

No more amalgams: Use of amalgam and amalgam alternative materials in primary dental care

C. D. Lynch,^{*1} D. J. J. Farnell,² H. Stanton,³ I. G. Chestnutt,⁴ P. A. Brunton⁵ and N. H. F. Wilson⁶

Key points

Provides readers with a greater appreciation of the challenges facing the profession in terms of the Minamata Treaty.

Explores the challenges in moving from amalgam to resin composite for the restoration of posterior teeth.

Discusses the relevant evidence base for placing posterior resin composites.

Objectives The aim of this study was to investigate the use of dental amalgam and amalgam alternate materials in primary dental care in Wales. **Methods** Following pre-piloting, a questionnaire was distributed to 667 dentists registered as working in primary dental care in Wales. The questionnaire sought to determine the current use of amalgam, and amalgam alternative materials in primary dental care services in Wales. In addition, the questionnaire sought to determine the attitudes and confidence of dentists in respect of placement of resin composites as alternatives to dental amalgam. **Results** A response rate of 40.4% was achieved (n = 270). High levels of reported confidence were seen in relation to placing resin composites in posterior teeth, but these levels reduced as the complexity of the cavity increased (while 82% of respondents 'strongly agreed' that they felt confident in placing resin composites in occlusal cavities, this reduced to 52.6% for three-surface occlusoproximal cavities). Patterns of care suggested that 73.3% of respondents often, or always, place amalgam restorations for NHS-funded dentistry in adults, where two or more posterior restorations are required. This proportion drops to 27% for the same scenario in children, and 19.4% in privately-funded care for adults. Sixty-seven percent of respondents reported that restoring posterior teeth with resin composite is too expensive for NHS-funded dentistry. A similar proportion of respondents (65.9%) agreed, or strongly agreed, that having to place resin composite routinely in posterior teeth would cause appointment delays. Respondents estimated that it would take them 1.61 times as long on average to place a resin composite, compared to an amalgam, in a moderately deep two-surface proximal-occlusal cavity in a lower first permanent molar. Respondents felt that the NHS fees would have to increase by 55–60% to support the restoration of posterior teeth with resin composite, rather than dental amalgam. **Conclusions** This study provided insight into current practising arrangements of primary dental care practitioners in relation to the use of dental amalgam and resin composites in the restoration of posterior teeth. Based on a sample of mainly UK-trained dentists, it would seem that amalgam remains the material typically selected for restoring posterior teeth in adults for NHS-funded care. While dentists are knowledgeable and embracing of new techniques for posterior resin composite placement, funding arrangements in NHS dentistry appear to be a barrier to the increasing use of resin composite-based, minimum intervention approaches to the restoration of posterior teeth.

Introduction

The restoration of teeth, most commonly affected by dental caries or trauma, remains the mainstay of the day-to-day work of most general dental practitioners. The contemporary approach to treatment continues to be based on the excision of the lesion of caries and obturation of the resultant cavity preparation with a filling material.

The most recent Adult Dental Health Survey reveals that most UK adults have been affected by dental caries and have restorations: 84% of UK adults with teeth have at

least one restoration, with each adult having, on average, 7.2 filled teeth each.¹ Analysis of databases of NHS-funded care reveals that 50% of fillings are replaced within 10 years,² placing increased pressures on NHS dental services. NHS-funded primary dental care services have traditionally relied heavily on dental amalgam as the dental material of choice.³ However, in an attempt to introduce international environmental controls on the use of mercury, a recent international agreement has included a commitment that there should be a phase-down in the use of dental amalgam.⁴

¹Professor/ Consultant in Restorative Dentistry, University Dental School & Hospital/ University College Cork, Wilton, Cork, Ireland; ²Senior Lecturer in Medical Statistics, School of Dentistry, Heath Park, Cardiff, CF14 4XY, United Kingdom; ³Research Associate, Centre for Trials Research, College of Biomedical and Life Sciences, Cardiff University, Heath Park, Cardiff, CF14 4YS, United Kingdom; ⁴Professor and Honorary Consultant in Dental Public Health, School of Dentistry, Heath Park, Cardiff, CF14 4XY, United Kingdom; ⁵Dean, Faculty of Dentistry, University of Otago, Dunedin, New Zealand; ⁶Emeritus Professor of Dentistry, King's College London Dental Institute, London, United Kingdom

