The management of deep caries in UK primary care: A nationwide questionnaire-based study

David Edwards1, Oliver Bailey2, Simon Stone2, Hal Duncan3

1Restorative Department, Newcastle Dental Hospital, Newcastle upon Tyne, UK
2School of Dental Sciences, Newcastle University, Newcastle upon Tyne, UK
3Division of Restorative Dentistry and Periodontology, Trinity College Dublin, Dublin Dental University Hospital, Dublin, Ireland

Abstract

Aim: To investigate current approaches and attitudes towards the management of deep caries in primary dental care within the United Kingdom (UK).

Methodology: Open distribution of an electronic questionnaire survey was undertaken to primary care dental professionals working in publicly funded National Health Service [NHS], privately funded, military and community dental services. Demographic variables investigated included the following: place of qualification, method of remuneration, level of restorative training, materials available, years qualified, appointment length and clinician type. Management variables focussed on case-based scenarios. Univariate analyses of responses to questions were undertaken using χ² tests with sequential Bonferroni correction. Variables with a statistical relationship of \( p \leq .2 \) were selected for binary logistic regression modelling.

Results: A total of 657 responses were received. Practitioners with formal postgraduate qualifications (PGQ) were more likely (OR, 95%CI) to undertake further tests to aid diagnosis including: gaining a patient history (1.80, 1.01–3.20), periapical radiography (1.43, 1.01–2.03), cold pulp testing (2.079, 1.46–2.97) and electric pulp testing (1.65, 1.02–2.65). Rubber dam was infrequently used for deep caries management (29.2%). Non-NHS practitioners were much more likely to use rubber dam (3.40, 2.15–5.37), as were those that had completed PGQ (2.24, 1.48–3.38). Non-selective caries removal was used in deep caries by 41.4% of practitioners. Indirect pulp caps were carried out by 56.7% of practitioners. NHS practitioners were more likely to place calcium hydroxide (3.74, 1.97–7.15), whilst non-NHS practitioners were more likely to place calcium silicate cements (CSCs) (3.303, 1.71–6.38) as were non-UK graduates (5.63, 2.47–12.86) and those with PGQ (2.12, 1.17–3.87).

Conclusions: This UK survey highlights significant variation in the management of deep caries. There is lack of consensus regarding the use of a standard systematic approach to diagnosing disease, with a reliance on history and tests with poor specificity. Non-selective caries removal for managing deep carious lesions remains common, with low rubber dam compliance underlining a lack of asepsis. Notably, a significant number of practitioners placed indirect pulp caps, but CSCs and GIC were not commonly used. At present, although clear guidelines are available this is not translating into consistent
INTRODUCTION

The management of deep caries continues to evolve and divide opinion (Bjørndal et al., 2019; Ricucci et al., 2019). Deep caries may be defined radiographically as that reaching the inner quarter of dentine, whilst extremely deep caries extends radiographically through the entire thickness of dentine (ESE, 2019). In the 1960s, the concept of a superficial ‘caries-infected zone’ and deeper ‘caries-affected zone’ within a carious lesion was reported (Fusayama et al., 1966). The potential of the ‘caries-affected zone’ to remineralize has also been long established (Kato & Fusayama, 1970; Miyauchi et al., 1978). These landmark studies resulted in a shift in caries management, from complete surgical excision of the lesion, to selective (incomplete) caries removal techniques. By removing the caries-infected zone, the bacterial load can be significantly reduced, a concept critical to the maintenance of pulp vitality (Kakehashi et al., 1965; Reeves & Stanley, 1966). The relatively intact dentine matrix in the caries-affected zone is maintained, which can subsequently remineralize, with the dentine–pulp complex able to increase the residual dentine thickness by the process of reactionary and reparative dentinogenesis (Duncan et al., 2019; ESE, 2019).

Strategies for managing the deep carious lesion were recently defined in the European Society of Endodontology (ESE) position statement on the management of deep caries and the exposed pulp (ESE, 2019) and also by the International Caries Collaboration Consensus (Innes et al., 2016). Both ‘stepwise excavation’ and ‘selective caries tissue removal in one-stage’ fall within the remit of vital pulp treatment (ESE, 2019). This important distinction highlights the aim of treatment, which is to maintain pulp vitality and promote the deposition of reactionary tertiary dentine to reduce the likelihood of further injury. A Cochrane review demonstrated that selective caries removal techniques significantly reduced the risk of pulp exposure (Ricketts et al., 2013), with others highlighting a reduced risk of vitality loss (Bjørndal et al., 2010, 2017; Orhan et al., 2010) and reduced incidence of pulpal symptoms (Barros et al., 2020; Schwendicke et al., 2013). Although, non-selective techniques may be considered overtreatment (Schwendicke et al., 2016), other prominent researchers continue to advocate them (Ricucci et al., 2019). Recently, research has reinforced the earlier findings of Reeves and Stanley (1966), identifying that in radiographically defined deep caries lesions, bacteria are largely confined to dentine, but in extremely deep caries lesions, bacteria in contact with the pulp were generally present (Demant et al., 2021). This would tend to reinforce selective approaches for caries removal in deep caries, but question the applicability of such approaches for extremely deep lesions, where complete caries removal and appropriate pulp management may be more appropriate.

Traditionally, pulp inflammation is diagnosed dichotomously as ‘reversible’ or ‘irreversible’ (AAE, 2013). Recently, alternative diagnoses have been proposed which acknowledge and reflect that inflammation is a continuum from pulp health through to necrosis (Hashem et al., 2015; Wolters et al., 2017). Selective caries removal techniques have currently only been shown to be appropriate for teeth with ‘healthy’ or ‘reversibly’ inflamed pulps. Recently, these clinical diagnoses have been shown to align well with histological diagnoses in the majority of cases (Ricucci et al., 2014); therefore, obtaining comprehensive information from teeth with deep caries is crucial in order to guide decision-making in vital pulp treatments, including deep caries management (ESE, 2019). This requires a detailed history of signs and symptoms, appropriate radiographic assessment and findings from further tests including the identification of allodynia through percussion and pressure testing, and responses from thermal and electric pulp testing (Allison et al., 2020).

