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DISSERTATION

Einblick in die praktische Anwendung und Lehre von
zahnärztlichen Reparaturrestaurationen:
Systematisches Review und Meta-Analyse

zur Erlangung des akademischen Grades
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Zusammenfassung

Einleitung: Bei der Behandlung von partiell insuffizienten zahnärztlichen Restaurationen stehen grundsätzlich zwei Handlungsalternativen zur Verfügung: Die vollständige Erneuerung der gesamten Restauration oder die Reparatur der insuffizienten Anteile unter Belassung des Großteils der bestehenden Restauration. Durch Reparaturmaßnahmen kann die Überlebenszeit des betroffenen Zahnes verlängert werden. Reparaturen sind mit einem geringeren Zeitaufwand, einem geringeren Risiko von Komplikationen sowie oftmals geringeren Kosten verbunden. Unklar ist jedoch, ob und warum Reparaturmaßnahmen von ZahnärztInnen durchgeführt bzw. von Universitäten gelehrt werden. Daher war es das Ziel, den Anteil an (1) ZahnärztInnen, die Reparaturrestaurationen anfertigen, (2) Restaurationen, die tatsächlich repariert wurden, und (3) Universitäten, die Reparaturrestaurationen lehren, sowie die bei der Entscheidungsfindung jeweils relevanten Einflussfaktoren zu ermitteln.

Methodik: Die elektronischen Datenbanken PubMed, CENTRAL, Embase und PsycINFO wurden per vorab definierten Kriterien durchsucht. Daten aus quantitativen sowie qualitativen Originalarbeiten mit Informationen über den Anteil von (1) reparierenden ZahnärztInnen, (2) tatsächlich reparierten Restaurationen und/oder (3) Reparaturen lehrenden Universitäten wurden unabhängig von drei Reviewern extrahiert. Im Rahmen der anschließenden Auswertung dienten Meta-Analysen und Meta-Regressionen der quantitativen Synthese. Entlang des Theoretical Domains Frameworks wurde zudem eine thematische Analyse der qualitativen Aspekte bei der Entscheidungsfindung synthetisiert.

Ergebnisse: Insgesamt konnten 29 der 401 identifizierten Publikationen eingeschlossen werden (überwiegend quantitative Fragebogenerhebungen). Dabei wurden insgesamt Daten von 7.228 ZahnärztInnen, 30.172 behandelten Restaurationen und 276 Universitäten ausgewertet. Durchschnittlich gaben 72% (95%-Konfidenzintervall: 50-86%) der befragten ZahnärztInnen an, partiell insuffiziente Restaurationen zu reparieren. Es konnte diesbezüglich festgestellt werden, dass der Anteil der reparierenden ZahnärztInnen in neueren Erhebungen signifikant höher ausfiel ($p = 0,004$). Bei der Betrachtung der tatsächlich reparierten (partiell) insuffizienten Restaurationen fiel der Anteil der Reparaturen mit nur 31% (95%-Konfidenzintervall: 26-37%) deutlich geringer aus. Im Hinblick auf die Lehre von Reparaturmaßnahmen gaben 83%

(95%-Konfidenzintervall: 74-90%) der befragten Universitäten an, Reparaturmaßnahmen zu lehren. Insgesamt erhöhte sowohl die Anstellung in Praxen des öffentlichen Gesundheitsdienstes als auch der Umstand, die (partiell) insuffiziente Restauration selbst angefertigt zu haben, die Wahrscheinlichkeiten, dass Reparaturmaßnahmen zur Anwendung kamen. Bestehende Amalgamrestaurationen reduzierten hingegen diese Wahrscheinlichkeit. Finanzielle Aspekte sowie Regulationen stellten weitere Hinderungsgründe dar.

Schlussfolgerungen: Die meisten der befragten ZahnärztInnen gaben an, Reparaturen anzufertigen. Auch der überwiegende Teil der befragten Universitäten lehrt Reparaturrestaurationen. Der Anteil an tatsächlich durchgeführten Reparaturen fiel dagegen gering aus. Bei weiteren Studien auf diesem Gebiet sollten echte qualitative Methoden eingesetzt werden, um die zahnärztlichen Entscheidungsfindung im Hinblick auf die Anwendung von Reparaturmaßnahmen noch genauer zu verstehen.

Abstract

Introduction: When treating partially defective dental restorations, two alternative options exist: Complete replacement of the entire restoration or repair of the insufficient part. Repair restorations can prolong the survival time of the affected tooth, require less treatment time, and are associated with a lower risk of complications and often lower treatment costs. It is unclear, however, whether and why repairs are implemented by dentists or taught at universities of different countries. Therefore, it was the objective of the present study to assess the proportion of (1) dentists practicing repair restorations, (2) restorations that were actually repaired, and (3) universities teaching repair measures as well as to identify factors relevant for the decision making.

Methods: Electronic databases (PubMed, CENTRAL, Embase, PsycINFO) were searched by means of predefined search criteria. Quantitative and/or qualitative studies reporting on the proportion of (1) dentists stating to perform repairs, (2) actually repaired restorations, and (3) dental schools teaching repairs were included. For this purpose, given data were extracted independently by three reviewers and random-effects meta-analyses as well as meta-regressions were performed for quantitative synthesis. Finally, a thematic analysis of the qualitative aspects regarding the decision-making process was conducted using the theoretical domain framework.

Results: A total of 29, mainly quantitative questionnaire surveys, of the 401 identified publications were included; 7,228 dentists, 30,172 treated restorations, and 276 universities were analyzed. Seventy-two percent (95% confidence interval: 50-86%) of the surveyed dentists stated to perform repairs. The proportion of dentists utilizing repairs was significantly higher in more recent studies ($p = 0.004$). However, the proportion of (partially) insufficient restorations that were repaired amounted to only 31% (95% confidence interval: 26-37%). With regard to the teaching of repair measures, 83% (95% confidence interval: 74-90%) of the surveyed dental schools indicated that they teach repairs. Overall, both the employment in public health service practices and being the dentists who placed the original restoration was associated with an increased probability of repair measures. Existing amalgam restorations reduced the probability, and financial aspects as well as regulations were barriers.

Conclusions: While most of the surveyed dentists indicated that they utilize repairs and the majority of universities reported to teach restoration repair, the proportion of actually performed repairs was low. Future studies should use true qualitative methods to further analyze dentists' decision-making processes with regard to repair measures.

Eidesstattliche Versicherung

Ich, Philipp Clemens Kanzow, versichere an Eides statt durch meine eigenhändige Unterschrift, dass ich die vorgelegte Dissertation mit dem Thema „Einblick in die praktische Anwendung und Lehre von zahnärztlichen Reparaturrestorationen: Systematisches Review und Meta-Analyse“ selbstständig und ohne nicht offengelegte Hilfe Dritter verfasst und keine anderen als die angegebenen Quellen und Hilfsmittel genutzt habe.

Alle Stellen, die wörtlich oder dem Sinne nach auf Publikationen oder Vorträgen anderer AutorInnen beruhen, sind als solche in korrekter Zitierung (siehe „Uniform Requirements for Manuscripts (URM)“ des ICMJE – www.icmje.org) kenntlich gemacht. Die Abschnitte zu Methodik (insbesondere praktische Arbeiten, Laborbestimmungen, statistische Aufarbeitung) und Resultaten (insbesondere Abbildungen, Graphiken und Tabellen) entsprechen den URM (s.o) und werden von mir verantwortet.

Mein Anteil an der ausgewählten Publikation entspricht dem, der in der untenstehenden gemeinsamen Erklärung mit dem Betreuer angegeben ist.

Die Bedeutung dieser eidesstattlichen Versicherung und die strafrechtlichen Folgen einer unwahren eidesstattlichen Versicherung (§156, 161 des Strafgesetzbuches) sind mir bekannt und bewusst.

Datum

Unterschrift

Ausführliche Anteilserklärung an der erfolgten Publikation

Publikation: **Kanzow P**, Wiegand A, Göstemeyer G, Schwendicke F. Understanding the management and teaching of dental restoration repair: Systematic review and meta-analysis of surveys. *J Dent* 2017; *Epub ahead of print*. <http://dx.doi.org/10.1016/j.jdent.2017.09.010>

Nach freundlicher Überlassung des Themas durch Herrn PD Dr. med. dent. Falk Schwendicke habe ich nach umfassender Einarbeitung in die Thematik gemeinsam mit ihm das Konzept der Studie ausgearbeitet. Die Registrierung der Studie bei PROSPERO sowie die systematische Suche in den elektronischen Datenbanken PubMed, CENTRAL und PsycINFO erfolgten durch mich. Gemeinsam mit weiteren Autoren habe ich die eingeflossenen Studien analysiert und relevante Parameter extrahiert (Tabellen 1-3).

Die Durchführung der Meta-Analysen (Abbildung 1) und Meta-Regressionen (Abbildung 2 und Anhang) sowie die Berechnung der Häufigkeitseffektgrößen (Abbildung 3) erfolgten ebenfalls durch mich persönlich. Die thematische Analyse der qualitativen Aspekte habe ich selbstständig entlang des Theoretical Domains Frameworks synthetisiert (Tabelle 4). Alle Abbildungen der Publikation und des Anhangs wurden durch mich erstellt.

