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Effect of Curing Cycles on the Mechanical Properties of Heat Cured Acrylic Resins

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Abstract - *Traditionally long curing cycles have been recommended for heat cured acrylic resin denture base materials. Recently manufacturers have produced materials for which they recommend short curing cycles. Specimens conforming to British Standards Specification were made using three different brands of heat cured acrylic resin denture base material. Each material was processed in three batches using either the manufacturer's recommended short curing cycle, an arbitrary medium curing cycle or a traditional long cycle. Specimens were subjected to a three point bending test. With one exception using the arbitrary medium curing cycle, all specimens achieved the British Standard suggesting that the manufacturers' recommended cycles should be followed.*

KEY WORDS: Acrylic resin, transverse strength, curing cycle

INTRODUCTION

Time and temperature are important variables in curing heat cured denture base acrylic resin. Longer cycles, lasting more than six hours either with or without a terminal boil have been shown to result in a polymer with lower residual monomer[1,2,3] and improved flexural strength[4,5]. However, many manufacturers have recently marketed materials with much shorter recommended curing cycles. Jerolimov et al[6] suggested that more rapid curing cycles would require the materials to be manufactured with appropriate initiator content and particle size.

A further problem traditionally encountered with more rapid curing cycles has been porosity. Yau et al[7] measured the temperature and pressure changes during processing heat cured acrylic resin. They showed that provided the clamp pressure exceeded the pressure developed by the bench press used to close the flasks, the pressure in the acrylic resin dough rose to 22 atm during the initial heating period up to 72°C. At this pressure (22atm) the boiling point of monomer would be 228°C, which is well above the maximum temperature reached by the dough, thereby preventing porosity. Once the temperature stopped rising the pressure gradually fell to slightly above atmospheric pressure in approximately four hours. Clark et al[8] observed that when the internal temperature reached 72°C the dough was still rubbery. However, one hour later it had gone hard suggesting it had polymerised. They correlated these observations with those of Yau et al[7] and hypothesised that as the temperature rose to 72°C thermal expansion caused the pressure in the dough to rise. The rate of polymerisation would increase when the temperature rose above 60°C and the initiator, probably benzoyl peroxide or similar compound begins to dissociate. Once the temperature stops rising, polymerisation contraction would replace thermal expansion and the pressure would drop. They suggested that when the pressure had reached its minimum, polymerisation contraction had also reached its minimum and polymerisation was for practical purposes complete. On this basis they suggested that manufacturers' processing instructions for shorter cycles could safely be followed.

The purpose of this study was therefore to investigate the effect of three different curing cycles on the transverse strength of three currently available brands of heat cured acrylic resin denture base materials.

MATERIALS AND METHODS

Three brands of heat-cured acrylic resins were selected for investigation based on their commercial popularity and widespread use and availability: Trevalon C (LOT: 03GP02, 2008-07), Meadway Supercure (LOT: 01325, 2006-11) and Paladon 65 (LOT: 014686, 2007-05). British Standards specifications (BS EN ISO 1567: 2001) on specimen dimensions for transverse strength determination were followed. The resultant specimens were 64 mm long, 10 ± 0.2 mm in width and 3.3 ± 0.2 mm in height. The specimens were manufactured using standardised aluminium patterns machined to the dimensions specified in the British Standard (BS EN ISO 1567:2001). The specimens, which were processed in conventional denture flasks, underwent conventional wet curing in three batches (Table 1).

The specimens were carefully finished to the British Standards specifications (BS EN ISO 1567: 2001) using the EXTEC Labpol 8-12 polishing machine and standard metallographic grinding papers of grain sizes 30µm (500 FEPA) and 14µm (1200 FEPA) under light finger pressure. A micrometer accurate to 0.01 mm and fitted with parallel anvils was used to ensure that each specimen was finished to the specified dimensions. Finished specimens were then stored in water for one month to ensure full saturation.

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A three-point bend test rig was selected in accordance with the British Standard guidelines (BS EN ISO 1567: 2001). An Instron 1193 calibrated to provide for a constant crosshead speed of 5 (±) 1 mm/min was used to perform the tests. Each specimen was laid flat symmetrically on the supports of the test rig which were 50mm apart. The force of the loading plunger, which was centrally placed between the supports, was increased from zero, uniformly using a crosshead speed of 5 (±) 1 mm/min until the specimens fractured.

The flexural strength σ was calculated in MPa using the formula $\sigma = 3Fl/2bh^2$ where F = maximum load in Newtons, l = Distance in millimetres between the supports, accurate to ± 0.1 mm, b = Width of the specimen measured in millimetres, h = Height of the specimen measured in millimetres.

STATISTICAL ANALYSIS

As the data conformed to a Normal distribution two-way analysis of variance (ANOVA) was used to assess the effect of different cycles and materials. There was considerable difference in the response to cycles between materials (interaction in the ANOVA model), and subsequent analysis was performed within each material separately. The Scheffe test was used to investigate post-ANOVA paired comparisons.

