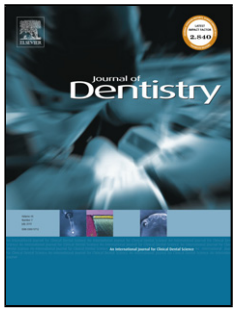
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Contemporary teaching of restoration repair at dental schools in Germany –close to universality and consistency

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Running title: Teaching restoration repair in Germany

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Abstract

Objectives: To identify potential changes in various aspects of teaching and to ascertain whether previously found inconsistencies in the teaching of criteria, indications and operative techniques for the repair of defective composite restorations at German dental schools have been resolved.

Methods: A validated questionnaire was used to gain the information sought. It was sent to all dental schools in Germany (n=30). Whenever possible, data were compared to previous studies conducted in 2000 and 2009. Statistical analysis was performed using Fisher's exact tests ($p<0.05$).

Results: Twenty-nine schools responded to the survey – a response rate of 97%. All respondents indicated positive experiences with the repair of restorations. The teaching of repairs in 2018 (90%) was found to be comparable to the findings from the 2009 survey (88%, $p=1.000$), but significantly increased since the 2000 survey (50%, $p=0.006$). Main reasons reported for teaching repairs are tooth substance preservation (97%) and reduction of pulpal damage (79%). Main clinical indications are marginal defects and secondary caries. When performing repairs, almost all dental schools were found to teach both mechanical and adhesive substrate surface conditioning. Marked variation was observed in the method of mechanical surface treatment, with air abrasion having gained widespread popularity. The average expected longevity of repairs was 7.4±3.0 years.

Conclusions: The teaching of the repair of resin composite restorations is widespread in dental schools in Germany. Aspects of this teaching were found to be more consistent between dental schools than in previous surveys, albeit variation in operative techniques still exists.

Clinical significance: Graduates from dental schools in Germany may be found to be well equipped with the knowledge and skills to perform repairs of defective resin based composite restorations in clinical practice.

Keywords: teaching; minimally invasive dentistry; restoration repair

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Introduction

For many years the evidence-base and demand for the use of tooth-coloured restorations, particularly in stress-bearing areas, has been growing [1-3]. The paradigm shift from a 'mechanically-driven' to a 'biologically-focused' preventatively-orientated minimally interventive approach to the restoration of posterior teeth and the phase down in the use of mercury containing amalgam fillings, as a result of the Minamata Convention, have led to composite resins being taught across the developed world as the material of choice for the restoration of posterior teeth [4-7]. Notwithstanding technological advances in resin-based dental biomaterials science, composite restorations, in common with all dental restorations, suffer deterioration and degradation in clinical service [8-11].

National and international surveys over the past 15 years on the teaching of the repair of direct composite restorations (DCRs) have demonstrated a progressive increase in instruction – didactic and clinical, on restoration repair [12-21]. A recent meta-analysis on the teaching of restoration repair indicates that the concept of restoration repair has become embedded in dental school curricula in Germany and many other countries [22]. The advantages of composite repair, i.e. partial replacement of a DCR allowing preservation of that portion of the DCR which presents no clinical or radiograph evidence of failure, as an alternative to restoration replacement, are considerable [10, 13]. Notwithstanding the widespread teaching of restoration repair, previous studies have shown marked variation in the criteria, indications and operative techniques taught for the repair of DCRs [13, 16]. Given that the last survey on the teaching of the repair of DCRs in dental schools in Germany was undertaken in 2009, let alone recent advancements in adhesive technologies, which led to the development of restoration repair protocols [23-31], it was considered timely to re-examine the teaching on the repair of DCRs in Germany. Further purposes were to ascertain whether previous inconsistencies in teaching had been resolved in favour of a more consistent approach to the repair of DCRs in dental schools in Germany.

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Materials and Methods

Survey

The study protocol was approved by the local Ethics Committee of the University Medical Center Göttingen, Germany (application number 25/12/17).

A survey questionnaire, based on the questionnaire developed by Blum et al. [13], was translated into German language, and mailed together with a covering letter to the Heads of Department of Operative/Restorative Dentistry in all 30 dental schools in Germany with undergraduate dental degree programmes. All mailings included a pre-stamped, addressed return envelope. The questionnaire sought information on the respondents' experience of repairing defective composite restorations, the teaching of such repairs in their undergraduate curriculum, together with details of criteria, indications and operative techniques considered appropriate for such procedures. The survey questionnaire contained both open and closed questions.

