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'Own-Label' Versus Branded Commercial Dental Resin Composite Materials: Mechanical And Physical Property Comparisons

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Authors

Dr Kathryn Shaw [§]
(MJDF (RCS Eng.))

Dr Ricardo Martins [ǂ]
(LMD, MSc)

Dr Mohammed Abdul Hadis *
(PhD, BSc (Hons.))

Prof. Trevor Burke *
(BDS, MDS, DDS, MSc, MGDS, FDS RCS, (Edin.), FDS RCS (Eng.), FFGDP(UK), FADM)

Prof. William Palin *
(BMedSci, MPhil, PhD, MSc, FADM)

Address for Correspondence

Dr Mohammed Abdul Hadis *

Email: HadisM@bham.ac.uk

* *University of Birmingham*

§ *General Dental Practitioner, Merseyside, UK*

ǂ *General Dental Practitioner, Hereford UK*

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ABSTRACT

A majority of dental materials are manufactured by companies who have experience in the field. However, a number of "own label" materials have become available, principally marketed by distributors and other companies with little or no experience in the field. These materials are attractive because of their reduced cost, but they may have no research on which clinicians might base their potential performance. It is therefore the purpose of this work to compare the performance of different batches of a number of "own-label" dental materials with a similar number from manufacturers with experience in the field, using a variety of laboratory test regimes which include filler determination, degree of conversion, flexural strength and flexural modulus, in order to evaluate key material properties. The results indicated that own-label dental resin composites produced similar results to materials from established companies in terms of flexural strength characteristics and degree of conversion. However, a greater batch-to-batch variation in several mechanical and physical properties of the own-label materials was noted.

INTRODUCTION

The dental materials market is competitive and the product cycle of "new" dental resin-based composites replacing older types may be rapid. Resin composite materials, which are becoming increasingly used by dentists worldwide,[1] are the subject of a large volume of research which aims to improve reliability, durability and clinical longevity and their associated properties such as polymerisation shrinkage stress,[2,3] polymer conversion,[2,4,5] cure depth,[6] handling,[7] and aesthetic quality.

The iterative product cycle of dental resin composites remains incredibly fast, which leaves the general practitioner with a large choice of product from numerous manufacturers. Because of the speed of change, the clinical evidence base for new materials is sparse and by the time clinical data is published, a newer product of the same brand may well be available. The insidious cycle remains, and this may hamper clinical practitioners when making informed decisions from a reliable evidence base. Nevertheless, there is a building body of evidence from long-term, large studies and systematic reviews which indicate good survival rates of resin composite restorations.[8-11]

There is substantial investment, by some companies, to develop resin composite materials from the conception of an idea (sometimes merely incremental in nature), numerous prototype materials, extensive in-house testing followed by toxicology and regulatory approval prior to launch and, in some cases, clinical trials. In order to provide return on that investment, the cost of commercially available resin composites by well-known manufacturers is relatively high. Some dental resin composite manufacturers bring to the shelf a new brand of material every 3-5 years in order to compete for a share of the market, some of these materials bringing an innovation to the market, others merely being variations on a previous material. Consequently, a reliable prediction of their clinical performance through a strong evidence base is limited unless a particular material brand is successful and remains commercially available for many years. Even then, newer brands (albeit mostly incremental in development) will appear and the iterative product cycle continues.

In addition to brand familiarity and any existing evidence such as, handling, performance, aesthetic quality, strength characteristics, etc., material cost is also a key factor in the selection of a suitable resin composite restorative, this being of particular relevance to the general dentist, given that dental practices have to be financially viable from their primary business of helping patients. Leading and recognised dental material manufacturers spend great efforts in research, development and clinical testing of resin composite technology and, understandably, this cost is partially offset by the profit margins of resin composite sales. Familiar branded resin composites from leading manufacturers are therefore significantly more expensive than those from smaller, less well-known companies, or large dental material distributors that sell "own-label" or "private-label" brands. For the purpose of the present work, these will be termed "own label" brands.