In order to use selective caries removal techniques appropriately, the use of rubber dam and focus on an aseptic technique are highly recommended (ESE, 2019). Previous studies investigating rubber dam use in the UK have shown it to be infrequently used, even during endodontic procedures (Gemmell et al., 2020; Whitworth et al., 2000). Tooth disinfection, as part of an aseptic protocol, is also proposed for deep caries management in the ESE position statement (ESE, 2019), a practice which although lacking in evidence from clinical outcome studies may be appropriate particularly when the pulp is exposed (Ballal et al., 2020).

Indirect pulp capping, first described in the 1960s, is essentially a complete caries removal technique followed by the application of material overlying the pulp (Kerkhove et al., 1967). More recently, it has been defined as, ‘application of a biomaterial onto a thin dentine barrier in a one-stage carious-tissue removal technique generally to hard dentine’ (ESE, 2019). This has evolved from the ESE’s earlier definition which was a ‘procedure in which a pulp is covered with a protective dressing or cement placed over a thin partition
of remaining dentine’ (ESE, 2006). The use of a biomaterial is the critical evolution in this definition, having both sealing ability, which will minimize monomer and bacterial ingress, as well as the ability to induce dentinogenesis. This approach is more invasive than selective techniques, aligning more closely with complete caries removal, but may involve leaving a small amount of caries-affected dentine overlying the pulp. Evidence is currently equivocal between the use of glass ionomer cement (GIC) and calcium silicate cements (CSCs) or conventional mineral trioxide aggregate (MTA), as at present, there is an absence of longer-term studies (Hashem et al., 2019). There is certainly sufficient evidence to support the use of CSCs over calcium hydroxide liners (CH) for indirect pulp caps, the latter being deemed unsuitable (Petrou et al., 2014).

The use of vital pulp treatments in permanent teeth has previously been explored in a questionnaire study of primary and secondary care practitioners in Wales (Chin et al., 2016). The authors concluded that CSCs were more commonly used in hospital compared with general practice; however, the management of deep caries was not explored in the study (Chin et al., 2016). Internationally, Schwendicke et al. (2017) explored deep caries management, finding significant variation in views and management strategy by country (Schwendicke et al., 2017). The majority of French and German practitioners preferred non-selective caries removal, in contrast to Norwegian dentists who largely used a stepwise approach.

The current approaches to managing deep caries in the UK, including the application of current consensus statements (ESE, 2019; Innes et al., 2016), have not previously been explored in a UK primary care setting. Analysing practitioners’ attitudes and approaches to deep caries management will enable improvements in the delivery of undergraduate and postgraduate education, as well as identifying barriers to the adoption of guidelines. Ultimately, this will lead to better outcomes for patients. A national cross-sectional survey was therefore undertaken, the aims of which were (a) to identify and quantify approaches to the management of deep caries, rubber dam use, cavity disinfection, use of linings and access to materials by UK dentists and dental therapists for deep caries management and (b) to determine any differences between subgroups. The data presented in this study focus on caries management and the non-exposed pulp, and are part of a larger project, the VITALITY study (VITAL Pulp Therapies In UniTed Kingdom Primary Care), which aims to explore attitudes and ability to provide vital pulp treatments in primary care in the UK.

MATERIALS AND METHODS

This report followed the STROBE guidance and checklist (von Elm E et al., 2008). A questionnaire exploring the provision and attitudes of primary dental care practitioners towards vital pulp treatment was designed by the research team and distributed using Jisc Online Surveys (Jisc, 2021) (Supporting information). A combination of open and closed questions was used, with clinical scenarios included based on history, clinical features and radiographs. The questionnaire was piloted with various stakeholder groups throughout development and received ethical approval by Newcastle University Research Ethics Committee (REF: 1224/2020).

The e-survey was distributed widely by open sampling through Local Dental Committees in the UK nations (LDCs), private dental payment plan providers (simplyhealth), corporate bodies (Bupa Dental, Mydentist), the Northern Dental Practice Based Research Network (NDPBRN), dental associations (British Society of Dental Hygiene and Therapy and the British Association of Private Dentists) and social media (Facebook groups including ‘For Dentists, by Dentists’, ‘Young Dentists’, ‘UK Dentistry’, ‘Scottish Dental Network’, ‘North East Dentists’ and ‘Restorative Dentistry For All’). Once confirmation was received from LDC chair people that they would distribute the survey, a reminder was sent to confirm distribution. With all other approaches, the e-survey was distributed twice. Primary dental care participants included Dental Therapists (DTs), General Dental Practitioners (GDPs), Dentists with a Special Interest (DwSI) and Specialists working full- or part-time in primary dental care. Dental professionals working in the public and private sector – National Health Service (NHS), private, military and community dental services (CDS) – were targeted. This enabled as broad a representation as possible from all sectors of dental primary care. The structure and governance of NHS dentistry vary within the regions of the UK, with some using a mixed model capitation, others a fee per item and also a banded structure where fees are paid for treatment groups for example, non-surgical periodontal management, direct restorations and root canal treatments fall within one band of co-payment (NHS, 2020a; NHS, 2020b; NIDIRECT, 2020). Further models are also currently being piloted (GOV.UK, 2018). DTs may provide care under the prescription of a dentist or via direct access and are a growing workforce in the UK (CFWI, 2014; GDC, 2013, 2021). CDS practitioners work within the NHS fee payment system to provide care to patients with special needs or patients with problems accessing care (NHS, 2020c). As a result of these variations, attempts were made to make the sample as diverse geographically as possible, which is why an open sampling frame was favoured.

Questionnaire distribution was planned for March 2020 but postponed due to the COVID-19 pandemic, and subsequently occurred between 02/09/2020 and 03/11/2020. Duplicate participant submissions were checked and removed by verification of email addresses. Data were pseudonymized before analysis, and no attempt was made during analysis to identify participants.
Power calculation

A previous survey exploring the use of rubber dam during root canal treatment in the UK found 23.4% of ‘younger’ graduates used rubber dam for endodontics compared to 12.9% of ‘older’ graduates (Whitworth et al., 2000). Based on an enrolment ratio of 1 in each group, type 1 error of 0.05, type 2 error of 0.2 and power of 0.8, a minimum survey respondent sample of at least 420 was required.

Based on a recent UK e-survey, a response rate of 6%–14% may be anticipated (Bailey et al., 2020). This would mean at least 3000–7000 primary care providers would need to be targeted to reach the minimum respondent sample using open frame sampling.