Gemeinsam mit Herrn Schwendicke habe ich das Manuskript geschrieben. An der kritischen Überarbeitung des Manuskripts und der finalen Freigabe waren alle Autoren gemeinsam beteiligt. Mit den Formatierungen und der Submission beim *Journal of Dentistry* war ich als korrespondierender Autor betraut und habe unser Manuskript so bis zum Abdruck begleitet.

Unterschrift, Datum und Stempel des betreuenden Hochschullehrers

Unterschrift des Doktoranden

Auszug aus der Journal Summary List (ISI Web of KnowledgeSM)

Journal Data Filtered By: **Selected JCR Year: 2016** Selected Editions: SCIE,SSCI
 Selected Categories: **“DENTISTRY, ORAL SURGERY and MEDICINE”**

Selected Category Scheme: WoS

Gesamtanzahl: 90 Journale

Rank	Full Journal Title	Total Cites	Journal Impact Factor	Eigenfactor Score
1	ORAL ONCOLOGY	8,242	4.794	0.014210
2	JOURNAL OF DENTAL RESEARCH	17,285	4.755	0.022250
3	PERIODONTOLOGY 2000	3,575	4.072	0.004180
4	DENTAL MATERIALS	11,915	4.070	0.015200
5	International Journal of Oral Science	827	3.930	0.002400
6	CLINICAL ORAL IMPLANTS RESEARCH	12,295	3.624	0.017630
7	European Journal of Oral Implantology	812	3.567	0.002450
8	JOURNAL OF CLINICAL PERIODONTOLOGY	12,144	3.477	0.014430
9	JOURNAL OF DENTISTRY	7,248	3.456	0.012310
10	JOURNAL OF PERIODONTOLOGY	14,843	3.030	0.013210
11	INTERNATIONAL ENDODONTIC JOURNAL	5,705	3.015	0.009220
12	Clinical Implant Dentistry and Related Research	3,412	2.939	0.009430
13	Molecular Oral Microbiology	630	2.908	0.002020
14	OPERATIVE DENTISTRY	2,930	2.893	0.003600
15	JOURNAL OF ENDODONTICS	13,456	2.807	0.015730
16	Journal of Oral & Facial Pain and Headache	221	2.760	0.000930
17	JOURNAL OF PERIODONTAL RESEARCH	3,907	2.662	0.005030
18	Journal of Prosthodontic Research	551	2.561	0.001480
19	Journal of Evidence-Based Dental Practice	408	2.477	0.001280
20	Clinical Oral Investigations	3,979	2.308	0.010990
21	COMMUNITY DENTISTRY AND ORAL EPIDEMIOLOGY	4,092	2.302	0.004620
22	INTERNATIONAL JOURNAL OF ORAL & MAXILLOFACIAL IMPLANTS	8,314	2.263	0.009590
23	JOURNAL OF THE AMERICAN DENTAL ASSOCIATION	6,024	2.150	0.005190
24	JOURNAL OF ORAL REHABILITATION	4,824	2.098	0.005280

Druckexemplar der ausgewählten Publikation

Die folgenden Seiten beinhalten das Druckexemplar des Verlags der folgenden Publikation:

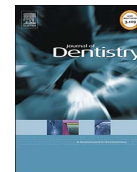
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Review article

Understanding the management and teaching of dental restoration repair: Systematic review and meta-analysis of surveys

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ABSTRACT

Objectives: Repair instead of complete replacement is recommended to manage partially defective restorations. It is unclear if and why such treatment is taught at dental schools or practiced by dentists. We aimed to identify barriers and facilitators for repairs using a systematic review and meta- and qualitative analysis.

Sources: Electronic databases (PubMed, CENTRAL, Embase, PsycINFO) were searched.

Study selection: Quantitative studies reporting on the proportion of (1) dentists stating to perform repairs, (2) dental schools teaching repairs, (3) failed restorations having been repaired were included. We also included qualitative studies on barriers/facilitators for repairs. Random-effects meta-analyses, meta-regression and a thematic analysis using the theoretical domains framework were conducted.

Data: 401 articles were assessed and 29, mainly quantitative, studies included. 7228 dentists and 276 dental schools had been surveyed, and treatment data of 30,172 restorations evaluated. The mean (95% CI) proportion of dentists stating to perform repairs was 71.5% (49.7–86.4%). 83.3% (73.6–90.0%) of dental schools taught repairs. 31.3% (26.3–36.7%) of failed restorations had been repaired. More recent studies reported significantly more dentists to repair restorations ($p = 0.004$). Employment in public health practices and being the dentist who placed the original restoration were facilitators for repairs. Amalgam restorations were repaired less often, and financial aspects and regulations came as barriers.

Conclusions: While most dentists state to perform repairs and the vast majority of dental schools teach repairs, the proportion of truly repaired restorations was low. A number of interventions to implement repair in dental practice can be deduced from our findings.

Clinical significance: Partially defective restorations are common in dental practice. While repairs are taught and dentists are aware of the recommendation towards repairs, the actually performed proportion of repairs seems low.

1. Introduction

Partially defective dental restorations have traditionally been managed via total replacement of the restoration. Alternatively, they can be repaired by only replacing the defective part. Recent studies have shown that repairs are able to significantly increase the lifetime of restorations [1], and come with reduced treatment time, possibly lower costs, and lower risks of complications than total replacements [2]. Repair of partially defective restorations prolongs tooth retention time and is cost-effective in certain situations [3]. Repair is highly accepted by patients as well [4,5].

A number of early survey studies, however, showed that a significant proportion of dentists rejects repairs, and does not practice them [6–8]. It is unclear if this gap between scientific evidence and clinical practice is generally present across countries, or whether it has

narrowed in recent years. It is also unclear if repairs are widely taught at dental schools, and what further factors (beyond knowledge) are affecting dentists' decision towards repairs.

We aimed to systematically review survey studies and to analyze the proportion of dentists/dental schools in different countries performing/teaching repairs of partially defective restorations in permanent teeth. A further objective was to identify potential barriers and facilitators regarding dental restoration repair. On the basis of this information, future implementation interventions might be developed and applied to increase the utilization of repairs in dental practice.

2. Methods

This review was registered at PROSPERO (CRD42017063855) prior to initiation. The reporting of this study is in accordance with the

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PRISMA and the ENTREQ statements [9,10].

2.1. Eligibility criteria

Observational studies which report on the proportion of (1) dentists stating to perform repairs of partially defective restorations, (2) dental schools teaching repairs, and (3) defective restorations having actually been repaired (yielded via treatment data) were included. Additionally, (qualitative) studies which report on barriers or facilitators for performing repairs were assessed. These could have been interviews, focus-group discussion, or ethnographic studies. We also gathered qualitative data reported in surveys. There were no language, time, or quality restrictions. Grey literature was not searched, as we assumed the depth of reporting to be too limited to allow synthesis.

2.2. Outcomes

The primary outcome of this review was the proportion of (1) dentists stating to use repairs in practice, (2) dental schools teaching repairs, and (3) defective restorations which had actually been repaired. Secondary outcomes were knowledge, attitudes, and behaviours acting as barriers or facilitators of evidence-based decision-making regarding the management of partially defective restorations in permanent teeth.

2.3. Information sources

Four electronic databases (Embase, Medline via PubMed, Cochrane CENTRAL, and PsycINFO) were searched. In addition, further hand searches were conducted and the reference lists of identified full texts screened and cross-referenced.

2.4. Search strategy

For the database screening, the following strategy was used for PubMed and individualized for the other databases: Search (((repair) OR refurbish) OR repolish) OR reseal) AND ((dental) OR dentists) AND (((((filling) OR fillings) OR restoration) OR restorations) OR crown) OR crowns) AND (((((((survey) OR questionnaire) OR interview) OR discussion) OR attitudes) OR beliefs) OR knowledge) OR teaching) OR teach) OR education) OR curriculum).

2.5. Study records

Three reviewers independently screened the identified records and compared their findings. Duplicative studies, studies which were not original, and studies without any relevant information were excluded (Appendix Table S1). Data extraction was performed independently by all reviewers using a pilot-tested spreadsheet. There were no disagreements during screening or data extraction.

2.6. Data items

The following items were collected: Authors; year in which the study was published; study type (e.g. questionnaire survey, secondary data analysis using treatment or claims data, qualitative study); sampling method and sample size, characteristics of the dentists being investigated (country and demographics) or the dental schools evaluated (country); scenario in which repair or replacement was to be decided or actual treatment situation (including original restoration materials) in which the decision to repair or replace was made; the proportion of (1) dentists stating to perform repairs, (2) dental schools teaching repairs, and (3) defective restorations having been repaired; barriers and facilitators for teaching/performing repairs (see below for thematic analysis).