RESULTS

The highest transverse strengths (Table 2) were achieved by the long and short curing cycles of Paladon 65 (116.5 MPa and 115.5 MPa respectively). With the exception of Trevalon C using the arbitrary medium cycle, all materials, whether cured by the short medium or long curing cycles, produced a transverse strength of over 65 MPa. In the case of Trevalon C the long curing cycle produced a transverse strength of 107.6MPa which was not statistically significantly different ($p>0.003$) from the transverse strength (94.8MPa) achieved by the short curing cycle. Both Trevalon C and Paladon 65 showed significant difference in transverse strength between the medium cycle (cycle 2) and both the manufacturer's recommended short curing cycles (cycle 1) and the long curing cycle (cycle 3). Meadway Supercure showed no difference between cycles.

Table 1. *Materials and processing cycles*

Materials	*Manufacturer*	*Manufacturers' recommended short curing cycle*	*Medium curing cycle*	*Long curing cycle*
		Cycle 1	*Cycle 2*	*Cycle 3*
Trevalon C Group 1	Dentsply Ltd, Weybridge, UK.	Place flask in cold water (23°C), slowly raise to boiling point 100°C (within 30 minutes) continue boiling for a further 30 minutes, allow to cool slowly in water.	4 hours at 70°C in an automatically controlled water bath.	7 hours at 70°C with a terminal boil of 1 hour.
Meadway Supercure Group 2	Bracon Ltd, Etchingham, UK.	Immerse the flask in boiling water and turn off the heat for 20 minutes. Then re-heat to boiling temperature and boil for 20 minutes.	4 hours at 70°C in an automatically controlled water bath.	7 hours at 70°C with a terminal boil of 1 hour.
Paladon 65 Group 3	Heraeus Kulzer GmbH & Co. Gruner Weg, Germany.	Immerse flask in boiling water for 10 minutes then let it cool down slowly ensuring that the temperature is above 175°F (80°C), for at least 15 minutes.	4 hours at 70°C in an automatically controlled water bath.	7 hours at 70°C with a terminal boil of 1 hour.

Table 2. *Mean (standard deviation) transverse strength (Mpa) by cycle within each material.*

	Cycle		
Material	*Short*	*Medium*	*Long*
Trevalon C	94.8 [a] (12.8)	60.4 [ab] (5.6)	107.6 [b] (17.1)
Meadway supercure	106.5 (23.1)	80.4 (17.1)	78.6 (16.3)
Paladon 65	115.5 [c] (10.7)	81.9 [cd] (17.0)	116.5 [d] (10.0)

Letters[abcd] indicate statistical significance ($p<0.003$ between means with each method)

DISCUSSION

In this study three different curing cycles were chosen, the manufacturer's recommended short curing cycle, an arbitrarily designed medium cycle and a traditional long curing cycle. The British Standard (BS EN ISO 1567:2001) states that if results for four out of five specimens are greater than 65 MPa then the material is deemed to have complied with the standard. In this study all materials, showed average transverse strength values greater than 65 MPa, with the exception of Trevalon C processed with the medium cycle. In the arbitrarily designed medium cycle the temperature of the water bath was only raised to 72°C. This is an artificially low temperature for a short cure and quite obviously the formulation of the material requires a higher temperature to achieve polymerisation. As this cycle was devised solely for this investigation, and was clearly unsuitable for the material, no importance should be attached to the result.

The manufacturer's recommended short cycles and the traditional long cycle all produced specimens with transverse strengths, which met the British Standard. The suggestion of Clark et al[8], that polymerisation can for practical purposes be considered to be complete after a short curing cycle, is supported by these results. Although there were statistically significant differences in transverse strength following different cycles, with the exception of Trevlon C with the medium cycle none of the protocols provided results that were potentially poor clinically. Generally, the manufacturer's recommended short cycle and the traditional long cycle produced the best results. Work over many years has tended to support the use of a long cycle. However, manufacturers continually strive to improve their products in terms of clinical performance and ease of use and quality control in the dental laboratory. The best advice therefore must always be to follow their instructions for the optimal results.

CONCLUSIONS

Statistical difference in the transverse strength of heat cured acrylic resin denture base materials were apparent between different curing cycles but in all cases the British Standard was met when the manufacturers' recommended short curing cycle or a traditional long curing cycle was used.

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MANUFACTURER'S DETAILS

- Dentsply Ltd, Weybridge, UK
- Heraeus Kulzer GmbH & Co., Newbury, Berkshire, UK
- Bracon Ltd, Etchingham, UK
- Derotor, Quayle Dental Mfg. Co. Ltd., Worthing, UK
- SiC-paper, PSA backed, Struers A/S Denmark
- Instron, High Wycombe, UK

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