*Correspondence to: Professor Chris Lynch
Email: chris.lynch@ucc.ie

Refereed Paper. Accepted 5 March 2018
DOI: 10.1038/sj.bdj.2018.538

Amalgam remains the most popular, cheapest, low cost, easily placed filling material within NHS-funded primary dental care services. Alternate tooth-coloured restorative filling materials, while offering the opportunity to adopt a minimum intervention approach, are regarded as being more costly, require more time for placement and may suffer increased failure rates.⁵ This presents challenges for the existing service, as well as patient safety and effectiveness of treatment concerns. While alternate filling materials, such as resin composite, exist for placement in posterior teeth, these are not universally popular and many UK dental practitioners are historically not skilled in their use.⁶ Surveys of dental school teaching show that many dentists who graduated up to 10 years ago had limited experience of placement of resin composites in posterior teeth while at dental school.^{7,8} This, in turn, leads to a concern that many dentists who qualified more than 10 years ago (for example, aged 35 years and over) may be less skilled or even incompetent in the placement of resin composites in posterior teeth. This presents risks in terms of delivering safe dental treatment, but also challenges in terms of providing necessary training for dentists to allow for the delivery of such treatments.

Given the relative infrequency with which many dental practitioners place amalgam-alternate materials in posterior teeth (in one survey 15% of UK dentists surveyed reported that they place resin composites in molar teeth),³ concern exists that higher failure rates will be seen when these materials are used. Given the ongoing phase-down in the use of amalgam, the purpose of this study was to survey the use of amalgam-alternate materials by primary care dental practitioners in Wales. The proposed research aimed to answer important questions on the use of current and alternate materials and training requirements for dentists working in primary dental care to facilitate delivery of resin composites and other alternate filling materials.

Methods

Ethical approval for this study was obtained from the Cardiff Dental School Research Ethics Committee (DSREC Ref. 15/04).

Following pre-piloting, a questionnaire was distributed to 667 dentists who were working in primary dental care in Wales. These dentists were randomly selected from the Dental Performer List held by the NHS Shared

Business Services Centre in Wales. The questionnaire sought to collect information such as:

- The current use of amalgam and amalgam-alternate materials in primary dental care services in Wales
- The attitudes, confidence and training needs of dentists in respect of placement of resin composite as alternatives to dental amalgam, including a number of described scenarios.

An initial mailing was sent by hard copy in the post, followed by two subsequent follow-up mailings using conventional mail. The study was carried out between May and July 2015.

Completed responses were returned centrally and entered onto an electronic database. Descriptive statistics such as the mean and associated 95% confidence intervals are quoted for continuous measurements such as estimated times for a procedure or estimated percentage increases in costs. Percentages for responses to specific items in the questionnaire are also reported here. Chi-squared analysis was used to determine if distributions of responses relating to usage and placement of amalgam across five categories (never, rarely, sometimes, often or all of the time) for different scenarios were flat or if there was a different pattern to these responses. Chi-squared analysis was also used to compare if the pattern of responses across these five categories for the usage and placement scenarios was different for the various scenarios; Bonferroni corrections were used to account for multiple pairwise comparisons between the different scenarios. Differences in the times estimated by each subject to place amalgam and the time estimated by them to place composites were normally distributed and so the mean times for amalgam versus composites could be compared statistically by using a paired t-test. Calculations were carried out using MS EXCEL for the chi-squared analysis and SPSS V23 for the t-tests.

Results

Of 667 dentists surveyed, 270 usable responses were received, resulting in a response rate of 40.4%.

Respondent profiles

Two hundred and twelve respondents (81%) graduated from dental schools in the United Kingdom, 42 (16%) graduated from dental schools in Europe, and the remainder (n = 7,

3%) graduated outside the European Union. The distribution of year of graduation is shown in Table 1.

Fifty-seven percent (n = 150) identified themselves as performers or associates, 40% (n = 105) identified themselves as providers or principals, 3% (n = 8) identified themselves as dental foundation trainees.

Across respondents it was reported that, on average, 71% of patients were treated under NHS contract, 15% were treated privately and 14% were seen under an insurance scheme.