2.7. Data synthesis

Meta-analyses of the proportions were performed using Comprehensive Meta-Analysis 3.3.070 (Biostat, NJ, USA). Cochrane's Q and I^2 -statistics were used to assess heterogeneity [11]. Since heterogeneity was found high, random-effect models were used. To assess potential changes of the proportions through the years, meta-regression using the maximum-likelihood method was performed [12,13]. Bonferroni correction was performed to adjust for alpha-inflation; as we performed three meta-regression analyses, $p < 0.05/3$, i.e. $p < 0.017$ was regarded as significant. Publication bias was evaluated using funnel plots as well as Egger's regression intercept test [14].

All included studies were quantitative in nature and did not employ truly qualitative methods. We nevertheless aimed to extract qualitative data, like remarks on barriers or facilitators made by the participants or the authors. These were synthesized using thematic analysis. Themes were abstracted by one reviewer (PK) and relationships between them identified [15]. Themes were then compared, grouped, and translated into the domains and constructs of the theoretical domains framework (TDF) [16,17]. Themes were classified as barriers, facilitators, or conflicting themes [16,18,19]. In order to improve the usability of the present study for further implementation of repairs, findings were subsequently aligned with domains of the Behavior Change Wheel [20]. To gauge the relative importance of the identified barriers and facilitators, frequency effect sizes (ES) were calculated by dividing the number of studies containing a particular theme by the total number of included studies reporting on dentists stating to perform repairs or treatment of failed restorations [21].

2.8. Quality assessment and confidence in data

Quality assessment of the included studies was based on the modified Newcastle-Ottawa Scale for cross-sectional studies, as described in the appendix (Appendix Table S2). Quality was assessed by one reviewer (PK) [22]. The assessment was validated by another reviewer (GG). The scale allowed for a maximum of 10 points ("stars"). Studies with high risk of bias were judged with 0–3, moderate risk resulted in 4–6 points, and low risk of bias in 7–10 points.

3. Results

3.1. Search and included studies

In total, 274 articles were identified via PubMed, 79 via Embase, 42 via PsycInfo, and 6 via Cochrane CENTRAL. Additionally, 5 articles were identified via cross-referencing and hand search. From all identified articles, 35 were screened in full-text and 29 included (Appendix Fig. S1). Details on excluded studies can be found in the appendix (Appendix Table S1).

Twenty-four of the included studies were surveys and five studies reported on collected treatment data. From the survey studies, 12 reported on the proportion of dentists stating to perform repairs (Table 1) and 12 on the proportion of dental schools teaching repairs (Table 2). A total of 7228 dentists and 276 dental schools had been surveyed. Studies were published between 2002 and 2017. Sample sizes ranged between 24 and 2026 dentists, or 6 and 52 dental schools. Response rates ranged between 28% and 100% (mean 76%). Among the survey studies reporting on the proportion of dentists stating to perform repairs, five studies used a scenario comprising description of cases or the teeth/restorations to be treated, including photographs, radiographs, and information on the patient's caries risk. The other 7 studies did not use a scenario (6 studies) or did not clearly describe the scenario (1 study). Additionally, the proportion of actually performed repairs was reported by five studies, which had collected treatment data on 30,172 failed restorations (Table 3).

Table 1
Included studies regarding dentists' theoretical repair behavior.

Study	Method	Country, year	Sample	Scenario/restoration materials	Treatment decision	Reasons, barriers, facilitators
Satcos et al. [6]	Questionnaire	USA, England, 2004	115 dental students and 19 faculty members from two dental schools (no description of the response rate)	Amalgam 45 selected posterior teeth with Class II partially defective amalgam restorations (i.e. marginal breakdown, deep marginal ditching, tooth discoloration, chipped or fractured restoration, tooth fracture and secondary caries) mounted in labstone, producing complete dental casts	885/6030 of all treatment decision were in favor of repairs: 504/3465 students' decisions from USA, 54/315 faculty decisions from USA, 257/1710 students' decisions from England, 70/540 faculty decisions from England	Decision to repair was based on: <ul style="list-style-type: none"> - lost part of restoration (75/220) - marginal ditching (206/938) - tooth fracture (32/213) - secondary caries (47/359) - marginal discoloration (18/140) - poor anatomy (87/874) - other reasons (74/1060) - bulk discoloration (5/87)
Blum et al. [27]	Questionnaire	England, 2005	560 vocational dental practitioners at the beginning of vocational training (66% response, final 306)	Composite	222/306 had performed repairs themselves at dental school	Reasons for repairs were: <ul style="list-style-type: none"> - tooth substance preservation (218/306) - reduction of potentially harmful effects on the pulp (148/306) - reduction in treatment time (92/306) - reduced costs to patients (37/306) Indications for repairs were: <ul style="list-style-type: none"> - marginal defects (177/306) - partial loss of an existing restoration (174/306) - secondary caries (141/306) - marginal discoloration (122/306) - superficial colour correction (101/306) - abrasion/attrition (100/306) - bulk fracture of anterior restorations (95/306) - bulk fracture of posterior restorations (88/306) - discoloration involving more than one surface (43/306)
			560 vocational dental practitioners at the end of vocational training (67% response, final 313)	Composite	242/313 had performed repairs	Reasons for repairs were: <ul style="list-style-type: none"> - tooth substance preservation (239/313) - reduction in treatment time (151/313) - reduction of potentially harmful effects on the pulp (129/313) Indications for repairs were: <ul style="list-style-type: none"> - reduced costs to patients (63/313) - partial loss of an existing restoration (219/313) - marginal defects (188/313) - marginal discoloration (147/313) - superficial colour correction (135/313) - abrasion/attrition (106/313) - bulk fracture of anterior restorations (97/313) - secondary caries (91/313) - bulk fracture of posterior restorations (50/313) - discoloration involving more than one surface (31/313)

(continued on next page)

Table 1 (continued)

Study	Method	Country, year	Sample	Scenario/restoration materials	Treatment decision	Reasons, barriers, facilitators
Gordan et al. [7]	Questionnaire	USA, 2009	901 practitioner-investigators participating in The Dental Practice-Based Research Network (DPBRN), performing restorative dentistry, 57% response, final 512 (not all dentists responded to all questions)	Amalgam + composite, three patient scenarios including caries risk and photographs of the restoration Scenario 1: maxillary incisor with existing composite restoration with secondary/recurrent caries Scenario 2: maxillary cuspid with existing composite restoration with restoration margins being discoloured, degraded, or ditched Scenario 3: mandibular molar with existing amalgam restoration with secondary/recurrent caries, entire restoration is discoloured, restoration margins being discoloured, degraded, or ditched	113/512 performed minimally-invasive interventions (e.g. repairs) on scenario 1, 249/509 performed minimally-invasive interventions (e.g. repairs) on scenario 2, 44/494 performed minimally-invasive interventions (e.g. repairs) on scenario 3	Relevant decision criteria for all three scenarios: - region (p < 0.0001) - type of practice (p < 0.0001) Barriers for performing repairs in all three scenarios were: - type of practice, as dentists participating in solo or small group private practice chose replacement of the entire restoration more often than dentists who participated in large group practices or public health practices (p < 0.0001)
Yousef et al. [8]	Questionnaire	Saudi Arabia, 2009	200 students and faculty members from one dental school in Jeddah, 78% response, final 156	Amalgam + composite	67/156 had performed repairs themselves, 110/156 participants were taught repairs	Reasons for repairs were: - tooth substance preservation (97/156) - reduction of potentially harmful effects on the pulp (42/156) - reduction in treatment time (16/156) - reduced costs to patients (2/156) Indications for repairs were: - fracture of the restoration (53/156) - marginal defects (33/156) - marginal staining of the tooth (25/156) - secondary caries (25/156) - partial loss of an existing restoration (14/156) - fracture of the tooth (6/156) Barriers for teaching repairs were: - lack of clinical experience (47/156) - supervisors' recommendation (44/156) - lack of sufficient clinical evidence (29/156) - difficulty in decision making (22/156) - poor clinical experience (14/156)
Abiodun et al. [28]	Questionnaire	Nigeria, 2012	28 participants of the 3rd African and Middle East Region Conference, conservative specialists, 86% response, final 24 (62.5% female)	Composite	24/24 perform repairs	Reasons for repairs were: - tooth substance preservation (23/24) - reduction of potentially harmful effects on the pulp (15/24) - reduction in treatment time (8/24) - reduced costs to patients (1/24) Indications for repairs were: - marginal defects (22/24) - marginal discolouration (20/24) - surface discolouration (19/24) - partial loss of an existing restoration (19/24) - abrasion/attrition (15/24) - bulk fracture of anterior restorations (7/24) - bulk fracture of posterior restorations (6/24) 18/24 considered repairs as a definitive measure (continued on next page)

Table 1 (continued)