Data analysis

All data were imported, cleaned, coded and analysed using SPSS (Version 25; IBM). Descriptive statistics were used to explore key themes within the research project. Free text answers underwent thematic analysis (Braun & Clarke, 2006). Variables investigated included place of qualification (UK/non-UK), method of remuneration (NHS/non-NHS), access to materials, years since qualification, time for emergency appointments and clinician type (dentist or DT). DTs were excluded from analysis for any procedures which were outside of their scope of practice in the UK (GDC, 2013). NHS providers included community dentists (who work within the NHS Units of Dental Activity [UDA] system) and primary care dentists/DTs that worked ≥70% in NHS dentistry; non-NHS providers included mixed dentists/DTs (<70%–≥30% NHS), private dentists/DTs (≤30% NHS), military dentists/DTs and ‘other’ salaried practitioners. Index of multiple deprivation (IMD) quintile was calculated using participants’ work postcode (Cymru, 2019; GOV.Scot, 2020; GOV.UK, 2019; NISRA, 2017). Where CSCs were analysed, this includes traditional Portland cement-based MTA unless specified (Camilleri, 2020).

Statistical analysis

Univariate analyses of differences in responses to questions were undertaken using χ² tests with sequential Bonferroni correction (Rice, 1989). Exact p-values were calculated where possible, but Monte Carlo estimates with confidence levels of 99% of exact p-values were calculated where specified. Binary logistic regression modelling was performed without assumption of predictive variables (Field, 2017). Therefore, variables with a statistical relationship of p ≤ .2 were selected for stepwise variable regression analysis (Labopin, 2003). Backward likelihood ratio (LR) was used to build models of key predictive variables. Cook’s distance, leverage values and DF Beta were checked for each model to identify and exclude influential cases. Missing value analyses were undertaken to ensure these cases did not significantly affect outcome.

RESULTS

Valid responses were received from 657 participants. Nine participants were excluded because they worked exclusively in secondary care (dental hospital) and did not meet the inclusion criteria. Responses were received from graduates of all 17 UK dental schools. Participant demographics are shown in Table 1.

Caries and pulp diagnosis

When shown a series of bitewing radiographs (Supporting information), the majority of participants (633/648; 97.7%) could identify ‘deep caries’. After a bitewing radiograph of ‘deep caries’ was displayed, the majority of participants said they would ‘always’ or ‘usually’ seek additional information before restoring the tooth (463/559; 82.8%). The majority of respondents would evaluate pre-operative symptoms (96.1%) and undertake percussion testing (83.9%), whilst approximately half would undertake cold testing (50.2%); however, electric pulp testing (EPT) was rarely used (15.6%) (Table 2).

Regression analysis demonstrated that good predictors of clinician type likely to gain additional information on pre-operative symptoms were those with formal post-graduate qualifications in restorative dentistry (PGQ) compared to those without (OR = 1.80 [1.01–3.20]), as well as dentists more recently qualified compared to more experienced dentists (OR = 3.15 [1.64–6.06]) (Table 3). The only good predictor of the likelihood of operators taking a periapical radiograph was dentists with PGQ compared to those without (OR = 1.43 [1.01–2.03]).

Regression analysis exploring pre-operative cold testing highlighted that non-UK graduates compared with UK graduates (OR = 2.58 [1.35–4.91]), and dentists with PGQ compared with those without (OR = 2.08 [1.46–2.97]) were statistically significantly more likely to perform cold testing (Table 3). Good predictors of operators using EPT included practitioners that worked principally in non-NHS practice, whose odds were higher than those working principally within the NHS (OR = 2.36 [1.43–3.92]), and dentists with PGQ compared to those without (OR = 1.65 [1.02–2.65]) (Table 3). Practitioners who worked principally in the NHS had higher odds of undertaking percussion testing than practitioners who worked mainly outside the NHS (OR = 1.70 [1.10–2.62]) (Table 3).
Caries removal techniques in teeth with deep caries

When shown a bitewing of ‘deep caries’ (Supporting information), 286/636 (29.2%) stated that they would always or usually place a rubber dam for carious-tissue removal (Table 4). There was an upward trend in the use of rubber dam as the proportion of private dentistry undertaken increased, with predominantly NHS being lowest (32/298; 11.7%), mixed NHS/private practitioners (16/48; 33.3%), predominantly private (83/186; 44.6%), military/other salaried (36/71; 50.7%), a finding that was statistically significant ($p \leq .001$) (Table S1). Regression analysis demonstrated that dentists who work principally outside the NHS used rubber dam 3.4 times more compared with dentists who worked principally within the NHS (OR = 3.40 [2.15–5.37]). Similarly, dentists who had completed PGQ compared with those who had not (OR = 2.24 [1.48–3.38]), and practitioners with longer (>20 mins) appointments compared to shorter (≤20 mins) appointments (OR = 2.71 [1.77–4.14]) were more likely to use rubber dam (Table 3).

When shown a bitewing radiograph of deep caries (Supporting information), respondents described a number of approaches for caries removal. Complete (non-selective) caries removal was undertaken always or usually by 41.4% of respondents, selective caries removal by 41.4% of respondents and stepwise caries removal by 14.7% of respondents. Both non-selective techniques and stepwise techniques were statistically significantly undertaken more by non-UK graduates than UK graduates (Table 4). No variables were identified for regression modelling for the use of selective caries removal techniques, although dentists that had qualified outside the UK were more likely to use non-selective caries removal techniques (OR = 2.34 [1.32–4.17]) (Table 3).

Disinfection of the dentine in deep caries management was rarely undertaken, with only 13.4% respondents reporting this practice (Table 4). NaOCl was most commonly used (35/83 [42.2%]), followed by CHX (27/83 [32.5%]), with acid etch (10/83 [12%]) with other methods (11/83 [13.3%]) less commonly reported. Regression analysis showed the odds of dentine disinfection were higher by non-NHS practitioners compared to those who work mainly within the NHS (OR = 3.79 [2.11–6.80]), dentists who had completed PGQ compared with those who had not (OR = 2.38 [1.46–3.89]), and dentists who were non-UK graduates compared to those who were UK graduates (OR = 4.37 [2.17–8.78]) (Table 3).
Use of linings

When participants were given a scenario where they had removed deep caries, there was no pulp exposure and they intended to restore the tooth with a direct composite (Supporting information), 366/645 (56.7%) said they would apply a lining. Regression analysis identified that the odds of linings being used were higher in non-UK graduates than UK graduates (OR = 2.13 [1.15–3.95]), and dentists who had completed PGQ compared to those who had not (OR = 1.71 [1.21–2.41]) (Table 3).