Several dental suppliers produce and/or sell their own label products for resin-based composites, bonding agents and impression materials in order to compete with well-established brands being sold at a significantly greater cost *(Table 1)*. Although the evidence base of newly introduced materials to the dental market by leading manufacturers may be limited, that for private-label products appears to be non-existent. In that regard, Mickenautsch[12] was unable to identify any glass-ionomer materials in research publications other than those from the major companies, while Burke, in 2013,[13] reported that, from an investigation of 444 International Association of Dental Research abstracts from the IADR meeting in 2011, there was no evidence of any own label product (bonding agents and resin composites) being subjected to *in vitro* or clinical studies. Clinical longevity data for own label products do not appear to be reported in the literature, presumably because this would mean an investment from the own label companies, thereby defeating the purpose of producing a less expensive material. However, and at the very least, some evidence should be developed in order to understand key properties of own-label materials and how they might compare with more reputable brands from companies who fund research into their dental materials.

Consequently, the aim of the present study was to compare dental resin composites of different brands and batches from different manufacturers in terms of key material properties (degree of conversion, flexural strength and modulus, and filler percentage) and to assess whether cheaper own label resin composites can perform as well as or better than the more expensive commercially branded products. The hypothesis is that branded resin composites will exhibit superior material properties than private-label which may be indicative of clinical performance.

Table 1. Cost comparison of "own label" versus branded materials

Manufacturer	Product	Package/ Weight	Quantity	Price (£)	Supplier	Product code	Price Date
3M ESPE	Filtek Z250	Syringe/ 4g	1	59.99	Henry Schein	202457	17/09/2015
3M ESPE	Filtek Z250	Syringe/ 4g	1	62.94	Dental Sky	BE720	17/09/2015
Dentsply	Ceram X Mono	Syringe/ 3g	1	43.29	Henry Schein	1106594	17/09/2015
Dentsply	Esthet X HD	Syringe/ 3g	1	48.49	Henry Schein	11062515	17/09/2015
Henry Schein	HS 20/20 Hybrid	Syringe/ 3g	1	11.39	Henry Schein	9006380	17/09/2015
Henry Schein	HS Natural Elegance	Syringe/ 4.5g	1	19.69	Henry Schein	200119	17/09/2015
Dental Sky	R&S Lumifil+	Syringe/ 4g	1	23.34	Dental Sky	RSLUMIFILUNIVERS	17/09/2015
Dental Sky	R&S Suprafil	Syringe/ 4g	1	23.94	Dental Sky	25-743	17/09/2015

EXPERIMENTAL PROCEDURES

MATERIALS AND METHODS

Two batches of eight different branded and private-label dental resin composite restorative materials (shade A2) were tested.

Branded materials: Esthet X HD and Ceram X mono (Dentsply, York, PA, USA); Filtek Z250 (3M ESPE Dental Products, Seefeld, Germany).

Own-label materials: HS 20/20, HS Natural Elegance 'micro-hybrid', and HS Natural Elegance 'mono-hybrid' (Henry Schein, Gillingham, UK), R&S Lumifil Anterior, and R&S Suprafil (Dental Sky, Kent, UK). The resin and filler constituents, limited to the information provided by the manufacturer, are presented in Table 2.

ASHING

To confirm, or otherwise, the filler percentages quoted by manufacturers *(Table 3)*, the filler mass percentage of each batch of the various resin composite materials was determined by an ashing technique which compares the differences in mass before and after ashing of 0.5 g (n=3) of each material at 900°C for 1 h. The materials were placed into porcelain crucibles and weighed using an analytical balance (Acculab Atilon, Sartorius Group, accurate to +/- 0.0001g) and then introduced into a furnace (Carbolite CWF 1300, UK) pre-heated to 900°C to remove the resin component. After 1 h the crucibles were removed and left to cool to room temperature before re-weighing. The difference in mass subtracted from the initial amount represents the amount of inorganic filler remaining.