Previous training

Overall, 74% (n = 198) reported that they had not received didactic training and 68% (n = 182) reported they had not received clinical training in the placement of posterior resin composites while at dental school. Sixteen percent (n = 43) reported that they had attended CPD courses on posterior resin composites since graduation.

Awareness of plans to phase-down amalgam

In total, 65% (n = 174) reported that they had heard about the planned phase-down of amalgam. Thirty-two percent (n = 86) either agreed or strongly agreed that the phase-down of amalgam was a “good idea”. Fifty-six percent (n = 150) either agreed or strongly agreed that the phase-down of amalgam would be a major disruption to their practice. A minority, 24% (n = 64) either agreed or strongly agreed that the phase-down of amalgam was not of concern to them.

Current and future use of restorative materials in posterior teeth

Respondents were asked to rank their choice of restorative material for a number of scenarios – primary vs permanent dentition, and varying age of patient. Respondents entered whole numbers such as ‘1’, ‘2’, ‘3’, etc where ‘1’ was their preferred choice and subsequent numbers indicated decreasing preference. The top three most common selections in rank order were (mean ranks are taken over all subjects that responded to this question appropriately):

- Primary dentition: glass ionomer (mean rank = 1.15), amalgam (mean rank = 2.65), resin composite (mean rank = 2.67)
- Permanent dentition in patients aged 17 years and younger: resin composite (mean rank = 1.71), amalgam (mean rank = 1.77), glass ionomer (mean rank = 2.87)

Table 1 Graduation profile of respondents

Period of graduation	n	%
1976 to 1980	8	3.0
1981 to 1985	28	10.5
1986 to 1990	35	13.1
1991 to 1995	21	7.9
1995 to 2000	39	14.6
2001 to 2005	42	15.7
2006 to 2010	46	17.2
2010 onwards	40	15.0
Missing data	2	0.7
Total	267	100.0

Table 2 Respondents were asked to indicate how often they placed amalgam in a number of different clinical scenarios in posterior teeth. (97% of subjects responded to these questions, that is, n = 259 here)

	Never	Rarely	Sometimes	Often	All of the time	N/A
Private adult patients who need restorative work in a single posterior tooth	14.4%	24.0%	29.3%	16.3%	0.8%	15.2%
Private adult patients who need restorative work in two or more posterior teeth	12.5%	22.1%	30.8%	18.6%	0.8%	15.2%
NHS adult patients who need restorative work in a single posterior tooth	2.7%	7.6%	18.3%	52.1%	13.7%	5.7%
NHS adult patients who need restorative work in two or more posterior teeth	2.3%	7.3%	11.1%	52.1%	21.1%	6.1%
Child patients who need restorative work in a single posterior tooth	13.6%	33.7%	34.5%	14.4%	3.4%	0.4%

- Permanent dentition in patients 18–59 years of age: amalgam (mean rank = 1.50), resin composite (mean rank = 1.91), glass ionomer (mean rank = 3.19)
- Permanent dentition in patients aged 60 years and older: amalgam (mean rank = 1.57), resin composite (mean rank = 2.26), glass ionomer (mean rank = 2.61).

Respondents reported their use of dental amalgam in a number of clinical scenarios. These are reported in Table 2.

Chi-squared analysis indicated that the distributions of frequencies across the response categories (that is, never, rarely, sometimes, often, all of the time, but excluding N/A) were not flat (that is, percentages in category were not equal to 20%) for each question shown

in Table 2 considered separately ($P < 0.001$). Chi-squared analysis showed also that the distributions of responses differed significantly between all of the questions in Table 2, where $P < 0.001$ generally even after Bonferroni corrections were used to account for the 15 possible 'pairwise comparisons' between the six questions. The only exceptions where $P > 0.05$ after Bonferroni correction were for 'Private adult patients, restorative, single posterior tooth' versus 'Private adult patients, restorative, two or more posterior teeth', 'Private adult patients, restorative, single posterior tooth' versus 'Child patients, restorative, single posterior tooth', 'Private adult patients, restorative, two or more posterior teeth' versus 'Child patients, restorative, two or more posterior teeth', and 'Child patients, restorative, single posterior tooth'

versus 'Child patients, restorative, two or more posterior teeth'. Indeed, visual inspection of the percentages in Table 2 confirms these results.