Of respondents who would place a lining, resin-modified glass ionomer (RMGIC) was most commonly used (47.0%), with GIC (20.9%), CSCs (19.4%) and CH (16.0%) less commonly used (Table 4). Regression analysis identified the odds of using CSCs was higher in non-UK graduates than UK graduates (OR = 5.63 [2.47–12.86]), practitioners who worked mainly outside the NHS compared to those who worked principally within the NHS (OR = 3.30 [1.71–6.38]) and those with PGQ compared to those without (OR = 2.12 [1.17–3.87]) (Table 3). Regression analysis identified no variables that were good predictors of GIC use. Regression analysis showed the odds of practitioners who worked mainly in the NHS using CH were higher than non-NHS practitioners (OR = 3.75 [1.97–7.15]) (Table 3). The odds of respondents using RMGIC were higher for those who had qualified more recently (≤10 years) compared with those qualified for longer (>10 years) (OR = 2.22 [1.42–3.48]), and the odds of non-NHS practitioners were higher compared to practitioners who work mainly within the NHS (OR = 2.26 [1.47–3.47]) (Table 3).

Access to materials

Respondents reported having access to CH lining material (90.7%), RMGIC (70%) and CSCs (38.0%) (Table 5). Specifically, respondents had access to modern CSCs (200/647 [30.9%]) more frequently than traditional MTA (130/647 [20.1%]). Regression analysis identified the odds of having access to MTA or CSCs were higher in non-NHS practitioners compared to those who worked mainly within the NHS (OR = 4.53 [3.12–6.59]), higher where they had undertaken PGQ than those who had not (OR = 2.30 [1.57–3.37]) and higher in respondents who had been qualified >10 years compared those who had not (OR = 1.78 [1.20–2.63]) (Table 3).

There was a statistically significant trend of increased access to CSCs in dental practices located in more affluent postcodes, ranging from 27/111 (27.3%) in the most deprived quintile, to 57/117 (48.7%) in the least deprived quintile (p = .001 [Monte Carlo 95% CI: <0.001–0.002]) (Table S2).
DISCUSSION

This questionnaire-based survey has highlighted that a limited range of diagnostic tests are generally employed in UK primary care, particularly in NHS practice. Rubber dam use during the conservative management deep caries clearly remains low in the UK, but higher than some other European countries (Schwendicke et al., 2017). Practitioners who did not work predominantly within the NHS were experienced in terms of qualifications and who had more time for appointments were more likely to use rubber dam. Non-selective caries removal techniques remain popular in the UK; however, no variables examined within this study were predictive for this approach. This was in contrast to the findings of Schwendicke et al. (2017) who demonstrated that private practitioners were more likely to use non-selective approaches. Limited access to CSCs remains a problem across the UK, with use particularly low in NHS practice. RMGIC was the most commonly used lining, with CSCs and GIC less commonly used.

Demographics

The demographic characteristics of the primary care dentists who responded appear representative of the UK primary care workforce in most respects (Table 1). Just over half (51.3%) of NHS dentistry is provided by females in the UK (NHS, 2020d). The precise split between NHS, mixed and private dental provision in the UK is not currently known, although 24 684 dentists reported

| TABLE 3 | Outcome of backward LR regression analysis |
|---------|-------------------------------------------|
| Sub-group | Odds ratio | 95% Confidence interval | p-value |
| Would gain additional information on pre-operative symptoms in a tooth with deep cariesa | PGQ | 1.80 | 1.01 | 3.20 | .045 |
| would take a periapical radiograph in a tooth with deep cariesa | PGQ | 1.43 | 1.01 | 2.03 | .046 |
| Would conduct cold testing in a tooth with deep cariesa | PGQ | 2.08 | 1.46 | 2.97 | <.001 |
| Would use electric pulp tester for a tooth with deep cariesa | PGQ | 1.65 | 1.02 | 2.65 | .040 |
| Would conduct percussion testing for a tooth with deep cariesa | NHS | 1.70 | 1.10 | 2.62 | .017 |
| Would use rubber dam for caries removal in a tooth with deep cariesa | Non-NHS | 2.36 | 1.43 | 3.92 | .001 |
| Would use non-selective caries removal in deep cariesa | UGT-non-UK | 2.34 | 1.32 | 4.17 | .004 |
| Would disinfect the dentine following deep caries managementa | Non-NHS | 3.79 | 2.11 | 6.80 | <.001 |
| Would use a lining following deep caries managementa | UGT-non-UK | 2.13 | 1.15 | 3.95 | .016 |
| Would use CSC/MTA for lining following deep caries managementa | UGT-non-UK | 5.63 | 2.47 | 12.86 | <.001 |
| Would disinfect the dentine following deep caries managementa | PGQ | 2.38 | 1.46 | 3.89 | .001 |
| Would use calcium hydroxide lining following deep caries managementa | NHS | 3.75 | 1.97 | 7.15 | <.001 |
| Would use resin-modified GIC lining following deep caries managementa | YQ≤10 | 2.22 | 1.42 | 3.48 | .001 |
| Access to CSCs/MTA | YQ>10 | 1.78 | 1.20 | 2.63 | .004 |

Abbreviations: PGQ, postgraduate qualifications in restorative dentistry or allied monospeciality; YQ>10, more than 10 years since qualifying as a dentist; YQ≤10, 10 years or less since qualifying as a dentist; UGT-non-UK, completed undergraduate dental training outside of the UK; non-NHS, provide <70% NHS care; NHS, provide ≥70% NHS care; Long-Em-Apt, >20 min for emergency appointments; GIC, glass ionomer cement; MTA, mineral trioxide aggregate; CSC, calcium silicate cement.