Study	Method	Country, year	Sample	Scenario/restoration materials	Treatment decision	Reasons, barriers, facilitators
Haeven et al. [29]	Questionnaire	USA, 2013	Practitioner-investigators participating in the DPRN, performing restorative dentistry, 63% response, final 508	Amalgam + composite, three patient scenarios including description of the patient including caries risk and photographs of the restoration scenario 1: maxillary incisor with existing composite restoration with secondary/recurrent caries, scenario 2: maxillary cuspid with existing composite restoration with restoration margins being discoloured, degraded, or ditched, scenario 3: mandibular molar with existing amalgam restoration with secondary/recurrent caries, entire restoration is discoloured, restoration margins being discoloured, degraded, or ditched	329/508 chose to repair at least one patient scenario	
Fayyaz et al. [30]	Questionnaire	Pakistan, 2015	200 dental graduates of four dental schools, 100%, final 200	Composite, four scenarios	121/200 had already performed repairs themselves. For the given scenarios of defective composite restorations, up to 131/200 chose repairs	Reasons for repairs were: - reduced costs (150/200) - reduction in treatment time (99/200) Indications for repairs were: - secondary caries (74/200) - partial loss of an existing restoration (59/200) - fracture of restoration (42/200) - discolouration (25/200) Facilitators for repairs were: - experience, as more experienced dentists showed a higher awareness of repair restorations ($p = 0.003$) and performed repairs more often ($p = 0.028$) 130/200 considered repairs as a definitive measure
Kopperud et al. [23]	Questionnaire	Norway, 2016	All dentists within the Norwegian Dental Association registered with an e-mail address, 61% response, 386 were excluded, final 2026 (age: 46.2 ± 11.9 years, 47.1% female)	Amalgam, one patient scenario (maxillary upper second premolar with existing fractured amalgam restoration, no sign of secondary caries, and overall low caries activity) including caries risk and photographs of the restoration	502/2026 chose to repair	Barriers for performing repairs were: - age, as older dentists chose minimal invasive treatment options (e.g. repairs) less frequently ($p < 0.01$, OR 0.54) Facilitators for repairs were: - employed in the Public Dental Service (PDS), as those dentists chose minimal invasive treatment options (e.g. repairs) more often ($p < 0.01$, OR 2.19) - practice location, as dentists working in counties with low dentist density chose minimal invasive treatment options (e.g. repairs) more often ($p = 0.03$, OR 1.01)
Staxrud et al. [31]	Questionnaire	Norway, 2016	All dentists within the Public Dental Service (PDS), 56% response, final 733 (age 41.8 ± 12.4 years, 69.6% female)	Composite, three patient scenarios including photographs and radiology information (no signs of caries and distance to the pulp was at least 1 mm), and caries activity information (low) scenario 1: Upper premolar with partially fractured composite restoration, scenario 2: Lower molar with fractured cusp adjacent to a composite restoration, scenario 3: Upper premolar with lost palatal cusp and remaining composite restoration	657/733 suggested repair in scenario one, 637/733 in scenario two and 397/733 in scenario three	Facilitators for performing repairs in scenario 3 were: - higher dentists' age, as older dentists prefer repairs more often ($p < 0.01$)

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Table 1 (continued)

Study	Method	Country, year	Sample	Scenario/restoration materials	Treatment decision	Reasons, barriers, facilitators
Kanzow, Hoffmann et al. [4]	Questionnaire	Germany, 2017	Lower Saxony, all dentists, 28% response, final 1805 (age 49.3 ± 11.1 years, 40.4% female, 21.6 ± 11.1 years since dental school graduation)	Amalgam + composite	1765/1805 perform repairs	<p>Reasons for repairs were:</p> <ul style="list-style-type: none"> - extending the longevity of restorations (1469/1805) - preservation of tooth substance (1188/1805) - reduction of patients' costs compared to replacement (1054/1805) - usage as temporary restoration (899/1805) - patients' request (865/1805) - reduction of treatment time compared to replacement (619/1805) - treatment of restorations within warranty period (112/1805) <p>Indications for repairs were:</p> <ul style="list-style-type: none"> - partial loss of restorations (Ag: 1493/1805, Co: 1458/1805) - loss of adjacent hard tissue (Ag: 1249/1805, Co: 1307/1805) - secondary caries (Ag: 767/1805, Co: 821/1805) - marginal gap (Ag: 718/1805, Co: 966/1805) - marginal discolouration (Ag: 184/1805, Co: 836/1805) - correction of anatomic form or colour (Ag: 96/1805, Co: 695/1805) <p>Relevant decision criteria:</p> <ul style="list-style-type: none"> - size of the defect (1644/1805), maximum size suitable for repair was 24.3% (± 13.3%) of the defective restoration - type of restoration material (1453/1805) - extension of the original restoration (1159/1805) - localization of the defect, e.g. palatal or approximal (928/1805) - age of the original restoration (773/1805) - who had placed the original restoration (430/1805) - type of tooth affected (404/1805), repairs are more often considered for molars (368/1805) than for premolars (322/1805) and anterior teeth (220/1805) - practice location - dentists' age <p>Facilitators for repairs were:</p> <ul style="list-style-type: none"> - composite restorations, as composite restorations were repaired more frequently than amalgam restorations (p < 0.001) - higher dentists' age, as amalgam restorations are repaired more frequently by older dentists (p < 0.001, $\tau = 0.08$) - practice location, as amalgam restorations are more frequently repaired in rural areas as well as by single practitioners (p < 0.001) - dentists' specialization, as amalgam and composite restorations are more frequently repaired by dentists without any specialization (p < 0.001) <p>1630/1805 considered repairs as a definitive measure</p>

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Table 1 (continued)

Study	Method	Country, year	Sample	Scenario/restoration materials	Treatment decision	Reasons, barriers, facilitators
Kanzow, Dieckmann et al. [5]	Questionnaire	Switzerland, 2017	Canton of Zurich, all active dentists, 39% response, final 498 (age 47.8 ± 11.6 years, 41.0% female, 20.2 ± 11.5 years since dental school graduation)	Amalgam + composite	497/498 perform repairs	<p>Reasons for repairs were:</p> <ul style="list-style-type: none"> - reduction of treatment costs in comparison with a newly made restoration (395/498) - prolongation of the lifespan of the restoration (387/498) - conservation of dental hard tissue (375/498) - patients' requests (312/498) - usage as temporary restoration (220/498) - time saving (132/498) - compliance with the warranty period (28/498) <p>Indications for repairs were:</p> <ul style="list-style-type: none"> - partial loss of restorations (Ag: 198/498, Co: 399/498) - loss of adjacent hard tissue (Ag: 190/498, Co: 371/498) - secondary caries (Ag: 117/498, Co: 285/498) - marginal gap (Ag: 90/498, Co: 321/498) - marginal discoloration (Ag: 15/498, Co: 221/498) - correction of anatomic form or colour (Ag: 10/498, Co: 241/498) <p>Relevant decision criteria:</p> <ul style="list-style-type: none"> - size of the defect (447/498), maximum size suitable for repair was 30.4% (± 14.8%) of the defective restoration - type of restoration material (419/498) - extension of the original restoration (314/498) - age of the original restoration (227/498) - localization of the defect, e.g. palatal or approximal (182/498) - type of tooth affected (96/498), as repairs are more often considered for molars (94/498) than for premolars (70/498) and anterior teeth (5/498) - who had placed the original restoration (63/498) - dental society membership - dentists' specialization <p>Barriers for performing repairs were:</p> <ul style="list-style-type: none"> - own bad experience (102/498) - insufficient training (55/498) - bad experience of other dentists (31/498) - missing knowledge regarding the necessary conditioning of surfaces to be treated (18/498) <p>Facilitators for repairs were:</p> <ul style="list-style-type: none"> - composite restorations, as composite restorations were repaired more frequently than amalgam restorations (p < 0.001) - dental society membership, as amalgam restorations are more frequently repaired by Swiss Dental Association (SSO) members (p = 0.027) - dentists' specialization, as composite restorations are more frequently repaired by dentists with a specialization (p = 0.019), amalgam restorations more frequently by dentists without any specialization (p = 0.003)

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Table 1 (continued)

Study	Method	Country, year	Sample	Scenario/restoration materials	Treatment decision	Reasons, barriers, facilitators
Maria et al. [32]	Questionnaire	Greece, 2017	Area of Athens, random sample of 800 dentists, 40% response, final 319 (40.4% female)	Amalgam + composite	277/319 perform repairs	<p>Reasons for repairs were:</p> <ul style="list-style-type: none"> - replacement risks - low cost of the repair - shorter time taken to perform the repair <p>Indications for a replacement</p> <ul style="list-style-type: none"> - little benefits of a replacement <p>Indications for repairs were:</p> <ul style="list-style-type: none"> - bulk fracture - colour discrepancies - marginal cracks - missing proximal contacts - cavity wall fracture - surface/marginal discolouration - missing proximal contacts - insufficient occlusal anatomy <p>Barriers for performing repairs were:</p> <ul style="list-style-type: none"> - over 65 years of age - multicaries presence - irregular dental appointments <p>Facilitators for repairs were:</p> <ul style="list-style-type: none"> - restorations had been placed by the same dentists

The proportion of dentists performing repairs for different scenarios or restoration materials were assessed. In addition, reasons (barriers, facilitators) for the decisions were recorded.