Attitudes to use of amalgam alternative materials

Use and confidence

Respondents were asked to agree, or not, that they were confident at placing resin composite in posterior teeth in a number of scenarios. These are reported in Table 3.

Attitudes

Respondents were asked to indicate their agreement, or not, with a number of statements relating to placement of resin composite in posterior teeth. These are reported in Table 4.

Additionally, 42.6% agreed, or strongly agreed, that their patients experience less post-operative sensitivity with amalgams compared to posterior resin composites. When asked about interdental food packing, 35.9% agreed, or strongly agreed, that their patients experience fewer problems with amalgam.

Overall, 72.5% of respondents agreed, or strongly agreed, that they felt up-to-date with current techniques and practices relating to the placement of resin composites in posterior teeth.

Implementing Minamata

Respondents were asked to indicate over what period of time following the signing of the Minamata Treaty (2014) should the use of dental amalgam be 'phased out' in UK dental practice. The responses were:

- Less than 5 years: 15.5%
- 5–9 years: 28.3%
- 10–19 years: 25.2%
- 20–29 years: 7.8%
- More than 30 years: 23.3%.

Time and financial implications for changes in practice from amalgam to resin composites

Time implications

Respondents were given the scenario of a moderately deep occlusal cavity in an upper premolar and asked to estimate how long it would take to restore such a cavity with amalgam. The mean response was 14.9 minutes (95% CI: 14.2 minutes to 15.6 minutes) (minimum: 2.0 minutes, maximum: 30.0 minutes). They were then asked to estimate how long it would take to restore the same cavity with resin composite. The mean response was 22.1 minutes (95% CI: 21.1 minutes to 23.1

minutes) (minimum: 4.0 minutes, maximum: 60.0 minutes). Calculating from the raw data, respondents estimated that it would take them 1.58 (95% CI: 1.51 to 1.65) times as long on average to place a resin composite, rather than an amalgam, in a moderately deep occlusal cavity in an upper premolar.

Respondents were also given the scenario of a moderately deep two-surface mesio-occlusal cavity in lower first permanent molar and asked to estimate how long it would take to restore such a cavity. The mean response was 19.6 minutes (95% CI: 18.8 minutes to 20.4 minutes) (minimum: 3.0 minutes, maximum: 45.0 minutes). They were then asked to estimate how long it would take to restore the same cavity with resin composite. The mean response was 30.2 minutes (95% CI: 29.1 minutes to 31.4 minutes) (minimum: 3.0 minutes, maximum: 45.0 minutes). Calculating from the raw data, respondents estimated that it would take them 1.61 (95% CI: 1.56 to 1.67) times as long on average to place a resin composite, rather than an amalgam, in a moderately deep two-surface mesio-occlusal cavity in lower first molar.

Financial implications

On average, respondents felt that the NHS fees would have to increase by 57.5% (95% CI: 50.4% to 64.6%) minimum: 0%, maximum: 400%, standard deviation = 53.9%) to support the placement of resin composite, rather than amalgam in posterior teeth.

Techniques used for restoring posterior teeth with resin composite

Protection of operatively exposed dentine

The reported use of techniques for protection of operatively exposed dentine is reported in Table 5. More than one-half of respondents selected a ‘total etch’ approach (that is, no lining or base) for the restoration of cavities of moderate and shallow depth (56% and 90.3%, respectively). A range of techniques were reported as being used for deep cavities.

Restoring proximal contour

Circumferential metal matrices were most commonly selected when restoring proximal contours (94.5%), followed by sectional metal matrices (58.9%) and circumferential clear matrices (45.4%). (Percentages quoted above are with respect to those subjects that responded, where the response rates to these questions were 87.4%, 58.5%, and 52.2%, respectively.)