DEGREE OF CONVERSION

The degree of polymer conversion was measured throughout cure in the mid-infrared range using attenuated total reflectance Fourier transform infrared spectroscopy (ATR-FTIRS) by measuring the ratio of the C=C bond (1637cm-1) against the aromatic bond (1608cm-1) in accordance with Equation 1.

$$Conversion\ \% = \frac{1637\,cm^{-1}/1608\,cm^{-1}\ cured}{1637\,cm^{-1}/1608\,cm^{-1}\ uncured} \times 100 \qquad \text{Equation 1}$$

Each material (n=3) was cured in a 12mm diameter, 2mm thick black Nylotron mould placed centrally over the germanium crystal on the ATR plate and firmly compacted on the upper surface with a thin cover slip to ensure intimate contact between the specimen and crystal prior to light-curing for 30 s. Polymer conversion is known to evolve for up-to 24h post irradiation but the majority of polymerisation takes place during light activation and therefore for that reason, DC at 180 s was chosen for comparison of the materials in the current study.

FLEXURAL STRENGTH AND MODULUS

Each resin composite (n=5) was packed into a bar-shaped mould (2mm thickness, 2mm breadth, 25mm length) and covered on both sides with glass cover slips. The specimens were then cured for 30 s using a dual peak LED light curing unit (Bluephase Polywave, High mode; Germany) with a 10mm diameter fibre optic tip overlapped across the length of the bar.

Table 2. Manufacturers information on filler, resin and photoinitiator constituents where available.

Manufacturer	Composite	Resin Constituent	Filler Constituent	Photoinitiator
3M ESPE	Filtek Z250	Bis-GMA, UDMA and Bis-EMA	60 vol% inorganic filler (without silane treatment); size 0.01-3.5µm,	
Dentsply	Esthet X HD	Bis-GMA adduct, Bis-EMA adduct, TEGDMA	Barium fluoroborosilicate glass < 1µm and nanofiller silica (0.04µm)	CQ
Dentsply	Ceram X Mono	10-25% Dimethacrlate resin, methacrylate modified polysiloxane	Barium-aluminium-borosilicate glass and silicon dioxide nano filler	CQ/EDMAB
Henry Schein	HS Natural Elegance (nano hybrid)	Methacrylates	77wt% inorganic filler (0.04-2.9µm); silanised barium glass, amphorphous silica, hydrophobed	
Henry Schein	HS 20/20	Bis-GMA resin	Inorganic filler 64 vol% (0.0-2µm). Total filler 75 vol%.	
R&S	R&S Lumfil Anterior	Bis-GMA	66 vol%. Organic and inorganic (Micro fillers: 0.05µm; Macro fillers 0.08-10µm)	
R&S	R&S Suprafil	Bis-GMA, Bis-EMA, TEGDMA	78 wt%. Inorganic filler (0.04-2.8µm); Barium glass, silanised amorphous silica	

Table 3. Manufacturers, brands, batch numbers and expiration dates of composites used in this study

Manufacturer	Composite	Classification	LOT/Batch
3M ESPE	Filtek Z250	Micro Hybrid	N304373/1
3M ESPE	Filtek Z250	Micro Hybrid	N304762/2
Dentsply	Esthet X HD	Micro Matrix	1106232/1
Dentsply	Esthet X HD	Micro Matrix	1109263/2
Dentsply	Ceram X Mono	Nano	1110000940/1
Dentsply	Ceram X Mono	Nano	1202000280/2
Henry Schein	HS Natural Elegance (micro hybrid)	Micro Hybrid	120210B/1
Henry Schein	HS Natural Elegance (micro hybrid)	Micro Hybrid	101311B/2
Henry Schein	HS Natural Elegance (nano hybrid)	Nano Hybrid	C37211/1
Henry Schein	HS Natural Elegance (nano hybrid)	Nano Hybrid	C41306/2
Henry Schein	HS 20/20	Hybrid	670692/1
Henry Schein	HS 20/20	Hybrid	653201/2
R&S	R&S Lumfil Anterior	Micro + Macro	948453/1
R&S	R&S Lumfil Anterior	Micro + Macro	1208079/2
R&S	R&S Suprafil	Micro Hybrid	C45856/1
R&S	R&S Suprafil	Micro Hybrid	C20175/2

Table 4. Composite ranking in terms of the tested properties. Letters in parentheses represent significant differences between composites. Branded materials are highlighted by red font.