3.2. Study quality assessment

Risk of bias of included studies is shown in the appendix (Appendix Table S3). Most of the included studies yielded representative samples of dentists/dental schools. However, not a single study reported on sample size calculations. The validity of the utilized surveys was not assessed or published by the majority of studies. Samples regarding dentists repair behavior had not always been drawn nationally and most non-response rates were high. Due to the design of survey studies, outcomes of these studies were only self-reported. Overall, risk of bias was classified as high in 14 studies, moderate in 13 studies and low in 2 studies.

3.3. Meta-analyses and meta-regression

Data of all 29 studies contributed to meta-analyses (Fig. 1). The mean (95% CI) proportion of dentists stating to perform repairs was 71.5% (49.7–86.4%). The mean proportion of dental schools teaching repairs was 83.3% (73.6–90.0%). The mean proportion of restorations which had actually been repaired was 31.3% (26.3–36.7%). Statistical and graphical analyses indicated the risk of publication bias (Appendix Figs. S2–S4).

The proportions of dentists stating to perform repairs was significantly associated with the year of study publication (Fig. 2), increasing by 1.3% per year ($p = 0.004$). No significant association between year of study and the proportion of dental schools teaching repairs or the proportion of actually repaired restorations was observed (Appendix Figs. S5–S6).

3.4. Reasons for repair

When performing repairs, dentists mainly aimed at extending the longevity of an existing restoration (80.6%), tooth substance preservation (69.0%), and reducing costs to their patients (51.5%), Table 1. Most common reasons for teaching repair restorations were tooth substance preservation (81.0%), promotion of minimal intervention dentistry (56.3%), and reduction of potentially harmful effects on the pulp (55.2%), Table 2.

3.5. Barriers and facilitators for repair

Identified barriers or facilitators as well as conflicting themes were mapped to a number of TDF domains and constructs, mostly on knowledge, social influence, environmental context, or beliefs and reinforcement, covering all aspects of the Behavioral Change Wheel domains (Table 4).

Knowledge was one of the most relevant domains. Fewer years since dental school graduation were associated with higher proportion of repairs, while age was ambiguously reported to affect the willingness to repair. Consistent results were found within the skills domain. More experienced dentists seem to be more aware of repair restorations and repaired more frequently while those with insufficient training or missing knowledge regarding the necessary conditioning of surfaces did not. Regarding the domain of memory, attention and decision processes, having been the dentist who placed the original restoration and performing caries risk assessment were associated with increased numbers of repairs, while having had bad experience with repairs worked as barrier. Social influences, reinforcement, as well as environmental context and resources seemed to impact on the decision to repair. Larger practices facilitated performing repairs regularly. Being situated in an area with a low dentist density and the associated low financial competition was associated with higher frequencies of repairs, as was being a member of the dental associations. Beliefs about consequences seemed to guide decision-making, as specific patient or tooth related aspects (patient's age, caries risk, frequency of dental appointments, affected tooth, failure reason, original restoration material,

Table 2
Included studies regarding dental schools teaching repairs.

Study	Method	Country, year	Sample	Scenario/restoration materials	Treatment decision	Reasons, barriers, facilitators
Blum et al. [33]	Questionnaire	England, Ireland, 2002	15 dental schools, 100% response, final 15	Composite	14/15 teach repairs	<p>Reasons for teaching were:</p> <ul style="list-style-type: none"> - clinical experience (15/15) - existing evidence (4/15) - case reports (1/15) - other reasons (1/15) <p>Reasons for repairs were:</p> <ul style="list-style-type: none"> - tooth substance preservation (14/15) - reduction of potentially harmful effects on the pulp (8/15) - reduction in treatment time (5/15) - reduced costs to patients (4/15) <p>Partially defective restorations of different cavities are repaired as follows:</p> <ul style="list-style-type: none"> - class II premolar (7/15) - class II molar (6/15) - class III (7/15) - class IV (9/15) <p>Indications for repairs were:</p> <ul style="list-style-type: none"> - marginal defects (13/15) - restoration discolouration labial/buccal (12/15) - partial loss of an existing restoration (11/15) - marginal discolouration (10/15) - secondary caries (10/15) - superficial colour correction (9/15) - abrasion/attrition (8/15) - restoration discolouration cervical (6/15) - restoration discolouration proximal (4/15) - restoration discolouration occlusal (3/15) - discolouration involving > 1 surface (3/15) <p>11/15 considered repairs as a definitive measure</p>
Blum, Mjör et al. [34]	Questionnaire	Sweden, Finland, Denmark, Norway, 2003	11 dental schools, 91% response, final 9	Composite	9/9 teach repairs at theoretical and practical levels	<p>Reasons for teaching were:</p> <ul style="list-style-type: none"> - personal clinical experience - existing literature <p>Reasons for repairs were:</p> <ul style="list-style-type: none"> - tooth substance preservation - reduction of potentially harmful effects on the pulp - reduction in treatment time - reduced costs to patients <p>Indications for repairs were:</p> <ul style="list-style-type: none"> - marginal defects (8/9) - partial loss of an existing restoration (8/9) - marginal discolouration (7/9) - secondary caries (7/9) - bulk fracture of posterior restorations (7/9) - surface discolouration (5/9) - abrasion/attrition (5/9) - bulk fracture of anterior restorations (5/9) - 8/9 considered repairs as a definitive measure
Blum, Schriever et al. [35]	Questionnaire	England, Ireland, Germany, Norway, Sweden, Denmark, Finland, 2003	58 dental schools, 83% response, final 48 (15 from England, 24 from Germany, 9 from Scandinavia)	Composite	35/48 teach repairs (14 from England, 12 from Germany, 9 from Scandinavia)	<p>Reasons for repairs were:</p> <ul style="list-style-type: none"> - tooth substance preservation (34/48, 14/15 from England, 11/24 from Germany, 9/9 from Scandinavia) - reduction of potentially harmful effects on the pulp (26/48, 8/15 from England, 11/24 from Germany, 7/9 from Scandinavia)

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Table 2 (continued)

Study	Method	Country, year	Sample	Scenario/restoration materials	Treatment decision	Reasons, barriers, facilitators
Gordán et al. [36]	Questionnaire	USA, Canada, Puerto Rico 2003	64 dental schools, 81% response, final 52	Composite	37/52 teach repairs	<ul style="list-style-type: none"> - reduction in treatment time (19/48, 5/15 from England, 11/24 from Germany, 5/9 from Scandinavia) - reduced costs to patients (8/48, 4/15 from England, 2/24 from Germany, 2/9 from Scandinavia) <p>Indications for repairs were:</p> <ul style="list-style-type: none"> - marginal defects (42/48, 10/15 from England, 24/48, 3/24 from Germany, 8/9 from Scandinavia) - partial loss of an existing restoration (30/48, 11/15 from England, 11/24 from Germany, 8/9 from Scandinavia) - marginal discolouration (25/48, 13/15 from England, 5/24 from Germany, 7/9 from Scandinavia) - labial/buccal discolouration (22/48, 12/15 from England, 3/24 from Germany, 7/9 from Scandinavia) - superficial colour correction (21/48, 9/15 from England, 7/24 from Germany, 5/9 from Scandinavia) - secondary caries (20/48, 10/15 from England, 3/24 from Germany, 7/9 from Scandinavia) - abrasion/attrition (17/48, 8/15 from England, 4/24 from Germany, 5/9 from Scandinavia) - cervical discolouration (11/48, 6/15 from England, 2/24 from Germany, 3/9 from Scandinavia) - discolouration involving more than one surface (6/48, 3/15 from England, 0/24 from Germany, 3/9 from Scandinavia) - proximal discolouration (6/48, 4/15 from England, 0/24 from Germany, 2/9 from Scandinavia) - occlusal discolouration (5/48, 3/15 from England, 0/24 from Germany, 2/9 from Scandinavia) <p>13/48 did not teach repairs. Barriers for German dental school teaching repairs were:</p> <ul style="list-style-type: none"> - no clinical experience (4/24) - poor experiences (3/24) - lack of sufficient clinical evidence (5/24) <p>30/48 (11/15 from England, 11/24 from Germany, 8/9 from Scandinavia) considered repairs as a definitive measure</p> <p>Reasons for teaching were:</p> <ul style="list-style-type: none"> - clinical experience (36/37) <p>Reasons for repairs were:</p> <ul style="list-style-type: none"> - tooth substance preservation (37/52) - reduction of potentially harmful effects on the pulp (27/52) - reduced costs to patients (17/52) - reduction in treatment time (13/52) - increasing the longevity of restorations (11/52) <p>Indications for repairs were:</p> <ul style="list-style-type: none"> - marginal defects (31/52) - marginal discolouration (27/52) - surface discolouration (25/52) - partial loss of an existing restoration (24/52) - abrasion/attrition (14/52) - secondary caries (13/52) - bulk fracture of anterior restorations (6/52) - bulk fracture of posterior restorations (4/52) <p>15/52 did not teach repairs. Barriers for teaching repairs were:</p> <ul style="list-style-type: none"> - lack of sufficient clinical evidence - 42/52 considered repairs as a definitive measure