Table 3 Respondents were asked to indicate if they felt confident at placing amalgam alternate materials in a number of clinical scenarios in posterior teeth. (98.5% of subjects responded to these questions, that is, n = 263 here)

I feel confident in my ability to place ...		Strongly agree	Agree	Neutral	Disagree	Strongly disagree
Resin composite	Occlusal (Class I)	82.0%	15.4%	1.1%	1.5%	0%
	Two-surface occlusoproximal (Class II)	62.0%	30.1%	5.3%	2.3%	0.4%
	Three-surface occlusoproximal (Class II)	52.6%	35.7%	7.5%	3.8%	0.4%
	Cervical (Class V)	71.8%	24.8%	2.3%	1.1%	0%
Glass ionomer	Occlusal (Class I)	68.0%	21.4%	5.3%	3.0%	2.3%
	Two-surface occlusoproximal (Class II)	44.1%	29.7%	12.5%	8.7%	4.9%
	Three-surface occlusoproximal (Class II)	36.5%	31.6%	16.0%	10.3%	5.7%
	Cervical (Class V)	70.9%	23.0%	4.5%	0.8%	0.8%
Inlays	Occlusal (Class I)	48.7%	26.8%	13.6%	9.1%	1.9%
	Two-surface occlusoproximal (Class II)	49.2%	32.7%	9.4%	8.6%	0%
	Three-surface occlusoproximal (Class II)	47.4%	30.8%	12.0%	9.4%	0.4%

Table 4 Respondents were asked if they agreed with the following statements. (99% to 100% of subjects responded to these questions, that is, n = 264 to 267 here)

	Strongly disagree	Disagree	Neither agree nor disagree	Agree	Strongly agree
I feel confident in my technical ability to use posterior composites for restorations where there is an unretentive cavity or cavities	6.7%	4.1%	7.5%	52.2%	29.5%
Having to use posterior composites to routinely restore teeth would cause appointment delays in my practice	10.0%	10.0%	14.1%	30.0%	35.9%
Having to use posterior composites to routinely restore teeth would have negative financial implications for my practice	7.9%	9.7%	22.55	23.6%	36.3%
If I had to use posterior composite for restorations tomorrow I would be concerned about the safety of my patients following their treatment	40.1%	33.7%	17.6%	5.2%	3.4%
Providing posterior composites is too expensive for NHS funded dentistry	4.1%	9.7%	19.1%	27.0%	40.1%
Amalgam restorations last longer than posterior composites	3.3%	13.7%	25.6%	38.9%	18.5%
My patients are not suitable for placing posterior composites	13.4%	28.3%	35.3%	17.5%	5.6%
I would be confident delegating the placement of posterior composites to a therapist	12.8%	24.8%	31.6%	25.9%	4.9%
I am not confident placing posterior composites in cavities with subgingival margins	4.9%	17.2%	14.9%	42.2%	20.9%
I am not confident placing posterior composites in ‘deep’ (close to pulp) cavities	15.2%	43.0%	15.2%	18.5%	8.1%
I have not had sufficient training to allow me to place posterior composites properly	37.5%	40.1%	14.1%	6.3%	1.9%
If amalgam were discontinued in UK dental practice, I would struggle to provide fillings for my patients	23.0%	29.7%	18.6%	20.8%	7.8%

Table 5 Techniques used for protection of operatively exposed dentine. (97% to 99% of subjects responded to these questions, that is, n = 259 to 265 here)

	None ('total etch')	Calcium hydroxide + glass ionomer cement Glass ionomers cement only	Glass ionomers cement only	Biodentine or MTA	I don't place posterior composites in this situation
Shallow cavities (outer third of dentine)	90.3%	1.9%	6.0%	0.4%	1.5%
Moderate cavities (middle third of dentine)	56.0%	16.9%	24.8%	1.1%	1.1%
Deep cavities (inner third of dentine)	19.9%	44.8%	24.9%	5.0%	5.4%

Wooden wedges were the most commonly selected for wedging (88.4%), followed by plastic or flexible wedges (62.3%) and light transmitting or clear wedges (33.1%). (Percentages quoted above are again with respect to those subjects that responded, where the response rates to these questions were 79.6%, 57%, and 44.8%, respectively.)

Materials selection

Of the 93.3% of subjects that responded to this question, 'etch and rinse' adhesive was used by 73.4% of respondents, while 26.6% reported use of a 'self etch' system.

Of the 97% of subjects that responded to a question in posterior cavities, 36.3% of respondents reported use of a bulk-fill resin composite. Of these, 80.5% reported they found bulk-fill resin composites to be 'better' (ease of placement, more predictable, less post-operative sensitivity) than traditional composites.