FILLER		DEGREE OF CONVERSION		FLEXURAL STRENGTH		FLEXURAL MODULUS	
Composite	Difference in Batches?	Composite	Difference in Batches?	Composite	Difference in Batches?	Composite	Difference in Batches?
Filtek Z250 (a)	No	HS 20/20 (a)	No	HS NE (nano hybrid) (a)	Yes	NE (Nano) (a)	No
Ceram X Nano (b)	No	R&S Lumfill (ab)	No	Filtek Z250 (ab)	No	Filtek Z250 (a)	No
R&S Suprafil (b)	No	NE (Nano) (bc)	Yes	Ceram X Mono (b)	No	NE (Micro) (b)	Yes
NE (Mono) (b)	No	R&S Suprafil (cd)	No	HS NE (micro hybrid) (abc)	Yes	Ceram X Mono (b)	No
HS 20/20 (c)	Yes	Filtek Z250 (de)	No	HS 20/20 (bc)	No	HS 20/20 (bc)	No
Esthet X HD (c)	No	Ceram X Mono (ef)	No	R&S Suprafil (c)	No	Esthet X HD (bc)	No
NE (Micro) (c)	No	Esthet X HD (fg)	No	Esthet X HD (c)	Yes	R&S Suprafil (c)	No
R&S Lumifil (d)	No	NE (Micro) (g)	No	R&S Lumfil (d)	No	R&S Lumifil (d)	No

The output of the light curing unit was verified to be 1456 +/- 18mW/cm^2 on a USB4000 UV-VIS spectrometer (Ocean Optics, Dunedin, USA, wavelength range 200-850nm). Following cure, the bar specimens were carefully removed from the mould and excess flash was cut away with a sharp blade before storing in an incubator (Laboratory thermal equipment LTD, Oldham, UK) with distilled water (25ml) at 37^{0}C for 7 days.

Flexural strength testing was performed at 1mm/min strain rate on a universal testing machine (Instron Ltd, Model 5544, Buckinghamshire, England) with a 3 point flexural test attachment (Equation 2); is the flexural strength, F is the maximum load (in Newtons), L is the distance between the supports, B is the width of the specimen and H is the height of the specimen.

$$\sigma = \frac{3FL}{2BH^2} \qquad \text{Equation 2}$$

The flexural modulus was calculated at the failure point using Equation 3, where is the flexural modulus, is the load failure, is the support span (20mm), is the specimen width (mm), is the specimen thickness (mm) and is the deflection (mm)

$$E_B = \frac{PL^3}{4bd^3D} \qquad \text{Equation 3}$$

STATISTICAL ANALYSIS

Statistical analysis was performed on each of the responses (Flexural strength, modulus, degree of conversion and filler percentage) in terms of comparing materials of different brands as well as comparing same brands but different batches. Data sets were analysed using one-way analysis of variance (ANOVA) and post-hoc Tukey tests in Minitab Version 15 ($p<0.05$).

RESULTS

One-way ANOVA and post-hoc Tukey tests ($p<0.05$) showed significant differences in all of the responses tested in terms of composite brands and batches (*Table 4* and *Figures 1-4*).

Filtek Z250 showed significantly higher filler percentage than all other resin composite materials tested in the present study ($p<0.05$) (*Figure 1*). No significant difference in filler mass was observed between Ceram X mono, R&S Suprafil and HS Natural Elegance 'nano-hybrid' ($p>0.05$), although these materials were significantly higher compared with HS 20/20, Esthet X HD, HS Natural Elegance 'micro-hybrid' and R&S Lumifil Anterior ($p<0.05$). Furthermore, R&S Lumifil anterior showed significantly lower filler percentage than all other composites tested ($p<0.05$). Generally, no significant differences in filler percentages between batches of the same brand were recorded except HS 20/20 (*Table 4*).