*aParticipants were shown the radiograph under the question heading ‘deep caries management’ reproduced in supporting information.
Participants that would ‘usually’ or ‘always’

| Use of rubber dam | All n (%) | Years since qualification n (%) | Remuneration n (%) | p     |
|-------------------|-----------|--------------------------------|--------------------|-------|
|                   | ≤10       | >10                            | NHS                | Other |       |
| 186/636 (29.2)    | 50/201 (24.9) | 120/402 (29.9) | .213 | 35/298 (11.7) | 135/305 (44.3) | <.001* |

| Non-selective     | 258/626 (41.4%) | 96/226 (42.5) | 161/399 (40.4) | .613 | 133/308 (43.2) | 125/318 (39.3) | .331 |
| Selective         | 260/628 (41.4%) | 94/227 (41.4) | 165/400 (41.3) | 1.000 | 116/305 (38.0) | 144/323 (44.6) | .105 |
| Stepwise          | 91/619 (14.7) | 35/231 (15.2) | 56/416 (13.5) | .557 | 55/317 (17.4) | 36/331 (10.9) | .023* |
| Any Selective (stepwise/ selective) | 331/648 (51.1%) | 119/231 (51.5) | 211/416 (50.7) | .870 | 159/317 (50.2) | 172/331 (52.0) | .694 |
| Use of indirect pulp cap | 366/645 (56.5) | 128/228 (56.1) | 237/416 (57.0) | .868 | 194/315 (61.6) | 172/330 (52.1) | .017* |
| Disinfection of dentine | 87/648 (13.4) | 24/231 (10.4) | 63/416 (15.1) | .094 | 19/317 (6.0) | 68/331 (20.5) | <.001* |

| Of those that would place an indirect pulp cap, respondents would most likely place | 
| RMGIC 173/368 (47.0) | 75/130 (57.7) | 97/237 (40.9) | .002* | 76/195 (39.0) | 97/173 (56.1) | .001* |
| CSC 71/366 (19.4) | 22/129 (17.1) | 49/236 (20.8) | .411 | 25/194 (12.9) | 46/172 (26.7) | .001* |
| GIC 77/369 (20.9) | 21/131 (16.0) | 56/237 (23.6) | .108 | 47/196 (24.0) | 30/173 (17.3) | .125 |
| CH 59/368 (16.0) | 22/130 (16.9) | 37/237 (15.6) | .767 | 45/195 (23.1) | 14/173 (8.1) | <.001* |

Abbreviation: FQ, formal qualifications.

*Significant at the p ≤ .05 level. NHS = Provides ≥70% NHS dentistry, Other = Provides <70% NHS dentistry. FQ = Formal postgraduate qualifications in restorative dentistry or allied monospecialty, D = dentist, T = therapist.

to provide at least some NHS care in 2019–2020 out of 42 470 registrants, highlighting that the sample is representative in this regard (GDC, 2019; NHS, 2020d). The sample does under-represent non-UK graduate dentists (<10% total), with European Economic Area trained dentists currently representing 16% of the UK dental workforce, and providing up to 22% of NHS care (Coughlan & Shah, 2020). DTs make up 8.6% of the dental workforce, making the sample broadly representative in this respect (GDC, 2021). 3.4% of registered dentists are specialists in restorative dentistry or allied monospecialties, demonstrating the sample to be representative (GDC, 2021). Notably, a significant proportion of respondents had completed PGQ. Dental practices were evenly distributed amongst indices of multiple deprivation in the UK.

**Practitioners are not maximizing diagnostic information**

Correct pulp diagnosis is critical in planning the most appropriate intervention, and this should include appropriate periapical radiography and sensibility testing (including EPT and cold testing) in addition to a detailed history (ESE, 2019). Although the majority of respondents would seek additional information when managing a tooth with deep caries, tests such as cold testing, EPT and radiography were less frequently performed. Given the potential for asymptomatic pulpitis and ‘silent’ pulp death (Michaelson & Holland, 2002), a combination of history and clinical indicators should be used, these being shown recently to correlate with the histological pulp diagnosis in the majority of cases (Ricucci et al., 2014). Failing to use cold testing and EPT in cases with deep caries increases the risk of misdiagnosis and incorrect management choice. In diagnostic accuracy studies, both cold testing and EPT have been shown to have good sensitivity and specificity (Gopikrishna et al., 2007), and when used in combination, EPT and cold testing can be even more accurate, correctly identifying up to 96% of necrotic pulps and 92% of vital pulps (Weisleder et al., 2009). In contrast, assessment of allodynia to percussion was frequently undertaken by primary care practitioners, a practice reported to have poor specificity (Pigg et al., 2016).
Patients may not be receiving optimal care

Despite the use of rubber dam and an aseptic technique being recommended in deep caries management (ESE, 2019), rubber dam use was particularly low in the sample. This is comparable to rubber dam use for root canal procedures in the UK, found to be 19%–30.3% (Gemmell et al., 2020; Palmer et al., 2009; Saunders et al., 1999; Whitworth et al., 2000). Rubber dam use for deep caries management internationally has been found to be lower in Norway (12%) and France (18%), but higher in Germany (48%) (Schwendicke et al., 2017). Despite the international variation in rubber dam use, the place of qualification was not a predictor for rubber dam use in this study. Likewise, some studies have reported rubber dam use is higher amongst more recent graduates (Peciuliene et al., 2010; Whitworth et al., 2000) but data from this study do not support that finding.

About two-fifths of practitioners report using non-selective (complete) caries removal for deep caries. This is concerning given the possibility of pulp exposure in the scenario presented to practitioners. There is now a substantial body of evidence to support the use of selective techniques in terms of reducing the risk of pulp exposure, maintaining vitality and reducing post-operative symptoms (Barros et al., 2020; Bjørndal et al., 2010, 2017; Orhan et al., 2010; Ricketts et al., 2013; Schwendicke et al., 2013). High-quality randomized controlled trials have now investigated 5-year maintenance of pulp survival, finding this to be 60%–80% (Bjørndal et al., 2017; Maltz et al., 2018), and statistically significantly better than non-selective techniques (Bjørndal et al., 2017). Selective approaches may be particularly important in primary care, where the low use of rubber dam may limit the ability to provide predictable vital pulp therapies such as direct pulp caps and pulpotomies. It can be speculated here that perhaps some of the resistance to wholesale acceptance of selective removal stems from high profile researchers continuing to strongly advocate for non-selective removal (Ricucci et al., 2019).