Light curing units (LCUs)

LEDs were the most common LCUs (95.7% reported use of these), followed by quartz tungsten halogen (41.5%), and plasma arc (6.0%). (Percentages quoted above are again with respect to those subjects that responded, where the response rates to these questions were 85.6%, 39.3%, and 30.7%, respectively.)

Discussion

The past twenty years have seen many, different advances in the implementation of minimally invasive techniques for the restoration of posterior teeth, facilitated mainly by the development of predictable application of posterior resin composites. Supported by an appropriate evidence base to demonstrate that, where used appropriately, the longevity

of posterior resin composites matches or exceeds that of amalgam, meaning that more minimally invasive and less destructive techniques may be selected.⁹⁻¹¹ From a time over 20 years ago when amalgam was considered the only material for direct restoration of posterior teeth,¹² European-level guidance now recommends that resin composites should be the preferred material for restoring posterior teeth.¹³ Furthermore, dental school teaching in this area has advanced significantly over the past 20 years.¹⁴ From a time in the late 1990s, where as few as one-in-ten dental students graduated with clinical experience at placing posterior resin composites, in 2015 the ratio of posterior composites to amalgam placed by dental students is 2:1.^{15,16} The more notable examples of published evidence to support the high success rates of posterior resin composites come primarily from the Nijmegen group, who have followed up restorations placed in primary care over a 12+ year period.⁹ Other studies, such as the US-based Bogacki study of dental insurance claims shows that posterior resin composites and amalgams have a high (>90%) and comparable success rate as long as the patient remains with the same dentist, and that this success rate drops for both restoration types when the patient changes dentists.¹⁷ Another notable study of US-army recruits shows that amalgam and posterior resin composites feature comparable replacement rates (that is, posterior resin composites were not replaced more frequently than amalgams).¹⁸

Interesting patterns emerge within the data reported in this study. The cohort of responding dentists are mainly UK-trained and they work in Wales, which contains significant areas of social and economic disadvantage with correspondingly high levels of caries experience. Within this group of dentists, it appears that

73.3% of respondents often, or always, place amalgam restorations for NHS-funded dentistry in adults where two or more posterior restorations are required. However, this proportion drops to 27% for the same scenario in children, and 19.4% for privately funded care for adults. This result highlights the effect of funding on the choice of material, and it is in keeping with other areas such as the provision of bridgework for replacement of missing maxillary molars compared to no treatment which was more likely for private patients when compared to NHS funded care.¹⁹ Such decisions, likely reflect the increased cost of resin composite materials, when compared to amalgam, as well as the costs of associated technology and instruments such as bonding agents, matrices, and light curing units. These considerations are further revealed in findings such as respondents estimating that it would take 1.61 times as long to place a resin composite, rather than an amalgam, in a moderately deep two-surface mesio-occlusal cavity in lower first molar, and that NHS fees would have to increase by 57.5% (95% CI: 50.4% to 64.6%) to support placing resin composites routine. There is a challenge here for stakeholders, funders and commissioners of NHS-funded dentistry. While the short-term costs and initial placement costs of posterior resin composites are higher when compared to amalgam, the 'lifetime costs' for the tooth may well be lower in terms of more minimally invasive treatments, more ease of repair of composite rather than amalgam, and potential avoidance of the consequence of more destructive treatment such as the need for root canal treatments and crowns. In contrast, a UK-wide survey of contemporary dental practice (carried out in 2015), found minimal perceived effects in terms of time or cost among their respondent group in terms of moving from amalgam to composite, possibly indicating different attitudes and practice circumstances in Wales.²⁰ The divergence of opinion between the results of this survey and the results of this paper illustrates the complexity of the challenges facing the profession in this difficult area. Health economic modelling/analysis is recommended to investigate these differences and the lifetime effects of changing from amalgam to resin composite.

Encouragingly, high levels of reported confidence are seen in relation to the placement of resin composites in posterior teeth among respondents, albeit these levels reduce as the complexity of the cavity increases. This high level of confidence suggests that many practitioners are ready to embrace and apply

techniques for the placement of posterior resin composites in an appropriate setting. It is noted that the placement of amalgam in children is much lower than in adults (27% for 'often' and 'all of the time' for children, while the corresponding proportion for adults was 73.3%). This is also welcomed and encouraged, in terms of avoiding developing or creating another 'heavy metal generation'.