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Table 2 (continued)

Study	Method	Country, year	Sample	Scenario/restoration materials	Treatment decision	Reasons, barriers, facilitators
Toyo et al. [37]	Questionnaire	Brazil, 2011	8 dental schools, State of Rio Grande do Sul, 75% response, final 6	Composite	6/6 teach repairs	<p>Indications for repairs were:</p> <ul style="list-style-type: none"> - superficial/surface colour correction (6/6) - bulk fracture (6/6) - tooth fracture (6/6) - marginal defects (5/6) - marginal discolouration (5/6) - restoration discolouration (5/6) - abrasion/attrition (5/6) - secondary caries (4/6) - surface staining as a result of aging (1/6) <p>5/6 considered repairs as a definitive measure</p> <p>Reasons for teaching were:</p> <ul style="list-style-type: none"> - clinical experience with composite repairs (22/25) - existing evidence (15/25) - information from case reports (8/25) - outcome of local audit (1/25) <p>Reasons for repairs were:</p> <ul style="list-style-type: none"> - tooth substance preservation (21/25) - reduction of potentially harmful effects on the pulp (17/25) - reduced costs to patients (10/25) - reduction in treatment time (7/25) <p>Indications for repairs were:</p> <ul style="list-style-type: none"> - marginal defects (20/25) - partial loss of an existing restoration (19/25) - bulk fracture of anterior restorations incisal (17/25) - bulk fracture of anterior restorations proximal-incisal (11/25) - bulk fracture of anterior restorations proximal (4/25) - bulk fracture of posterior restorations marginal ridge fracture (15/25) - bulk fracture of posterior restorations box fracture (14/25) - bulk fracture of posterior restorations occlusal (12/25) - bulk fracture of posterior restorations isthmus fracture (9/25) - secondary caries (13/25) - superficial/surface colour correction (11/25) - marginal discolouration (10/25) - restoration discolouration labial/buccal (8/25) - abrasion/attrition/erosion (6/25) - restoration discolouration occlusal (4/25) - restoration discolouration cervical (4/25) - restoration discolouration proximal (3/25) <p>Clinical scenarios involving tooth fracture to existing restorations being suitable for repair:</p> <ul style="list-style-type: none"> - posterior tooth with cusp fracture (18/25) - anterior tooth with tooth fracture from incisal region (15/25) - anterior tooth with tooth fracture from proximal-incisal region (11/25) - anterior tooth with tooth fracture from proximal region (6/25) - cracked posterior tooth (4/25) <p>3/17 did not teach repairs. Barriers for teaching repairs were:</p> <ul style="list-style-type: none"> - lack of sufficient clinical evidence (1/17) <p>Barriers for performing repairs were:</p> <ul style="list-style-type: none"> - restoration discolouration involving more than one surface (25/25) - lack of sufficient clinical evidence (1/25) <p>20/25 considered repairs as a definitive measure</p> <p>Reasons for repairs were:</p>
Blum et al. [38]	Questionnaire	Germany, 2011	30 dental schools, 83% response, final 25	Composite	22/25 teach repairs	<p>Reasons for repairs were:</p> <ul style="list-style-type: none"> - marginal defects (20/25) - partial loss of an existing restoration (19/25) - bulk fracture of anterior restorations incisal (17/25) - bulk fracture of anterior restorations proximal-incisal (11/25) - bulk fracture of anterior restorations proximal (4/25) - bulk fracture of posterior restorations marginal ridge fracture (15/25) - bulk fracture of posterior restorations box fracture (14/25) - bulk fracture of posterior restorations occlusal (12/25) - bulk fracture of posterior restorations isthmus fracture (9/25) - secondary caries (13/25) - superficial/surface colour correction (11/25) - marginal discolouration (10/25) - restoration discolouration labial/buccal (8/25) - abrasion/attrition/erosion (6/25) - restoration discolouration occlusal (4/25) - restoration discolouration cervical (4/25) - restoration discolouration proximal (3/25) <p>Clinical scenarios involving tooth fracture to existing restorations being suitable for repair:</p> <ul style="list-style-type: none"> - posterior tooth with cusp fracture (18/25) - anterior tooth with tooth fracture from incisal region (15/25) - anterior tooth with tooth fracture from proximal-incisal region (11/25) - anterior tooth with tooth fracture from proximal region (6/25) - cracked posterior tooth (4/25) <p>3/17 did not teach repairs. Barriers for teaching repairs were:</p> <ul style="list-style-type: none"> - lack of sufficient clinical evidence (1/17) <p>Barriers for performing repairs were:</p> <ul style="list-style-type: none"> - restoration discolouration involving more than one surface (25/25) - lack of sufficient clinical evidence (1/25) <p>20/25 considered repairs as a definitive measure</p> <p>Reasons for repairs were:</p>
Hasan et al. [39]	Questionnaire	Pakistan, 2011		Composite		<p>Reasons for repairs were:</p>

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Table 2 (continued)

Study	Method	Country, year	Sample	Scenario/restoration materials	Treatment decision	Reasons, barriers, facilitators
Blum, Lynch, Wilson [40]	Questionnaire	England, Ireland, 2012	Faculty members in operative/restorative department from 10 dental institutions in Karachi, 90% overall response, final 38 faculty members from 9 dental institutions	Composite	17/38 faculty members teach repairs	<ul style="list-style-type: none"> - tooth substance preservation (30/38) - reduction of potentially harmful effects on the pulp (4/38) - increasing longevity of the restoration (2/38) - reduction in treatment time (1/38) - reduced costs to patients (1/38) <p>Indications for repairs were:</p> <ul style="list-style-type: none"> - partial loss of an existing restoration 13/38 - marginal defects (8/38) - marginal and surface discolouration (7/38) <p>21/38 faculty members did not teach repairs. Barriers for teaching repairs were:</p> <ul style="list-style-type: none"> - lack of predictability (16/38) - absence of established technique (14/38) - lack of sufficient scientific evidence (7/38) - no limitation (1/38) <p>28/38 considered repairs as a definitive measure</p> <p>Reasons for teaching were:</p> <ul style="list-style-type: none"> - clinical experience (12/17) - existing evidence (7/17) - information from case reports (2/17) <p>Reasons for repairs were:</p> <ul style="list-style-type: none"> - tooth substance preservation (15/17) - reduction of potentially harmful effects on the pulp (10/17) - reduction in treatment time (5/17) - reduced costs to patients (2/17) <p>Indications for repairs were:</p> <ul style="list-style-type: none"> - partial loss of an existing restoration (13/17) - marginal defects (12/17) - marginal discolouration (11/17) - superficial/surface colour correction (11/17) - restoration discolouration labial/buccal (10/17) - restoration discolouration cervical (8/17) - abrasion/attrition/erosion (8/17) - restoration discolouration occlusal (7/17) - bulk fracture of posterior restoration box fracture (7/17) - bulk fracture of anterior restorations incisal (6/17) - bulk fracture of anterior restorations proximal (6/17) - secondary caries (6/17) - bulk fracture of anterior restorations proximal-incisal (5/17) - bulk fracture of posterior restorations occlusal (5/17) - bulk fracture of posterior restoration marginal ridge fracture (5/17) - discolouration involving more than one surface (5/17) - restoration discolouration proximal (4/17) - bulk fracture of posterior restorations isthmus fracture (2/17) <p>Clinical scenarios involving tooth fracture to existing restorations being suitable for repair:</p> <ul style="list-style-type: none"> - posterior tooth with cusp fracture (14/17) - anterior tooth with tooth fracture from incisal region (11/17) - anterior tooth with tooth fracture from proximal region (11/17) - anterior tooth with tooth fracture from proximal-incisal region (10/17) - cracked posterior tooth (7/17) <p>2/17 did not teach repairs. Barriers for teaching repairs were:</p> <ul style="list-style-type: none"> - not enough time within the dental school curriculum (1/17) - poor experiences and concerns regarding recurrent caries (1/17)

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Table 2 (continued)

