available at www.sciencedirect.com

ScienceDirect

journal homepage: www.intl.elsevierhealth.com/journals/jden

The effect of clinically relevant thermocycling on the flexural properties of endodontic post materials

Dominic A. Stewardson *, Adrian C. Shortall, Peter M. Marquis*

University of Birmingham, School of Dentistry, St Chads Queensway, Birmingham B4 6NN, UK

ARTICLE INFO

Article history:
Received 20 October 2009
Received in revised form
19 February 2010
Accepted 19 February 2010

Keywords:
Materials testing
Dental restoration failure
Flexural strength
Flexural modulus
Fibre composite
Thermocycling
Endodontic post
Metal
Dentine
Elasticity

ABSTRACT

Objectives: It is suggested that fibre-reinforced composite (FRC) posts have lower elastic moduli than metal posts and this will reduce the incidence of root fracture. However, the mechanical properties may be altered in the oral environment. The aims of this study were to determine the effect on the flexural properties of FRC and metal post materials produced by: (1) a thermocycling regime which was clinically relevant and representative of that which would occur during 1 year in the mouth and (2) storage for 1 year at body temperature.

Methods: Nine FRC and two metal post material samples were sealed in polythene sleeves and thermocycled between 10 °C and 50 °C for 10,000 cycles. Additional samples were stored dry at 37 °C for 1 year. The flexural strength and moduli were determined by three-point bending and compared with untreated control samples.

Results: Thermocycling and storage at 37 °C for 1 year decreased the mean flexural modulus of all materials. This was statistically significant for 8 of 11 materials after thermocycling, and 4 of 11 materials after storage at 37 °C ($p < 0.05$). Thermocycling and storage at 37 °C produced a non-significant increase in yield strength for both metal post materials. Thermocycling significantly increased the flexural strength of Postec while it decreased for the other FRC materials. Storage at 37 °C increased the flexural strength of three FRC materials (significantly for Postec) while it was decreased among the other materials.

Conclusions: Although some of the changes noticed in flexural properties were statistically significant, it is doubtful that they are of sufficient magnitude to affect clinical performance.

1. Introduction

Endodontic posts used in the reconstruction of severely damaged teeth have traditionally been made of metal. Over the past two decades, posts manufactured from fibre-reinforced composites (FRC) have been introduced. FRC posts exhibit comparable flexural strength to some metal posts and it has been claimed that by virtue of their lower elastic moduli, FRC posts will distribute stress within the root more favourably than their metal counterparts and consequently reduce the incidence of root fracture.[1–3] The mechanical properties of FRC materials are determined not only by the properties of the fibres and matrix resin but also by the bond between filler and matrix and by the shape, orientation and relative proportions of the reinforcing filler phase.[4,5] Endodontic posts from different manufacturers contain different matrix resins, different proportions, diameters and types of fibre and may vary in their interfacial bonding.[6] Dental restorative materials are required to maintain their properties in the challenging environment of the oral cavity where they may be in direct contact with saliva and subject to deterioration through water sorption, pH changes and enzymatic degradation. They must withstand repeated cyclic loading and the stresses induced by changes in oral temperatures. Evaluation of dental materials often includes testing of the property of interest after a sequence of thermal stressing in

* *Corresponding author*. Tel.: +44 0121 237 2812.
E-mail address: d.a.stewardson@bham.ac.uk (D.A. Stewardson).
0300-5712/$ – see front matter
doi:10.1016/j.jdent.2010.02.003