Information collected on the use of techniques associated with placing posterior composites suggest encouragingly that respondents are engaging with current, evidence-based approaches to posterior resin composite placement. Much more consistency is seen in relation to the use of bases to no liners or bases for the protection of operatively exposed dentine for shallow and moderately deep cavities compared to previous similar surveys of general dental practitioners or dental school teaching.^{6,8,21,22} This is to be welcomed. Laboratory-based research and recent *ex-vivo* modelling has demonstrated that etching (with phosphoric acid or total etch) rather than placing a base (for example, glass-ionomer cement) is preferable for inducing dental pulp stem cells to differentiate into odontoblasts and promote 'auto-repair' of dentine.²³ (This finding has yet to be demonstrated in clinical studies.) While a proportion of respondents were concerned about post-operative sensitivity associated with posterior resin composites, clinical studies, such as that of Burrow *et al.*,²⁴ have demonstrated that where placed appropriately the incidence of post-operative sensitivity with posterior resin-composites is low, even in a cohort of young adults, and is independent of the use of a base, or not, or choice of bonding system. As well as this, the use of circumferential and section metal matrices and associated flexible, plastic or wooden wedges appear more popular than clear or light-transmitting matrices or wedges. The literature shows that the most favourable results for occlusoproximal restorations resin composites are achieved with sectional metal matrices, and to a lesser extent circumferential metal matrices.²⁵ It is of concern that 45% of respondents reported use of clear/light-transmitting systems. The use of such techniques is associated with open proximal contacts and significant overhang formation and their use has been discredited for almost 15 years.²⁶ There is also emerging use of 'bulk-fill' resin composite materials (36.3% of respondents). These techniques are still developing, but are supported by developing clinical evidence.²⁷ Their ease of

application may address some of the concerns relating to predictability and chairside time spent when moving from amalgam to posterior resin composite placement.

As with all surveys, caution is advised when interpreting the results. The response rate for this survey (40.4%) is low. Despite the follow-up mailings, the response is lower than the usually accepted 67% response rate (based on an average of response rates seen in published surveys).²⁸ That said information has been captured from a large group of primary care practitioners at an important time in dental practice (that is, at the beginning of the phase-down of dental amalgam). The findings of this study should be of interest to many in, and associated with the dental profession, including dental materials companies and the funders and commissioners of NHS-funded dental services.

Conclusion

This study has demonstrated that amalgam remains the material of choice for restoring posterior teeth in adults for NHS funded care among respondent dentists. While dentists are knowledgeable and they embrace new techniques for posterior resin composite placement, funding arrangements in NHS dentistry appear to be a barrier to increasing use of resin composite in posterior teeth. Policy makers, funders and commissioners of NHS-funded dental services are encouraged to reflect on the findings of this study against the backdrop of the Minamata Treaty.

Acknowledgements

This study was funded by a grant from the Wales School for Primary Care Research, for which CDL and IGC were co-Principal Investigators. The assistance of the funder, and in particular Mr Robyn Davies and Michaela Gal, is gratefully appreciated. We are also very grateful to those practitioners who took time from their busy schedules to complete the questionnaire.

1. Adult Dental Health Survey 2009. Available online at <https://digital.nhs.uk/data-and-information/publications/statistical/adult-dental-health-survey> (accessed 22 May 2018).
2. Burke F J, Lucarotti P S. How long do direct restorations placed within the general dental services in England and Wales survive? *Br Dent J* 2009; **206**: E2.
3. Brunton P A, Burke F J, Sharif M O *et al*. Contemporary dental practice in the UK in 2008: aspects of direct restorations, endodontics and bleaching. *Br Dent J* 2012; **212**: 63–67.
4. Lynch C D, Wilson N H F. Managing the phase-down of amalgam. Part I: educational and training issues. *Br Dent J* 2013; **215**: 109–113.
5. Lynch C D. *Successful posterior resin composites*. London: Quintessence Publishing Co., 2008.