Study	Method	Country, year	Sample	Scenario/restoration materials	Treatment decision	Reasons, barriers, facilitators
Lynch et al. [41]	Questionnaire	USA, Canada, 2012	67 dental schools, 72% response, final 48	Composite	42/48 teach repairs	<p>Reasons for teaching were:</p> <ul style="list-style-type: none"> - clinical experience (42/48) - existing evidence (34/48) - case reports (11/48) <p>Reasons for repairs were:</p> <ul style="list-style-type: none"> - tooth substance preservation (42/48) - reduction of potentially harmful effects on the pulp (41/48) - reduced costs to patients (26/48) - reduction in treatment time (25/48) <p>Indications for repairs were:</p> <ul style="list-style-type: none"> - marginal defects (42/48) - marginal discolouration (38/48) - partial loss of an existing restoration (37/48) - superficial/surface colour correction (28/48) - secondary caries (27/48) - surface wear (22/48) - restoration discolouration labial or buccal (27/48) - restoration discolouration cervical (19/48) - bulk fracture of anterior restoration incisal (19/48) - bulk fracture of posterior restoration marginal ridge fracture (14/48) - restoration discolouration occlusal (13/48) - bulk fracture of posterior restoration box fracture (12/48) - bulk fracture of anterior restoration proximal-incisal (9/48) - restoration discolouration proximal (9/48) - restoration discolouration involving more than one surface (9/48) - bulk fracture of posterior restoration occlusal (9/48) - bulk fracture of posterior restoration isthmus fracture (9/48) - bulk fracture of anterior restoration proximal (7/48) <p>Clinical scenarios involving tooth fracture to existing restorations being suitable for repair:</p> <ul style="list-style-type: none"> - anterior tooth with tooth fracture from incisal region (27/48) - anterior tooth with tooth fracture from proximal-incisal region (18/48) - posterior tooth with cusp fracture (14/48) - anterior tooth with tooth fracture from proximal region (14/48) - cracked posterior tooth (7/48) <p>6/48 did not teach repairs. Barriers for teaching repairs were:</p> <ul style="list-style-type: none"> - poor experiences (2/48) - lack of sufficient clinical evidence (2/48) - lack of clinical experience (1/49)
Blum, Lynch, Wilson [42]	Questionnaire	Sweden, Finland, Denmark, Norway, 2012	12 dental schools, 100% response, final 12	Composite	11/12 teach repairs	<p>Reasons for teaching were:</p> <ul style="list-style-type: none"> - personal clinical experience (11/12) - existing literature (10/12) - case reports (3/12) <p>Reasons for repairs were:</p> <ul style="list-style-type: none"> - tooth substance preservation (11/12) - reduction of potentially harmful effects on the pulp (10/12) - reduced costs to patients (6/12) - reduction in treatment time (3/12) <p>Indications for repairs were:</p> <ul style="list-style-type: none"> - marginal defects (10/12) - abrasions/attrition/erosion (9/12) - secondary caries (9/12) - bulk fracture of posterior restoration marginal ridge fracture (9/12)

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Table 2 (continued)

Study	Method	Country, year	Sample	Scenario/restoration materials	Treatment decision	Reasons, barriers, facilitators
Lynch et al. [43]	Questionnaire	Japan, 2013	29 dental schools, 66% response, final 19	Composite	18/19 teach repairs	<ul style="list-style-type: none"> - bulk fracture of posterior restoration occlusal (9/12) - bulk fracture of posterior restoration isthmus fracture (8/12) - partial loss of an existing restoration (8/12) - bulk fracture of posterior restoration box fracture (7/12) - restoration discolouration labial/buccal (6/12) - marginal discolouration (5/12) - restoration discolouration cervical (4/12) - bulk fracture of anterior restoration incisal (4/12) - bulk fracture of anterior restoration proximal-incisal (4/12) - bulk fracture of anterior restoration proximal (3/12) - superficial/surface colour correction (3/12) - restoration discolouration occlusal (2/12) - restoration discolouration proximal (2/12) - restoration discolouration involving more than one surface (1/12) <p>Clinical scenarios involving tooth fracture to existing restorations being suitable for repair:</p> <ul style="list-style-type: none"> - posterior tooth with cusp fracture (11/12) - anterior tooth with tooth fracture from incisal region (8/12) - cracked posterior tooth (7/12) - anterior tooth with tooth fracture from proximal-incisal region (7/12) - anterior tooth with tooth fracture from proximal region (5/12) <p>1/12 did not teach repairs. Barriers for teaching repairs were:</p> <ul style="list-style-type: none"> - lack of personal clinical experience (1/12) <p>Reasons for teaching were:</p> <ul style="list-style-type: none"> - clinical experience (13/19) - existing evidence (6/19) - information from case reports (6/19) <p>Reasons for repairs were:</p> <ul style="list-style-type: none"> - tooth substance preservation (18/19) - reduction of potentially harmful effects on the pulp (12/19) - reduction in treatment time (8/19) - reduced costs to patients (4/19) <p>Indications for repairs were:</p> <ul style="list-style-type: none"> - marginal defects (18/19) - marginal discolouration (16/19) - partial loss of an existing restoration (15/19) - secondary caries (14/19) - restoration discolouration labial/buccal (13/19) - superficial/surface colour correction (12/19) - abrasions/attrition/erosion (12/19) - restoration discolouration occlusal (11/19) - restoration discolouration cervical (11/19) - bulk fracture of anterior restoration incisal (11/19) - bulk fracture of posterior restoration marginal ridge fracture (10/19) - restoration discolouration proximal (8/19) - restoration discolouration involving more than one surface (8/19) - bulk fracture of anterior restoration proximal (8/19) - bulk fracture of anterior restoration proximal-incisal (6/19) - bulk fracture of posterior restoration occlusal (6/19) - bulk fracture of posterior restoration box fracture (4/19) - bulk fracture of posterior restoration isthmus fracture (3/19) <p>Clinical scenarios involving tooth fracture to existing restorations being suitable for repair:</p> <ul style="list-style-type: none"> - anterior tooth with tooth fracture from incisal region (11/19)

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Table 2 (continued)

Study	Method	Country, year	Sample	Scenario/restoration materials	Treatment decision	Reasons, barriers, facilitators
Brunton et al. [44]	Questionnaire	Australia, New Zealand, Fiji, Papua New Guinea, 2017	16 dental schools, 100% response, final 16	Composite	13/16 teach repairs	<ul style="list-style-type: none"> - anterior tooth with tooth fracture from proximal region (8/19) - posterior tooth with cusp fracture (7/19) - cracked posterior tooth (7/19) - anterior tooth with tooth fracture from proximal-incisal region (6/19) <p>Reasons for teaching were:</p> <ul style="list-style-type: none"> - clinical experience (12/16) - existing evidence (8/16) - included in recommended texts (4/16) - case reports (2/16) <p>Reasons for repairs were:</p> <ul style="list-style-type: none"> - tooth substance preservation (13/16) - promotion of minimal intervention dentistry (9/16) - slowing the “restorative death spiral” (6/16) - reduction of potentially harmful effects on the pulp (5/16) - reduction in treatment time (4/16) - reduced costs to patients (4/16) <p>Indications for repairs were:</p> <ul style="list-style-type: none"> - marginal defects (13/16) - secondary caries (9/16) - restoration discolouration labial/buccal (8/16) - superficial colour correction (8/16) - marginal discolouration (8/16) - partial loss of an existing restoration (7/16) - abrasion/attrition/erosion (5/16) - restoration discolouration proximal (3/16) - restoration discolouration cervical (3/16) - restoration discolouration occlusal (3/16) - discolouration involving more than one surface (2/16) <p>3/16 did not teach repairs. Barriers for teaching repairs were:</p> <ul style="list-style-type: none"> - absence from current recommended curriculum - lack of sufficient scientific evidence - absence in recommended textbooks - perceptions about insufficient adhesion of new increments of composite to cured/aged composite <p>10/16 considered repairs as a definitive measure</p>

The proportion of dental schools performing repairs for different scenarios or restoration materials were assessed. In addition, reasons (barriers, facilitators) for the decisions were recorded.

Table 3
Included studies regarding dentists' repair behavior by treatment data collection.