which the sample is moved between high and low temperature surroundings for a predetermined number of cycles. The temperatures selected, the duration at each temperature, the time of transfer between temperatures and the number of cycles can, and are varied by different researchers. In their review of thermal cycling, Gale and Darvell[7] concluded that the temperatures commonly chosen by investigators were too extreme to provide a representative simulation of temperature fluctuations in vivo, and suggested that 15 °C and 45 °C be used, with a transition time of 28 s at 35 °C. This is a 20 °C narrower range than the most frequently used regime of 5–55 °C as proposed in ISO 11405 recommendations (ISO, 1994). They also proposed a short dwell time of 2 s at either peak temperature. Youngson and Barclay[8] observed that in the many studies where thermocycling had been carried out, a wide range of dwell times were selected but that most employed times between 10 s and 60 s. The choice of dwell times appears arbitrary but no effect of dwell time on results has been established. Not all restorative materials however will come into direct contact with the oral cavity. Endodontic materials and posts will be enclosed by other restorative materials or root dentine. They will be insulated from dramatic temperature fluctuations,[9] but their structure may be affected by prolonged periods at body temperature. While thermocycling protocols which do not reflect clinical conditions may provide information on the behaviour of materials, prediction of their performance in the mouth would require a thermocycling regime which more closely reproduces the thermal stresses to which a restoration will be subjected in use and/or storage at body temperature for a meaningful period of time. The average number of thermal cycles which would normally occur in the mouth has been variously estimated as under 4000[10] to over 10,000 per year.[7,11]The aims of this study were thus to determine the effect on the flexural properties of FRC and metal post materials produced by (1) a thermocycling regime which was clinically relevant and representative of that which would occur during 1 year in the mouth (2) storage for 1 year at body temperature.

The null hypothesis tested was that there would be no significant effect on flexural modulus or flexural strength produced by either the chosen thermocycling regime or storage at 37 °C for 1 year.

2. Materials and methods

Samples of nine FRC and two metal materials from which posts are fabricated were supplied by manufacturers as 100 mm rods of approximately 2 mm diameter. The composition and dimensions of all the tested materials are given in Table 1.

2.1. *Measurement of flexural properties of post materials*

Each material was cut into 48 mm lengths and subjected to three-point bending on an Instron universal testing machine (Instron UK, High Wycombe, England), model 5544 with an inter-support distance of 32 mm according to ISO 3597-2. Loads were applied at 1 mm per min. The diameter of each sample was measured at six points close to the centre of the rod using a digital micrometer (Mitutoyo, Japan), and a mean calculated. Load/extension data was exported to a computer spreadsheet programme, Excel 2007 (Microsoft Corp., USA) for analysis. Ten samples of each material were tested and the flexural moduli and flexural strengths calculated using the appropriate formulae.[13] For the metal samples the yield strength was approximated by producing a 0.2% offset on the load/extension plot.

Flexural modulus of a cylindrical rod using three-point bending.[13]

$$E = \frac{4L^3}{3\pi D^4} \times \frac{F}{Y} \quad (1)$$

Table 1 – Endodontic post materials evaluated; their diameters and composition.

Material	Manufacturer	Diameter (mm)	Composition (manufacturer's information except where indicated)
Carbon fibre composites (mean fibre diameter, filler volume fraction)			
Composipost	RTD, France	1.9	Carbon 6 μm 64%; epoxy resin
Carbonite	Harald Nordin Switzerland	2.1	Carbon 6 μm 65%; epoxy resin
Glass fibre composites (mean fibre diameter, filler volume fraction)			
Aesthetiplus	RTD, France	1.9	E-glass 8 μm 62%; epoxy resin
Lightpost		2.5	Quartz glass 8 μm 60%; epoxy resin
Glassix	Harald Nordin Switzerland	2.1	E-glass 8 μm 60%; epoxy resin
Snowpost	Carbotech	2.0	E-glass with 18% Zirconia 8 μm 60%; epoxy resin
Snowlight	Ganges, France		E-glass with 18% Zirconia 8 μm 65%; polyester/ methacrylate resin.
Postec	Ivoclar Schaan, Leichtenstein	2.5	E-glass 8 μm 55%; filler ytterbium trifluoride and dispersed silicon dioxide; urethane dimethacrylate/TEGMA
Easypost	Dentsply, Ballaigues, Switzerland	1.9	E-glass with 18% Zirconia 8 μm 60%; epoxy resin
Metals (alloy composition)			
Stainless Steel	Coltene/Whaledent	1.7	Fe 72.21%, Cr 18.18%, Ni 8.62%[12]
Titanium	USA	1.7	Ti 90%, Al 6%, Va 4%