6. Gilmour A S M, Latif M, Addy L D, Lynch C D. Placement of posterior resin composite restorations in United Kingdom dental practices: techniques, problems, and attitudes. *Int Dent J* 2009; **59**: 148–154.
7. Mjör I A, Wilson N H F. Teaching of Class I, Class II direct resin composite resin restorations: results of a survey of dental schools. *J Am Dent Assoc* 1998; **129**: 1415–1420.
8. Lynch C D, McConnell R J, Wilson N H F. Trends in the placement of posterior resin composites in dental schools. *J Dent Educ* 2007; **71**: 430–434.
9. Opdam N J M, Bronkhorst E M, Loomans B A C, Huysmans M-C. 12-year survival of resin composite vs amalgam restorations. *J Dent Res* 2010; **89**: 1063–1067.
10. Da Rosa Rodolpho P A, Donassollo T A, Cenci M S *et al*. 22-year clinical evaluation of the performance of two posterior composites with different filler characteristics. *Dent Mater* 2011; **27**: 955–963.
11. Pallesen U, van Dijken J W, Halken J, Hallonsten A-L, Höigaard R. Longevity of posterior resin composite restorations in permanent teeth in Public Dental Health Service: a prospective 8 years follow up. *J Dent* 2013; **41**: 297–306.
12. Wilson N H F, Dunne S M, Gainsford I D. Current materials and techniques for direct restorations in posterior teeth. Part 2: resin composite systems. *Int Dent J* 1997; **47**: 185–193.
13. Lynch C D, Opdam N J, Hicel R *et al*. Guidance on the use of resin composites for direct restoration of posterior teeth: Academy of Operative Dentistry European Section. *J Dent* 2014; **42**: 377–383.
14. Wilson N H, Lynch C D. The teaching of posterior resin composites: planning for the future based on 25 years of research. *J Dent* 2014; **42**: 503–516.
15. Wilson N H F, Mjör I. The teaching of class I and class II direct resin composite restorations in European dental schools. *J Dent* 2000; **28**: 15–21.
16. Lynch C D, Blum I R, McConnell R J, Frazier K B, Brunton P A, Wilson N H F. Teaching posterior resin composites in UK and Ireland dental schools: do current teaching programmes match the expectation of clinical practice arrangements? *Br Dent J* 2018; **224**: 967–972.
17. Bogacki R E, Hunt R J, del Aguila M, Smith W R. Survival analysis of posterior restorations using an insurance claims database. *Oper Dent* 2002; **27**: 488–492.
18. Laccabue M, Ahlf R L, Simecek J W. Frequency of restoration replacement in posterior teeth for US Navy and Marine Corps Personnel. *Oper Dent* 2014; **39**: 43–49.
19. Patel P M, Lynch C D, Sloan A J, Gilmour A S M. Treatment planning for replacing missing teeth in UK general dental practice: current trends. *J Oral Rehabil* 2010; **37**: 509–517.
20. Wilson N H F. Personal communication.
21. Blum I R, Wilson N H F. An end to linings under posterior composites? *J Am Dent Assoc* 2018; **149**: 209–213.
22. Blum I R, Younis N, Wilson N H F. Use of lining materials under posterior resin composite restorations in the UK. *J Dent* 2017; **57**: 66–72.
23. Sadaghiani L, Brownrigg-Gleeson H, Youde S, Waddington R J, Lynch C D, Sloan A J. Growth factor liberation and DPSCs response following dentine conditioning. *J Dent Res* 2016; **95**: 1298–1307.
24. Burrow M F, Banomyong D, Harnirattaisai C, Messer H H. Effect of glass-ionomer cement lining on postoperative sensitivity in occlusal cavities restored with resin composite – a randomized clinical trial. *Oper Dent* 2009; **34**: 648–655.
25. Loomans B A, Opdam N J, Roeters F J, Bronkhorst E M, Burgersdijk R C, Dörfer C E. A randomized clinical trial on proximal contacts of posterior composites. *J Dent* 2007; **34**: 292–297.
26. Müllejjans R, Badawi M O, Raab W H, Lang H. An *in vitro* comparison of metal and transparent matrices used for bonded class II resin composite restorations. *Oper Dent* 2003; **28**: 122–126.
27. Hickey D, Sharif O, Janjua F, Brunton P A. Bulk dentine replacement versus incrementally placed resin composite: A randomised controlled clinical trial. *J Dent* 2016; **46**: 18–22.
28. Tan R T, Burke F J. Response rates to questionnaires mailed to dentist. A review of 77 publications. *Int Dent J* 1997; **47**: 349–354.