In terms of degree of conversion, HS 20/20 was significantly higher than all other resin composites except R&S Lumifil ($p<0.05$) (*Figure 2*). HS Natural Elegance 'micro-hybrid' showed the significantly lowest degree of conversion compared with all other tested materials. No significant differences in the degree of conversion were observed for different batches of the same resin composites, except for Batch 2 of HS Natural Elegance 'nano' which exhibited significantly lower degree of conversion compared with Batch 1 (*Figure 2; Table 4*).

No significant difference in flexural modulus was observed between HS Natural Elegance 'nano-hybrid' and Filtek Z250 ($p>0.05$) although both materials exhibited significantly highest flexural modulus compared with the other materials (*Figure 4*; $p<0.05$). R&S Lumifil Anterior showed the significantly lowest flexural modulus compared with all of the resin composites tested ($p<0.05$). A batch variation was recorded for HS Natural Elegance 'micro-hybrid', where Batch 1 exhibited significantly lower flexural modulus compared with Batch 2 ($p<0.05$) (*Table 4*).

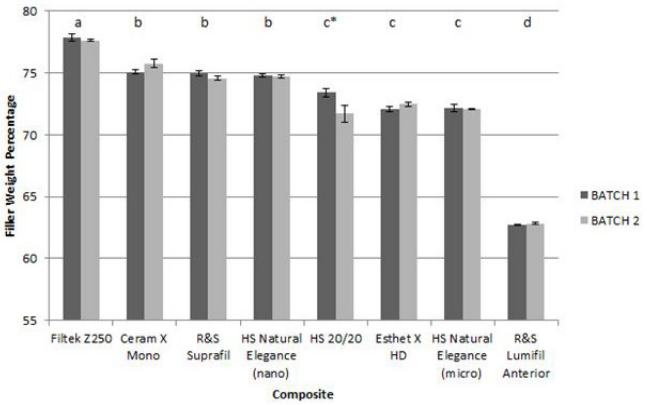

Figure 1: The filler percentages of the composites used in this study, determined through 'ashing'. Letters represent significant differences between the different composites and * represents significant differences between the two batches tested.

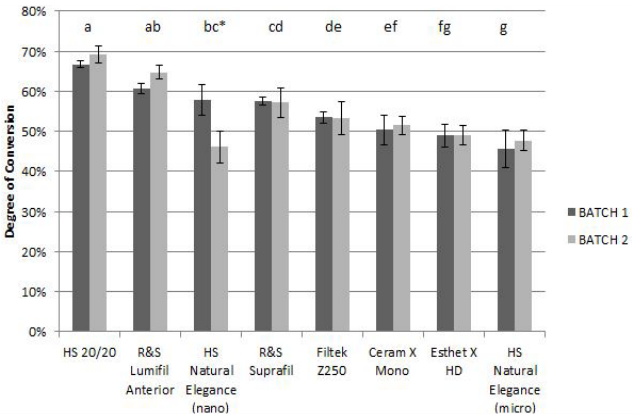

Figure 2: The degree of conversion of the composites used in this study. Letters represent significant differences between the different composites and * represents significant differences between the two batches tested.

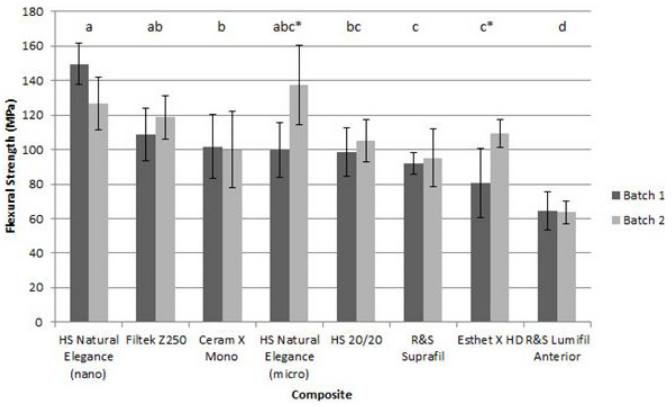

Figure 3: The flexural strength of the composites used in this study, determined through the three point bend test. Letters represent significant differences between the different composites and * represents significant differences between the two batches tested.

