured and smoothened. The waxed-up denture on the cast was fixed to a flat acrylic plate with wax and boxed with a wax sheet. A silicone mould was prepared according to the manufacturer's instructions and a negative impression of the waxed-up denture was made. After one hour, the waxed up denture was removed and a silicone mould was obtained.

Acrylic teeth were placed in the silicone mould and the stone cast repositioned. Molten wax was poured in the sprue hole and the waxed-up denture was duplicated. Fine crosses were marked with No 15 sharp scalpel blade on the palatal surface of the upper left central incisor and the palatal facing surface of the mesiobuccal cusp of the second molar teeth. The crosses were designated as A on incisors, B and C on left and right molars.

The dimensions AB, BC, CA were measured with a Global Lab Image Computer System. The waxed-up cast was placed on an adjustable table, which was altered to the horizontal using a spirit level. An optical calibration slide was positioned on occlusal surface and the Global Lab Image system was calibrated. Calibration was re-confirmed for each denture. The measurements AB, BC and CA were measured five times.

The casts with the wax pattern were invested with Kaffir D dental stone in brass flasks. The flasks were placed in a boiling water tank for 12 minutes to soften the wax prior to opening, de-waxing and washing with detergent to remove all traces of wax. The flasks were allowed to cool and two coats of cold-mould seal (sodium alginate solution) were applied to the surface of the moulds.

Heat cured clear acrylic resin was mixed, in a ratio of 24g of polymer powder to 10ml of universal monomer liquid, with a stainless steel spatula in a dry bowl and left covered for fifteen minutes at room temperature. After the dough stage was reached, the material was packed into the mould. The closed flasks were kept in a hydraulic press at pressure 100 Kp/cm^2 for five minutes. The flasks were then transferred to a spring clamp. A 36Nm torque was applied to the spring clamp by a torque bar in order to maintain a pressure equivalent to the hydraulic press[10].

The flasks were placed in a water bath for curing for five hours. The standardised curing cycle was 30 minutes from room temperature to 72°C for 5 hours. After curing, the flasks were allowed to cool by one of three methods. The first ten dentures were cooled by quenching in running cold tap water at 20°C and kept under room temperature running water for twelve hours. The next ten dentures were cooled in the water bath for sixty hours. And the last ten dentures were bench cooled for twelve hours at room temperature, 18^{0}C. After cooling, the dentures and the casts that they were processed on were devested by carefully sectioning the plaster around the cast with a saw. At this stage the dentures were not removed from the cast. The dimensions AB, BC, CA on the denture on the processing cast were measured using the Global Lab Image computer system. The cast was then removed from the denture and the dimensions re-measured.

Statistical analysis

The data were analysed using STATA 7 (Stata Co, TX 77845, USA). All variables exhibited a Normal distribution. Initially, analysis of variance (ANOVA) was used to test if there were statistically significant differences in the three dimensions (AB, BC, CA) before curing. In the event, because differences were observed at baseline, ANOVA was performed on proportional changes in dimension from baseline to before and after removal of the cast after curing. Subsequent post-ANOVA contrasts between cooling methods were performed using the Scheffe test. Statistical significance was inferred where *p* levels were less than 0.05.

RESULTS

Tables 1, 2 and *3* show the mean and the standard deviation of measurements AB (left first incisor to left 2nd molar), BC (left 2nd molar to right 2nd molar) and CA (right 2nd molar to left first incisor) before curing, and before and after removing the denture from the cast after curing for each of the three cooling methods.

There was an apparent increase in dimensions from before curing to after curing, before and after removing the denture from the cast with the quenching cooling method. In contrast, there was a slight decrease in dimensions with the overnight cooling and bench cooling methods. These changes were not statistically significant, possibly due to the small numbers of dentures used in this study. However, statistically significant differences were observed between cooling methods for the changes in dimension between baseline and after curing (*Tables 4–6*). In particular, the changes from baseline dimensions to those after removal from the cast were significant at $p<0.001$. Undoubtedly, the contrast in an apparent increase and decrease in dimensions of different cooling methods contributed to these findings.

The results suggest that there is less dimensional change with the two slow cooling methods, than with the rapid cooling quenching method.

DISCUSSION

Dimensional changes of heat-cured acrylic dentures could be due to processing shrinkage, expansion due to water sorption, distortion from induced strain, which may be affected by the cooling methods used after processing. Although this study used the Global Lab Image computer system, rather than a travelling microscope, the same three points that have been previously reported were used[6,8,11]. The distances between these points measured in the same plane are used to represent dimensional change. However, because dentures are such complex shapes these measurements only give an indication that dimensional change is taking place. No conclusions can be safely drawn in relation to the actual shape of the denture following the dimensional change.

In this present study the dimensional changes occurring

Table 1. *Mean (standard deviation) of measurement AB (mm) by cooling method and stage*

Stage	*Cooling method* *Quenching*	*Overnight*	*Bench*
Before curing	43.5(2.4)	47.2(2.2)	47.9(2.0)
After curing (with cast)	46.1(2.8)	44.6(1.5)	47.4(0.9)
After curing (removed from cast)	47.3(2.4)	43.3(1.4)	45.7(1.0)

Table 2. *Mean (standard deviation) of measurement BC (mm) by cooling method and stage*

Stage	*Cooling method* *Quenching*	*Overnight*	*Bench*
Before curing	39.9(0.3)	42.0(2.0)	42.0(1.5)
After curing (with cast)	41.4(1.4)	40.7(1.2)	41.4(1.2)
After curing (removed from cast)	42.5(1.2)	39.9(1.2)	40.8(1.5)

Table 3. *Mean (standard deviation) of measurement CA (mm) by cooling method and stage*