To assist respondents in their task, and in an attempt to standardise the completion of the questionnaire, each respondent was sent a glossary, used in previous studies [13-18], to explain the terms used. The recipients were initially given eight weeks to complete and return the questionnaire, together with any additional information considered relevant to the survey. In March 2018, a reminder letter, including a copy of the questionnaire, was sent to the dental schools that had not responded. By April 2018, no further responses were received.

The returned questionnaires were scanned (EvaSys, version 7.1, www.evasys.de), computerised and analysed using Microsoft Excel (Excel for Mac 16.12, Microsoft, Redmond, Washington, USA). Data from handwritten information was entered manually into the spreadsheet. Statistical analysis was performed using the 'R Software for Statistical Computing' (R version 3.4.4; www.r-project.org). Whenever possible, findings were compared with results from previous, related surveys carried out in 2000 and 2009, using Fisher's exact tests with Bonferroni-Holm corrections. The overall level of significance was set at the 0.05 level.

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Results

Completed questionnaires were returned by 29 of the dental schools included in the survey, giving a 97% response. One school refused to participate for reasons unknown.

The findings returned by the participating schools included responses to all, or most of the questions. All respondents reported that they have undertaken repairs of defective composite restorations as a definitive treatment, and that they considered this treatment option to be clinically viable and successful.

Teaching

Teaching of DCR repairs, as an alternative to restoration replacement, was found to be provided in 90% (n=26) of the dental schools. This finding is comparable to the 2009 finding (88%) which was a significant increase compared to the 2000 finding (50.0%; p=0.006).

All 26 schools reported that the teaching of the repair of DCRs was both theoretical and practical and took place mainly in the clinical phase of the programme. The three schools that did not teach this topic indicated an intention to include restoration repair in their undergraduate curriculum within the next three years. Therefore, all the following results are based on the total number of respondents in this survey (n=29).

The vast majority of respondents (97%) reported that they taught the repair of DCRs largely on the grounds of personal clinical experience. Further reported justifications included evidence from the literature (79%) and case reports (21%). High patient-acceptance and the minimally interventive nature of performing repairs (i.e. tooth-substance preservation, avoidance of more invasive indirect restorations) were mentioned as positive advantages of repairs.

Reasons for repairs

An overview of the reasons reported for performing repairs of DCRs and how these compare to the survey findings of 2000 and 2009 are shown Table 1. Tooth substance preservation was

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significantly more commonly stated as a reason for repairs in 2018 compared to 2000 ($p<0.001$) but was similar to 2009.

Indications for repairs

The reported indications for DCR repairs are presented and compared to previous survey findings in Table 2. Both secondary caries and marginal defects were significantly more often reported as indications for repairs in 2018 than in 2000 ($p<0.001$), but not relative to the corresponding 2009 findings.

Operative techniques

Aspects of the reported mechanical and adhesive operative techniques employed for surface treatment of the substrate composite along with comparisons to the previous survey findings are presented in Table 3. The use of air abrasion techniques and application of an adhesive system were significantly more frequently reported in 2018 than in 2000 ($p\leq0.001$). No significant differences were observed between the 2018 and 2009 operative technique findings.

Success of repairs

The respondents' expected longevity of repaired DCRs was reported as 7.4 (sd: ±3.0, range: 2-15) years. Two dental schools did not specify the number of years but estimated the longevity of repairs to be equivalent to that of newly placed composite restorations and above 10 years, respectively. In 2009, 5/22 German dental schools considered the acceptable longevity of repaired DCRs to be three years, whilst the majority of the dental schools (10/22) estimated the longevity of DCR repairs to be between three and five years [16]. A range between five and seven years was mentioned by 7/22 dental schools. No dental school expected a longevity of more than seven years [16]. In 2000, 8/12 German dental schools teaching repairs considered

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the longevity of repaired composite restorations to be less than three years, 2/12 to be three or more years, and 2/12 to be equal to the remaining part of the restoration [13].

Discussion

The purpose of the present study was to survey the teaching of the repair of DCRs in dental schools in Germany. It was considered important to ascertain whether marked variations in attitudes and techniques identified in previous surveys, specifically in relation to indications and operative techniques, had been resolved, creating a more consistent approach across Germany to the teaching of the repair of DCRs.

This study achieved a 97% response. This response rate was higher than in the studies of 2009 (83%) and 2000 (75%).