Linions were used by almost three fifths of respondents. A recent Cochrane review demonstrated that there was minimal
### TABLE 5 Participants access to materials

| Years since qualification | Remuneration n (%) | Post-graduate training; dentists only n (%) | Place of qualification | Dentist or Therapist |
|---------------------------|--------------------|-------------------------------------------|-----------------------|----------------------|
|                           | All n (%)  | ≤10 | >10 | p | NHS | Other | p | Nil | FQ | p | UK | Non-UK | p | D | T | p |
| CH                        | 588/648     | 220/231 | 386/416 | .004* | 301/317 (95.0) | 287/331 | <.001* | 390/415 | 163/195 | <.001* | 536/592 | 50/54 | .647 | 556/613 | 32/35 | 1.000 |
| RMSGIC                    | 453/647     | 157/231 | 295/415 | .421 | 186/316 (58.9) | 267/331 | <.001* | 286/341 | 137/195 | .778 | 417/591 | 35/54 | .438 | 426/612 | 27/35 | .449 |
| CSC/                       | 246/647     | 57/231 | 189/415 | .001* | 58/316 (18.4) | 188/331 | <.001* | 118/414 | 116/195 | <.001* | 222/591 | 24/54 | .380 | 235/612 | 11/35 | .476 |
| MTA                        | 130/647     | 32/231 | 98/415 | .004* | 29/316 (9.2) | 101/331 | <.001* | 54/414 | 74/195 | <.001* | 112/591 | 18/54 | .014* | 129/612 | 1/35 | .008* |
| CSC                        | 200/647     | 45/231 | 155/415 | .001* | 41/316 (13.0) | 159/331 | <.001* | 97/414 | 93/195 | <.001* | 181/591 | 19/54 | .539 | 190/612 | 10/35 | .852 |

Abbreviation: FQ, formal qualifications.

*Significant at the p ≤ .05 level. NHS = Provides ≥ 70% NHS dentistry, other = Provides <70% NHS dentistry. FQ = Formal post-graduate qualifications in restorative dentistry or allied monospeciality, D = dentist, T = therapeut.
through pulp exposure, bacterial contamination, heat and administration of local anaesthesia. These factors, allied with the increased cost of a second procedure and risk of a patient not returning, would explain the increased popularity of ‘selective caries tissue removal in one stage’ over stepwise techniques in primary care. It is important to highlight that current evidence for the single-stage procedure is limited to well-defined lesions in the pulpal quarter of dentine. Regression analysis did not identify any predictors of caries removal approach, in contrast to Schwendicke et al. (2017), who reported that private practitioners were more likely to undertake complete caries removal.

**Health inequalities**

These data have identified management differences, which may translate into potential health inequalities between NHS and non-NHS provided dentistry. First, NHS practitioners may be less likely to make a correct pulpal diagnosis, being reliant on tests with poor specificity (tenderness to percussion) and being less likely to use a combination tests (EPT and thermal) to improve accuracy.

Secondly, rubber dam was much less likely to be used by NHS practitioners. There may be a perception amongst dentists that the application of a rubber dam takes too long (Whitworth et al., 2000), which may explain why length of appointment was a predictor of use. This may also explain why the use of rubber dam was lowest in the NHS practitioner group, where there may be increased time pressures compared with private practitioners (Bailey et al., 2020). Failing to use rubber dam increases the likelihood of bacterial contamination of the pulp, and should a pulp exposure occur, the tooth is already isolated to enable disinfection and aseptic placement of a direct pulp cap or pulpotomy. Given the significant proportion of practitioners managing deep caries with non-selective techniques, this is of critical importance.

Thirdly, practitioners that worked mainly outside the NHS were more likely to use CSCs for linings, whereas being a mainly NHS practitioner was a good predictor for using CH. In fact, practitioners who worked mainly outside the NHS were 4.5 times more likely to have access to CSCs than those who worked mainly within the NHS. This limitation in access to materials could be due to a number of factors in NHS dentistry including the remuneration structure which means costs and time may be limited. In terms of hard tissue bridge formation, there is evidence that MTA and CH perform similarly following deep caries removal (Leye Benoist et al., 2012; Mathur et al., 2016), but MTA may offer a superior histological (Nair et al., 2008) and clinical outcome in terms of maintenance of vitality (Leye Benoist et al., 2012). Although long-term data are not available, the increased solubility, reduced bond strength and increased leakage compared with MTA (and CSCs) mean the CSCs/MTA should be favoured (Ferk Luketić et al., 2008; Prosser et al., 1982; Torabinejad & Parirokh, 2010).

**Implications for education**

Completing PGQ was an independent predictor for a number of clinical practices which align more closely with current guidelines (ESE, 2019). In terms of diagnosis, PGQ was consistently a good predictor of using a combination of more accurate diagnostic tests which highlights the importance placed on diagnosis in postgraduate training and may highlight deficiencies in the undergraduate curriculum in this respect.

Significant predictors for the use of linings following deep caries removal were PGQ and primary qualification outside of the UK. In terms of material selection, non-UK graduates were five times more likely to use CSC/MTA for linings following deep caries removal, and those with PGQ were more than twice as likely, possibly identifying further deficiencies in the UK undergraduate curriculum in terms of educating dentists of the benefits of CSCs/MTA.

Similarly, the fact that PGQ were a good predictor for rubber dam suggests that the importance of rubber dam use is highlighted in postgraduate courses and may suggest that its importance is not sufficiently emphasized at undergraduate level. Further research into the UK undergraduate curriculum delivery would be beneficial.

**Cavity disinfection**

Tooth disinfection is recommended for deep or extremely deep caries management in the ESE position statement, but discussed under the section on managing pulp exposures, where it may be more appropriate (Ballal et al., 2020; ESE, 2019). There is currently no clinical evidence that cavity disinfection has a positive impact on outcome, with one study finding no difference in 5-year restoration survival (van der Farag et al., 2009). A recent ICCC consensus recommendation suggests their use is questionable (Banerjee et al., 2017), and given their potential for compromising bond strength of adhesive restorations, careful consideration of disinfectant choice is needed, if they are to be used at all (Alrahlah et al., 2020; Dalkilic et al., 2012; Ersin et al., 2009; Sekhar et al., 2017). There is emerging evidence that the bonding of calcium silicate cements to sound dentine may also be compromised where sodium hypochlorite is used, but bonding may actually be enhanced to caries-affected dentine (Meraji et al., 2018). The number of practitioners reporting disinfecting the cavity following deep caries management in the present
study was very low, suggesting it is not common practice in UK primary care. This is in contrast to other countries in Europe, including France and Germany, where it is common practice (Schwendicke et al., 2017).