Stage	*Cooling method* *Quenching*	*Overnight*	*Bench*
Before curing	51.5(0.8)	54.6(1.7)	54.9(1.3)
After curing (with cast)	53.7(2.7)	50.5(4.4)	53.9(1.1)
After curing (removed from cast)	56.3(2.4)	52.0(1.4)	53.0(1.3)

Table 4. *Statistical significance (p values) for post-ANOVA contrasts of change in measurement AB comparing cooling methods at each post-curing stage*

Stage	*Cooling method* *Quenching vs Overnight*	*Quenching vs Bench*	*Overnight vs Bench*
After curing (with cast)	0.003	0.136	0.260
After curing (removed from cast)	<0.001	0.001	0.277

Table 5. *Statistical significance (p values) for post-ANOVA contrasts of change in measurement BC comparing cooling methods at each post-curing stage*

Stage	*Cooling method* *Quenching vs Overnight*	*Quenching vs Bench*	*Overnight vs Bench*
After curing (with cast)	<0.001	0.001	0.451
After curing (removed from cast)	<0.001	<0.001	0.249

Table 6. *Statistical significance (p values) for post-ANOVA contrasts of change in measurement CA comparing cooling methods at each post-curing stage*

Stage	*Cooling method* *Quenching vs Overnight*	*Quenching vs Bench*	*Overnight vs Bench*
After curing (with cast)	0.003	0.276	0.109
After curing (removed from cast)	<0.001	<0.001	0.635

during processing were assessed before and after removing the denture from the cast. No statistically significant differences in the dimensions of the dentures before and after removal from the cast were found. This implies the acceptability of the results of previous studies that have either compared measurements before removal of the dentures from the processing casts or have not stated whether the post processing measurements were made before or after the dentures had been removed from their casts[8,9].

Statistically significant differences in all measurements were found between the quenching and the slow cooling in the water bath methods, with quenching resulting in more dimensional change. Similarly, there was a statistically significant difference between the quenching method and the bench cooling method. However no statistically significant difference was found between the bench cooling method and the slow cooling in the water bath method.

The differential in thermal contraction between the mould and the acrylic resin during cooling is believed to be the cause of the residual stress in the processed denture and is also considered to be the main contributor to the stress release that occurs when the denture is separated from the cast. The rate of cooling of the flask after processing has a definite effect on the dimensional changes of dentures. With the quenching cooling method a sudden change in the temperature of the denture causes unequal thermal contraction in various areas and thus induces a greater amount of stress that results in greater warpage. Slow cooling in a water bath can be expected to result in more uniform cooling of the denture, resulting in less stress build up and less dimensional change. The bench cooling method might also be expected to allow slow cooling without excessive stress build up, but may be susceptible to local drafts and minor temperature difference in the local laboratory environment. The absence of a statistically significant difference between cooling overnight in the water bath and bench cooling can be explained by the probability that there really is very little difference between the two methods and as a result many more samples would be required to identify any statistically significant difference.

The clinical implications of dimensional change in the denture base during processing may vary from case to case depending on clinical variables such as the shape of the edentulous ridges, the displaceability of the denture bearing mucosa, the effect of the impression on the displacement of the mucosa, the ability of the mucosa to adapt to the resultant denture base and the viscosity of the saliva. However, the benefits of dimensional accuracy are self evident. Close mucosal contact is thought to be important in denture retention[1] because flow of saliva into the space between the denture and the mucosa is resisted in inverse proportion to the thickness of the saliva film.

This study has shown that slow cooling, either in the water bath or on the bench results in less dimensional change than quenching. This clearly has implications for laboratory practice. Processing cycles, which allow slow cooling, are preferable and technical laboratories protocols to allow for this should be developed. Very few commercially available heat cured acrylic resins give instructions regarding cooling after processing. The processing instructions of modern heat cured acrylic resins generally advocate heating for approximately four hours, which is less than has been advocated previously and is based on the manufacturer's knowledge of their product. With such a short heating cycle, overnight cooling should be feasible. A protocol, which allowed an extra day, would also have an advantage[10]. Processing on Friday night, which would probably result in cooling over the weekend with deflasking on Monday morning, might be considered ideal.

Cooling by quenching in cold water should be deprecated as it has been shown to result in greater dimensional change. In this present study cooling by quenching was achieved by plunging the hot flask straight into a sink full of cold tap water at 20°C. To achieve quicker cooling the flask was left in the sink with the tap running so that the heat was carried away by the water and the dentures were not deflasked until the next day. However in a busy laboratory, using the quenching method, it might be expected that the denture would be devested at the first possible opportunity, possibly before the flask was completely cold and with little care being taken to remove the investment with minimal levering on the denture base. This might be the source of further dimensional change.

CONCLUSIONS

1. There was no difference in linear dimensions before and after devesting the cast with quenching, overnight cooling and bench cooling.
2. There was a difference in linear dimensions between those dentures quenched in water to those dentures overnight cooled and bench cooled.

Thus it confirms that overnight cooling and bench cooling methods are the preferred methods for cooling heat-cured poly(methylmethacrylate) dentures if the highest accuracy is to be obtained.

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MANUFACTURER'S DETAILS

- Kaffir D, East London Builders Merchants, UK
- Compounding Ingredients Limited,Lancashire, UK
- Swann Morten Limited, Sheffield, UK
- Data Translation Limited, Basingstoke, UK
- Tracor Northern, Middleton, USA
- Teledyne Hanau, Buffalo, New York, USA
- Dentsply, International, UK
- Bego, Bremen, Germany
- Quayle Dental Manufacturing Company Limited, UK
- Strata Corp. Texas, USA

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