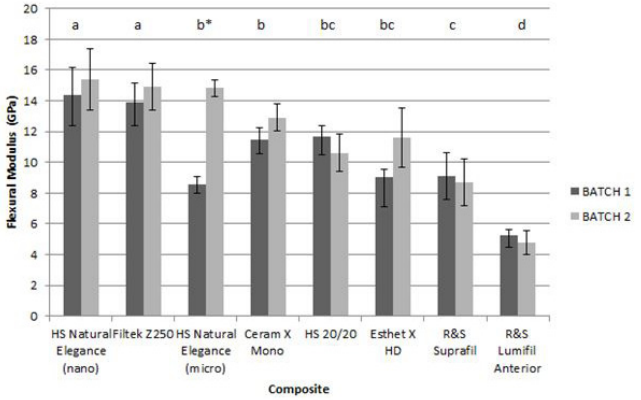

Figure 4: The flexural modulus of the composites used in this study, determined through the three point bend test. Letters represent significant differences between the different composites and * represents significant differences between the two batches tested.

DISCUSSION

The filler content, size and particle distribution have all been shown previously to influence the mechanical and physical properties of dental resin composites.[14-17] A strong correlation exists between the filler mass percentage and/or volume fraction and material strength, elastic modulus and fracture toughness.[17] Here, a similar general trend was observed in which Filtek Z250 and Lumifil Anterior exhibited the significantly highest and lowest filler mass percentage, respectively, with associated high and lowest strength characteristics *(Figures 1, 3, 4*). However, the manufacturer of both materials reported similar filler volume percentages (60% and 66vol% respectively*; Table 2*), and with a higher degree of conversion for Lumifil Anterior, perhaps more similar mechanical properties with Z250 would have been expected. Further, the mass % of filler recorded following ashing was significantly different (~78% and 63% for Z250 and Lumifil Anterior, respectively; *Figure 1*). The filler percentage may be underestimated since ashing would remove the organic portion of the resin composite, hence the resin matrix and any organic filler component such as pre-polymerised filler particulates (Leprince *et al*., 2010) commonly used in microfilled-type resin composites such as Lumifil Anterior. More traditional microfilled composite materials that contain a high percentage of micron-sized particles may result in more extensive particle agglomeration and a drastic increase in surface area to volume ratio, which increases filler wetting and limits its mass percentage within the resin. Such effect may provide a reason for the significantly lower mechanical properties of Lumifil Anterior and hence its contraindication for restoration of posterior cavities.

According to the manufacturers' literature, the 'branded' composites, Ceram X Mono, Esthet X HD (Dentsply) and Filtek Z250 (3M ESPE), have optimised filler particle size distributions. Ceram X contains novel fillers derived from organically modified inorganic ceramic nano-particles with a polysiloxane backbone, which provides in situ filler modification for chemical adhesion to the resin matrix[19] without the need for silane coating used for more traditional monolithic fillers. These novel processing methods may provide more highly dispersed and less agglomerated nano-sized particles[20] and may explain the ability to achieve an increased filler weight percentage *(Figure 1*) and relatively high strength characteristics *(Figure 3, 4*). Although Filtek Z250 is a more conventional micro-hybrid resin composite, which contains mainly monolithic zirconia-silica particles, filler content and mechanical properties are also comparably high compared with most other material types tested in the present study. The filler type and content is well known to affect rheology, curing kinetics and degree of conversion[21,22] and based on the filler mass percentage alone, it could be assumed that Filtek Z250 would at least outperform the other materials in terms of flexural strength and modulus. However, one private-label composite, HS Natural Elegance 'nano-hybrid', which had significantly lower filler mass percentage, performed comparably with Filtek Z250 in terms of flexural strength and modulus. Filtek Z250 is classified as a micro-hybrid composite and has filler particle sizes ranging from 0.01 to 20µm, whereas HS Natural Elegance 'nano-hybrid' suggests an increased content of nano-sized as well as micro-sized fillers. The use of a higher quantity of nano-sized fillers in HS Natural Elegance 'nano-hybrid' would give rise to an increased volume of filler despite its low mass percentage observed here, and may explain the equivalent strength characteristics compared with Z250 even with a lower mass percentage of filler.[23,24] In fact, the use of denser filler particles would increase the mass percentage within the resin composite without a proportional increase in volume fraction.[18] Therefore, it is important to note that a manufacturer's stated volume of filler, rather than a mass percentage is far more relevant in terms of the general mechanical properties of the material.