**Dental therapists as primary care providers**

Although responses from dental therapists were limited ($n = 35$), it is important to note that their approach to deep caries did not differ from dentists in terms of materials selection and access, rubber dam use, caries removal technique and use of linings. This may provide some evidence to support the role of dental therapists within the dental team, including ‘direct access’ whereby they may work without the prescription of a dentist (GDC, 2013).

**LIMITATIONS**

Although this large sample is geographically and demographically representative of UK primary dental care practitioners, various potential sources of bias and error exist. For example, the exact response rate of this questionnaire cannot be readily established using this method. Using open sampling has a risk of self-selection bias, and this is highlighted by the fact that over 30% of respondents had PGQ, which appears high, although the actual figure is not known. As with all questionnaire surveys, recall bias and self-reporting may also be issues. The use of clinical scenarios with radiographs and pictures covers specific situations but cannot account for the complex multidimensional clinical situation which may impact the generalizability of the data.

Within the questionnaire (Supporting information), one question referred to the use of linings following the placement of a posterior composite. Although posterior composites are not likely to be placed under publicly funded NHS care in England and Wales (NHS, 2020b), they may be frequently placed by NHS practitioners on pregnant patients, children or on a private basis.

The COVID-19 pandemic led to the temporary closure of primary care sites, and a decision was made to delay the distribution of the survey. Once distributed, it is possible participation was reduced due to the added pressures imposed by the ongoing COVID-19 pandemic. Similarly, practice had changed for many since the onset of the pandemic, with rubber dam being more routinely used for aerosol-generating procedures. Despite the fact participants were instructed to answer questions ‘pertaining to their normal practice and not the additional measures imposed by the COVID-19 pandemic’, this may have had an effect on their responses.

Finally, although the current approach to deep caries in terms of diagnosis and caries removal technique has been explored, the attitudes behind practitioner’s decision-making are incompletely explored. Therefore, this research provides an insight to current practice in the UK, but further research is needed to explore main drivers in terms of decision-making for caries removal.

**CONCLUSION**

This study has identified considerable variation in the management of deep carious lesions within UK primary care. Many clinicians do not consider asepsis as necessary or follow recent guidance in this area. Practitioners are regularly not employing the full range of diagnostic tests, being reliant on patient history and tests with a poor specificity such as allostynia to percussion. Within this sample, non-selective caries removal for deep caries remained common practice in the UK, and rubber dam usage low. There are indications that a significant number of practitioners place linings after caries management, but GIC and newer materials such as CSCs are less commonly used for this purpose. Clear differences were evident in the responses from groups of practitioners, with NHS practitioners limited in their access to CSCs, rarely using rubber dam and employing less extensive diagnostic testing than their non-NHS counterparts. In the future, there is a pressing need to emphasize the importance of diagnosis, asepsis and the benefits of CSCs at undergraduate and postgraduate level with further exploration of the undergraduate UK curriculum required. Finally, although the benefits of postgraduate education are suggested in this study, there is an urgent need for improved dissemination of current guidelines into primary care.

**ACKNOWLEDGEMENTS**

We would like to thank the following for their assistance in distributing the questionnaire: the British Society of Dental Hygiene and Therapy, the Local Dental Committees of the UK nations, Bupa Dental (in particular Craig Flemming), MyDentist (in particular Jaz Ali), Simplyhealth (Denplan), Defence Primary Healthcare (in particular Colonel Alun Thomas), and Graham Walton (Consultant in Special Care Dentistry). The lead author would also like to thank Professor John Whitworth for his input during the design of this study, and his ongoing academic support.

**CONFLICT OF INTEREST**

The authors have stated explicitly that there are no conflicts of interest in connection with this article.

**AUTHOR CONTRIBUTION**

David Edwards contributed to the design, conduct, data analysis, data interpretation and write-up. Simon Stone contributed to the design, data interpretation and write-up. Oliver
Baily and Hal Duncan contributed to the data interpretation and write-up of the study.

ETHICAL APPROVAL

This project was awarded a favourable opinion from Newcastle University Ethics Committee (1224/2020).

ORCID

David Edwards © https://orcid.org/0000-0002-0462-7463
Hal Duncan © https://orcid.org/0000-0001-8690-2379

REFERENCES

AAE. (2013) Endodontic Diagnosis [WWW document]. http://www.aae.org/specialty/wp-content/uploads/sites/2/2017/07/endodontic-diagnosisfall2013.pdf [Accessed 22nd February 2021].

Allison, J.S., Stone, S.J. & Pigg, M. (2020) The painful tooth: mechanisms, presentation and differential diagnosis of odontogenic pain. Oral Surgery, 13, 309–320.

Alrahlah, A., Niaz, M.O., Abrar, E., Vohra, F. & Rashid, H. (2020) Treatment of caries affected dentin with different photosensitizers and its effect on adhesive bond integrity to resin composite. Photodiagnosis and Photodynamic Therapy, 31, 101865.

Bailey, O., Vernazza, C.R., Stone, S., Ternent, L., Roche, A.G. & Lynch, C. (2020) Amalgam phase-down part 1: UK-based posterior restorative material and technique use. Journal of Dental Research Clinical and Translational Research. https://doi.org/10.1177/2380084420978653

Ballal, N.V., Duncan, H.F., Rai, N., Jalan, P. & Zehnder, M. (2020) Sodium hypochlorite reduces postoperative discomfort and painful early failure after carious exposure and direct pulp capping-initial findings of a randomized controlled trial. Journal of Clinical Medicine, 9(8), 2408.

Banerjee, A., Frencen, I.E., Schwendicke, F. & Innes, N.P.T. (2017) Contemporary operative caries management: consensus recommendations on minimally invasive caries removal. British Dental Journal, 223(3), 215–222.

Barros, M.M.A.F., De Queiroz Rodrigues, M.I., Muniz, F.W.M.G. & Rodrigues, L.K.A. (2020) Selective, stepwise, or nonselective removal of carious tissue: which technique offers lower risk for the treatment of dental caries in permanent teeth? A systematic review and meta-analysis. Clinical Oral Investigations, 24(2), 521–532.

Bjørndal, L., Fransson, H., Bruun, G., Markvart, M., Kjeldgaard, M., Näsman, P. et al. (2017) Randomized clinical trials on deep carious lesions: 5-year follow-up. Journal of Dental Research, 96(7), 747–753.

Bjørndal, L., Reit, C., Bruun, G., Markvart, M., Kjeldgaard, M., Näsman, P. et al. (2010) Treatment of deep caries lesions in adults: randomized clinical trials comparing stepwise vs. direct complete excavation, and direct pulp capping vs. partial pulpotomy. European Journal of Oral Science, 118(3), 290–297.