The findings on the teaching of DCR repairs observed in the present study are comparable to the finding from 2009 [88% (n=22)], but significantly higher than the findings from 2000, when only 50% of schools were found to teach the repair of DCRs. The widespread teaching observed in this study and in the 2009 study is attributed to the respondents' good clinical outcomes and experience with performing such repairs, coupled with the growing body of positive evidence from clinical trials [32-35] on the success and longevity of repaired DCRs.

A recent meta-analysis on the teaching of restoration repair found that between 2002 and 2017, on average, 83% of the 276 dental schools worldwide have included restoration repair in their undergraduate curricula [22]. This finding must, however, be viewed with caution as only a limited number of studies were included, let alone the heterogeneity of the studies included in terms of sample size and, amongst other factors survey methods.

The findings from this study indicate that the percentage of German dental schools teaching restoration repair is slightly above the international average reported in the recent meta-analysis. Notwithstanding the finding of the present study that the repair of DCRs is widely taught in dental schools in Germany, both at theoretical and practical/clinical levels, no

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information exists regarding the nature of this teaching, i.e. lectures, seminars, clinical simulation, clinical instruction) nor the hours dedicated to this teaching.

Regarding the indications for performing repairs of DCRs, secondary caries and marginal defects were the most common indications for performing a DCR repair. This is comparable to the 2009 survey finding, but presents a shift from the finding of 2000, when partial loss of restoration and restoration fracture were reported as the main indications for the repair of DCRs [13, 16]. This shift emphasizes that repairs are no longer performed only in case of functional failures (i.e. fractures), but also when biological failure occurs, i.e. secondary caries. A recent cost-effectiveness analysis of repairs has shown that repairs of large resin composite restorations with secondary caries are especially cost-effective [36].

Opdam et al. [32] have shown in a clinical practice-based study that restorations repaired due to secondary caries, which may be considered as a new primary caries lesion adjacent to the restoration, may be found to have a higher survival rate than fractured restorations that had been repaired. It may be assumed that restorations requiring repair following a fracture may be subjected to the same forces that caused the fracture of the original restoration. As a result, it is more likely that a repaired restoration will fracture again, unless the cause of the fracture can be identified and eliminated. Thus, repairs of restorations due to secondary caries may be considered to have a better prognosis than restorations repaired following functional failures [32].

Operative techniques for intraoral repairs depend on the restorative material and various mechanical and adhesive conditioning methods [23]. German dental schools are aware of the need for both mechanical and adhesive surface conditioning to achieve durable repair bond strengths. With the exception of one dental school, all dental schools reported the use of both mechanical and adhesive repair surface treatments. The significant increase in the reported teaching of the use of air abrasion for mechanical surface treatment of the resin composite substrate when performing a repair of DCRs is noteworthy. This is in line with various studies

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showing that air abrasion leads to higher repair bond strengths compared to other means of mechanical roughening, or no mechanical pretreatment [37-40]. Also, the additional application of an adhesive bonding system resulted in increased repair bond strengths [41]. As a consequence, modern clinical repair protocols for the repair of partially defective DCRs recommend the use of air abrasion and adhesive bonding systems [23, 25, 27]. According to data from laboratory and clinical investigations published to date, the repair of DCRs may be best achieved by the combination of silica – coated air abrasion of the substrate surface followed by the application of silane and a corresponding adhesive bonding system [32, 38, 40].

Long-term survival of repaired composite restorations has been assessed in only a few clinical studies [32, 34, 35, 42]. These studies report an annual failure rate of repairs between 0.0 [42] and 5.7 [32]. Annual failure rates were either reported directly or estimated based on USPHS scores [36]. Participating dental schools of the current survey rated the longevity of repairs to be 7.4 years, or to be equivalent to newly placed composite restorations, or above 10 years. This is in line with observations made by Opdam et al. [32] who have found in their practice-based study looking at the survival of restoration repairs that 31% of repairs tend to fail after seven years. Thus, the perception of longevity of repairs of DCRs is in keeping with presently available clinical results.

Conclusions

The repair of DCRs is well established in most German dental undergraduate curricula and may be anticipated to be universal in a few years' time. The indications and operative techniques for performing repairs are more consistent than in previous surveys on the repair of DCRs at German dental schools.

Conflict of interest

The authors declare no conflict of interest.

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Tables

Table 1: Reasons for performing repairs.