Although filler content, particle size and distribution are important factors in terms of physical and mechanical properties, the resin matrix and photoinitiator(s) types, which ultimately affect polymer conversion[4,26] differ considerably between products and should also be considered. Changes in mechanical and physical properties occur as the composite converts from liquid to solid. The polymer properties are primarily affected by the cross linking density of the network. Degree of conversion is typically limited to 55-75% due to vitrification of the polymer network.[27,28] In the present study, conversion ranged from circa 45%-65%. Although the branded materials performed comparably in terms of mechanical properties, most of the private-label composites exhibited significantly higher degrees of conversion (*Figure 2*). The kinetics of polymerisation and overall formation of the polymer network is complex and dependent upon several factors including monomer composition, photoinitiator chemistry and filler content.[4,26,29] Although a higher degree of conversion relates to lower residual monomer, polymer network formation may be considerably different depending on the rate of reaction, polymer chain length and degree of crosslinking, which, in turn, may affect flexural modulus (*Figure 4*), shrinkage, water uptake and elution of the residual components.[4,30,31] A highly crosslinked network is crucial for mechanical and physical properties of the composite, however, degree of conversion should not be considered the 'gold-standard' for evaluating the performance of resin-based composites.

Although this study was limited by the number and variety of resin composites and the material properties analysed, one striking observation was the apparent difference in properties between batches, which occurred predominantly in the private-label materials. Whilst most private-label composites performed comparably with more established brands, the reliability of the product might be questionable, given the batch-to-batch variation observed in the current study. Is this due to poorer quality control of the cheaper material, or by could this be explained by different batches of the material being manufactured under varying conditions or even by a different manufacturer? This should be a worry to clinicians, who might experience differing handling of one batch of material to the next that they purchase, with, in the longer term, the clinician perhaps being aware of differing clinical performance of the material in terms of, for example, stain resistance or even restoration survival.

Finally, despite the fact that the laboratory performance of some "own label" materials appeared satisfactory, clinicians should be mindful of the repercussions of premature failure of a restoration, with litigation against dentists in England and Wales rising by over 10% between the years 2013 and 2014 (KJ Lewis, Dental Director, Dental Protection London; personal communication). The choice of material for a given clinical situation is therefore a critical decision, not only for the patient, but also for the clinician and his/her employer(s). However, dental practices have many competing factors in this era of continuing austerity and increasing corporatisation (in the UK and Ireland at least) and it may therefore be tempting for those in control of the ordering of materials (which, anecdotally, is not always the clinician in a practice or chain of practices) to choose the cheapest material. The person making decision on the purchase of dental materials might strike lucky, because there is anecdotal evidence that some own label materials are a historic formulation of a previously-marketed reputable brands, and some own-label brands in the present work performed satisfactorily in some parameters. However, the question must be asked – is the money saved by purchasing a cheaper material which has no research background worth it when the cost of a lost or prematurely failed restoration is calculated in terms of clinician's time, notwithstanding the potentially adverse medicolegal consequences and cost of a prematurely failed restorative procedure.[32]

CONCLUSION

The hypothesis was partially accepted since own-label dental resin composites may be a more cost-effective alternative than more established commercial materials when considering restorations for anterior and posterior cavities based on flexural strength characteristics and degree of conversion. However, a greater batch-to-batch variation in several mechanical and physical properties of the own-label materials tested in the current investigation may question product reliability, and ultimately their clinical performance, when compared with more reputable brands.

CONFLICT OF INTEREST

The authors do not have any financial interest in the company whose material was included in this study. The study was not funded.

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