Bjørndal, L., Simon, S., Tomson, P.L. & Duncan, H.F. (2019) Management of deep caries and the exposed pulp. International Endodontic Journal, 52(7), 949–973.

Braun, V. & Clarke, V. (2006) Using thematic analysis in psychology. Qualitative Research in Psychology, 3, 77–101.

Camilleri, J. (2020) Classification of hydraulic cements used in dentistry. Frontiers in Dental Medicine, 1, 9. https://doi.org/10.3389/fdmed.2020.00009

CFWI. (2014) Securing the future workforce supply. Dental care professionals stocktake. [WWW document]. https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/507376/CFWI_Dental_care_professionals_stocktake.pdf [Accessed 22nd February 2021].

Chin, J.S., Thomas, M.B., Locke, M. & Dummer, P.M. (2016) A survey of dental practitioners in Wales to evaluate the management of deep carious lesions with vital pulp therapy in permanent teeth. British Dental Journal, 221(6), 331–338.

Coughlan, J. & Shah, S. (2020) The impact of Brexit on oral health. British Dental Journal, 229(9), 622–626.

Cymru, L. (2019) Welsh Index of Multiple Deprivation (full Index update with ranks): 2019. [WWW document]. https://гов.wales/welsh-index-multiple-deprivation-full-index-update-ranks-2019 [Accessed 22nd February 2021].

Dalkilic, E.E., Arisu, H.D., Kivanc, B.H., Uctasli, M.B. & Omurlu, H. (2012) Effect of different disinfectant methods on the initial microtensile bond strength of a self-etch adhesive to dentin. Lasers in Medical Science, 27(4), 819–825.

Demant, S., Dabelsteen, S. & Bjørndal, L. (2021) A macroscopic and histological analysis of radiographically well-defined deep and extremely deep carious lesions: carious lesion characteristics as indicators of the level of bacterial penetration and pulp response. International Endodontic Journal, 54(3), 319–330.

Duncan, H.F., Cooper, P.R. & Smith, A.J. (2019) Dissecting dentine-pulp injury and wound healing responses: consequences for regenerative endodontics. International Endodontic Journal, 52(3), 261–266.

Ersin, N.K., Candan, U., Aykut, A., Eraton, C. & Belli, S. (2009) No adverse effect to bonding following caries disinfection with chlorhexidine. Journal of Dental Child (Chic), 76(1), 20–27.

ESE. (2006) Quality guidelines for endodontic treatment: consensus report of the European Society of Endodontology. International Endodontic Journal, 39(12), 921–930.

ESE. (2019) European Society of Endodontology position statement: management of deep caries and the exposed pulp. International Endodontic Journal, 52(7), 923–934.

Farag, A., van der Sanden, W.J., Abdelwahab, H., Mulder, J. & Frencen, J.E. (2009) 5-year survival of ART restorations with and without cavity disinfection. Journal of Dentistry, 37(6), 468–474.

Ferk Luketić, S., Malcić, A., Jukić, S., Anić, I., Segović, S. & Kalenić, S. (2008) Coronal microleakage of two root-end filling materials using a polymicrobial marker. Journal of Endodontics, 34(2), 201–203.

Field, A. (2017) Discovering statistics using IBM SPSS statistics, 5th edition. London: SAGE Publications Ltd.

Fusayama, T., Okuse, K. & Hosoda, H. (1966) Relationship between hardness, discoloration, and microbial invasion in carious dentin. Journal of Dental Research, 55(7), 923–932.

GDC. (2013) Scope of practice. In: Council GD, ed. pp. 8. Available at: https://www.gdc-uk.org/docs/default-source/scope-of-practice/scope-of-practice.pdf [Accessed 22nd February 2021].

GDC. (2019) Annual report and accounts 2019. General Dental Council. Available at: https://www.gdc-uk.org/docs/default-source/annual-reports/gdc-annual-report-and-accounts-2019.pdf?sfvrsn=4c4d4coo2_4

GDC. (2021) Registration report – January 2021. [WWW document]. https://www.gdc-uk.org/docs/default-source/registration-reports/registration-report---january-2021968d36
Palmer, N.O., Ahmed, M. & Grieveson, B. (2009) An investigation of current endodontic practice and training needs in primary care in the north west of England. British Dental Journal, 206(11), E22; discussion 584-585.

Parirokh, M., Torabinejad, M. & Dummer, P.M.H. (2018) Mineral trioxide aggregate and other bioactive endodontic cements: an updated overview – part I: vital pulp therapy. International Endodontic Journal, 51(2), 177–205.

Peciuliene, V., Rimkuviene, J., Aleksejuniene, J., Haapasalo, M., Parirokh, M., Torabinejad, M. & Dummer, P.M.H. (2018) Mineral trioxide aggregate and other bioactive endodontic cements: an updated overview – part II: non-vital and periapical lesions. International Endodontic Journal, 51(2), 213–225.

Pigg, M., Nixdorf, D.R., Nguyen, R.H. & Law, A.S. (2016) Validity of preoperative clinical findings to identify dental pulp status: a national dental practice-based research network study. Journal of Endodontics, 42(6), 935–942.

Ricucci, D., Loghin, S. & Siqueira, J.F. Jr. (2014) Correlation between clinical and histologic pulp diagnoses. Journal of Endodontics, 40(12), 1932–1939.

Ricucci, D., Siqueira, J.F. Jr, Li, Y. & Tay, F.R. (2019) Vital pulp therapy: histopathology and histobacteriology-based guidelines to treat teeth with deep caries and pulp exposure. Journal of Dentistry, 86, 41–52.

Saunders, W.P., Chestnutt, I.G. & Saunders, E.M. (1999) Factors influencing the diagnosis and management of teeth with pulpal and periapical disease by general dental practitioners. Part 2. British Dental Journal, 187(10), 548–554.

Schenkel, A.B., Peltz, I. & Veitz-Keenan, A. (2016) Dental cavity liners for Class I and Class II resin-based composite restorations. Cochrane Database Systematic Review, 10(10), Cd010526.

Schwendicke, F., Dörfer, C.E. & Paris, S. (2013) Incomplete caries removal: a systematic review and meta-analysis. Journal of Dental Research, 92(4), 306–314.