Reason / indication for repairs	2000 (n = 24) [%]	2009 (n = 22)* [%]	2018 (n = 29) [%]
Tooth substance preservation	45.8 ^{A}	95.5 ^{B}	96.6 ^{B}
Reducing pulpal damage	45.8 ^{A}	77.3 ^{A}	79.3 ^{A}
Reduction in treatment time	45.8 ^{A}	31.8 ^{A}	41.4 ^{A}
Reduced treatment costs	8.3 ^{A}	45.5 ^{A}	34.5 ^{A}

Reasons for repairs as indicated by the German dental schools in 2000, 2009, and 2018. Multiple selections were possible. Different letters indicate significant differences between the surveys. Additionally, one respondent emphasized the advantages of repairs especially in older patients in 2018. *In 2009, reasons for performing repairs were only assessed among dental schools teaching repairs (n=22 among 25 participating dental schools).

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Table 2: Indications for performing repairs.

Reason / indication for repairs	**2000 (n = 24) [%]**	**2009 (n = 22)* [%]**	**2018 (n = 29) [%]**
Secondary caries	12.5 ^{A}	59.1 ^{B}	82.8 ^{B}
Marginal defects	12.5 ^{A}	90.9 ^{B}	96.6 ^{B}
Marginal discolouration	20.8 ^{A}	45.5 ^{A}	65.5 ^{A}
Superficial colour correction	29.2 ^{A}	50.0 ^{A}	69.0 ^{A}
Discolouration labial / buccal	12.5 ^{A}	36.4 ^{A}	44.8 ^{A}
Discolouration occlusal	0.0 ^{A}	18.2 ^{A}	10.3 ^{A}
Discolouration cervical	8.3 ^{A}	18.2 ^{A}	24.1 ^{A}
Discolouration proximal / lateral	0.0 ^{A}	13.6 ^{A}	13.8 ^{A}
Discolouration involving more than one surface	0.0 ^{A}	0.0 ^{A}	17.2 ^{A}
Abrasion / attrition	16.7 ^{A}	27.3 ^{A}	48.3 ^{A}
Partial loss of restoration	45.8 ^{A}	86.4 ^{A}	69.0 ^{A}
Fracture of restoration	12.5 – 37.5 **	18.2 – 77.3 **	51.7
Tooth fracture	-	-	58.6

Indications for repairs as indicated by German dental schools in 2000, 2009, and 2018. Multiple selections were possible. Different letters indicate significant differences between the surveys. *In 2009, indications for performing repairs were only assessed among dental schools teaching repairs (n=22 among 25 participating dental schools). **Various different fractures and fracture locations were separately assessed in the surveys in 2009 and 2000, but are merged in this table. Therefore, no statistical comparisons were done.

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Table 3: Operative techniques used for performing repairs.

Operative technique	**2000 (n = 24) [%]**	**2009 (n = 22)* [%]**	**2018 (n = 29) [%]**
No mechanical surface treatment	0.0 ^{A}	0.0 ^{A}	0.0 ^{A}
Diamond finishing instruments	45.8 ^{A}	86.4 ^{A}	79.3 ^{A}
Metal finishing instruments	4.2 ^{A}	0.0 ^{A}	10.3 ^{A}
Finishing discs	16.7 ^{A}	18.2 ^{A}	24.1 ^{A}
Arkansas stones	0.0 ^{A}	-	10.3 ^{A}
Air abrasion	20.8 ^{A}	59.1 ^{AB}	82.8 ^{B}
Other instruments	4.2 ^{A}	-	6.9 ^{A}
Hydrofluoric acid	4.2 ^{A}	13.6 ^{A}	13.8 ^{A}
Phosphoric acid	41.7 ^{A}	77.3 ^{A}	62.1 ^{A}
Silane coupling agent	20.8 ^{A}	45.5 ^{A}	51.7 ^{A}
Adhesive system	45.8 ^{A}	86.4 ^{AB}	96.6 ^{B}
Flow composite	-	77.3 ^{A}	72.4 ^{A}
Hybrid composite	-	72.7 ^{A}	69.0 ^{A}
Nanohybrid composite	-	36.4	-

Mechanical and adhesive surface treatments and repair composites indicated by the German dental schools in 2000, 2009, and 2018. Multiple selections were possible. Different uppercase letters indicate significant differences between the surveys. *In 2009, operative techniques were only assessed among dental schools teaching repairs (n=22 among 25 participating dental schools). Further operative techniques were inquired in 2009 and 2000, but were not listed here.