Study	Method	Country, year	Sample	Scenario/restoration materials	Treatment decision	Reasons, barriers, facilitators
Gordan, Riley, Worley, Gilbert [45]	Treatment data collection	USA, 2012	8921 restorations in permanent teeth treated by 197 practitioner-investigators participating in the DPBRN (30% female, 21.7 ± 10.5 years since dental school graduation)	Amalgam + composite	2264/8921 were repair restorations	
Gordan, Riley, Geraldini et al. [46]	Treatment data collection	USA, 2012	9484 restorations treated by 197 practitioner-investigators participating in the DPBRN (30% female, 21.7 ± 10.5 years since dental school graduation)	Amalgam, direct tooth coloured, indirect tooth coloured, and gold restorations	2411/9484 were repair restorations: 1031/5110 amalgam, 1012/3342 direct tooth coloured, 195/505 indirect tooth coloured, and 116/211 gold restorations	<p>Barriers for performing repairs were:</p> <ul style="list-style-type: none"> - molars, as defective restoration in molars were more likely to be replaced than restorations in premolars (OR = 0.052, 95% CI: 0.046-0.60, p < 0.001) or anterior teeth (OR = 0.47, 95% CI: 0.39-0.56, p < 0.001) - high number of surfaces, as with higher numbers of surfaces involved in the original restoration, restorations are more likely to be replaced (OR = 0.40, 95% CI: 0.37-0.43, p < 0.001) - longer time since dental school graduation (OR = 0.84, 95% CI: 0.79-0.89, p < 0.001) <p>Facilitators for repairs were:</p> <ul style="list-style-type: none"> - compared to an amalgam restoration, if the existing restoration was a direct tooth-coloured material (OR = 1.89, 95% CI: 1.64-2.18, p < 0.001), indirect tooth-coloured material (OR = 2.82, 95% CI: 2.29-3.47, p < 0.001), or gold material (OR = 3.15, 95% CI: 2.39-4.15, p < 0.001), it was more likely to have been repaired - practicing in a large group practices compared to solo or small group practices (OR = 1.47, 95% CI: 1.29-1.68, p < 0.001) - public health practices (OR = 1.30, 95% CI: 1.01-1.69, p = 0.47) - public health practices are more likely to repair than dentists in solo or small group private practices for direct tooth-coloured materials (OR = 1.46) - amalgam is more likely to be repaired in large group than in solo or small group private practices (OR = 1.90) - having been the dentist who placed the original restoration (OR = 1.49, 95% CI: 1.31-1.70, p < 0.001) - older patient age (OR = 1.24, 95% CI: 1.19-1.29, p < 0.001)
Gordan et al. [47]	Treatment data collection	USA, 2014	8186 restorations treated by 194 practitioner-investigators participating in the DPBRN	Amalgam, direct tooth coloured, indirect tooth coloured, and gold restorations	943/2155 amalgam and 1212/6031 non-amalgam restorations were repaired	<p>Barriers for performing repairs were:</p> <ul style="list-style-type: none"> - amalgam restorations (OR = 0.4, p < 0.001) - fractured restorations (OR = 0.7, p < 0.001) - larger restorations (OR = 0.8, p = 0.008) * <p>Facilitators for repairs were:</p> <ul style="list-style-type: none"> - having been the dentist who placed the original restoration (OR = 1.6, p < 0.001) - molars (OR = 1.9, p < 0.001) <p>* Due to the given OR, larger restorations were classified as barriers despite publication reading "A greater number of surfaces was associated with increased likelihood of a repair".</p>
Heaven et al. [26]	Treatment data collection	USA, 2015	3478 restorations treated by 193 practitioner-investigators participating in the DPBRN, performing restorative dentistry (29.5% female, 18.2 years since dental school graduation)	Amalgam + composite	931/3478 were repaired	

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Table 3 (continued)

Study	Method	Country, year	Sample	Scenario/restoration materials	Treatment decision	Reasons, barriers, facilitators
Javidi et al. [48]	Treatment data collection	England, 2015	All general dental practitioners in North West of England, 13% response, final 38 having treated 103 patients with failed restorations	Amalgam + composite	37/103 patients underwent repair	<p>Barriers for performing repairs were:</p> <ul style="list-style-type: none"> - amalgam restorations, as restorations consisting of amalgam were less frequently repaired ($p = 0.001$) - D2 or D3 levels of caries depth, as the majority of the failed restorations which were replaced were associated with D2 (33/103) or D3 (22/103) levels of caries depth ($p = 0.001$) <p>Facilitators for repairs were:</p> <ul style="list-style-type: none"> - minimal caries depth, as the majority (14/103) of the failed restorations which subsequently underwent repair were associated with minimal caries depth ($p = 0.001$) - composite or glass ionomer cement restorations, as restorations consisting of composite or glass ionomer cement were more frequently repaired ($p = 0.001$)

The proportion of dentists performing repairs for different scenarios or restoration materials were assessed. In addition, reasons (barriers, facilitators) for the decisions were recorded.

number of restoration's surfaces, size of defect, caries lesion depth) impacted on dentists' repair behavior.

Overall, employment in public health practices (frequency ES: 0.18) and being the dentist who placed the now defective restoration were the most frequently found facilitators to repair (frequency ES: 0.18). Defective restorations being made of amalgam was the most frequently stated barrier for repair (frequency ES: 0.29; Fig. 3).

4. Discussion

Our results indicate that most dental schools teach repairs but not all dentists employ repairs as part of their own management of partially defective restorations. Even more so, data collected from truly treated defective restorations indicate that only a minority of all restoration had in fact been repaired, while most were completely replaced. The current management of partially defective restorations is thus only limitedly in line with scientific evidence [3].

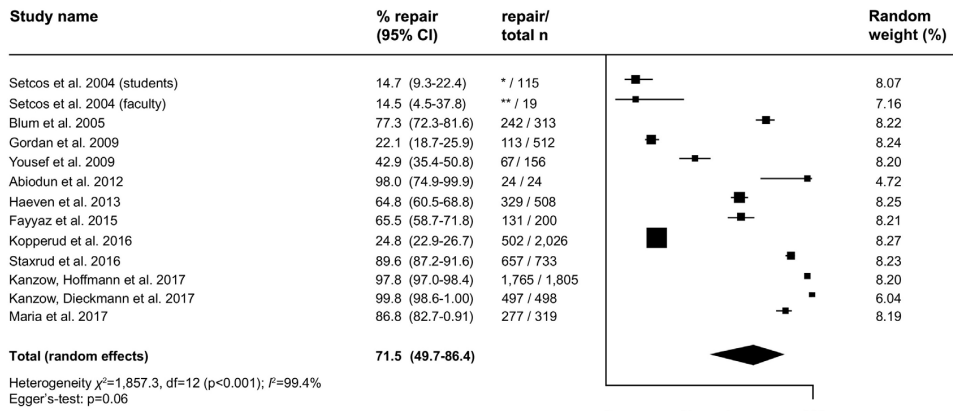
Our results further unambiguously show that amalgam restorations are more frequently replaced and not repaired compared with composite restorations. This observation might be explained by the fact that generally, the placement of amalgam restorations might be less common nowadays due to esthetic reasons, safety controversies, or efforts to limit or even ban its use in dentistry [23,24]. Thus, both dentists and patients might opt for removing these restorations rather than for repairing them. However, after optimal mechanical and adhesive surface conditioning, repairs of amalgam are possible and bond strengths are clinically sufficient [25].

While more recent surveys yielded a higher proportion of dentists stating to perform repairs based on self-reported data, this was not confirmed when assessing (via treatment records) how defective restorations were actually managed. It is conceivable that dentists are increasingly aware of what answers are expected from them in surveys on this topic (especially as repairs are widely taught at dental schools), while the associated behavior change from replacement to repair has not taken place uniformly. It should, however, be noted that the meta-regression analyses might have been underpowered, but also that we have used year of study publication as proxy for year of study conduct, which could have introduced some bias. More important, it could not always be ascertained in hindsight if the restorations to be managed where in fact partially or completely defective, i.e. candidates for repairs or not. Thus, this analysis should be interpreted cautiously.

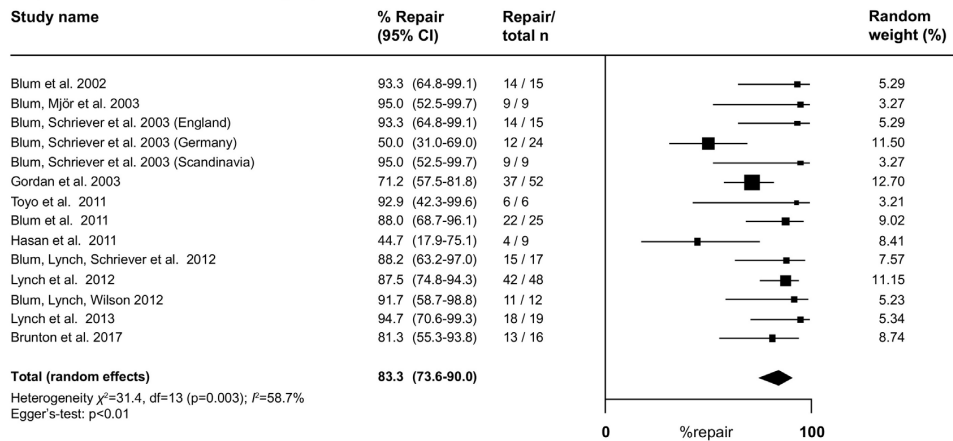
This study has a number of limitations. First, our results build on a limited number of included studies, which were additionally very heterogeneous with regards to sample sizes, survey methods, and employed scenarios. Moreover, survey studies are prone to risk of selection bias, with responding dentists not necessarily being representative for all other dentists. Our analyses for possibly missing data (publication bias etc.) also indicate that such distortions are likely. Second, outcomes were mainly self-reported, with obvious risk of bias, as discussed above. However, a recent study has compared the responses in questionnaires and actual treatment decisions regarding repair or replacement of partially defective restorations and has found a high agreement between both [26]. Third, we entered subgroups of dentists (i.e. students/faculty, dentists from different countries, or different restoration materials) separately into meta-analyses. This might lead to some distortion of the pooled proportions from meta-analyses [12]. Last, we only extracted themes for our qualitative analysis from by-comments made in reports of quantitative (survey) studies. Obviously, such data do not have the depth required for fully understanding dentists' decision making.

A number of recommendations can be drawn from this study. Future research in this field should utilize qualitative research to yield a deeper understanding of relevant barriers and facilitators. For example, our qualitative findings are unlikely to represent all relevant themes and new themes and concepts could emerge more easily in discussions or focus groups. To enhance evidence-based management of defective

(1) Proportion of dentists stating to perform repairs



(2) Proportion of dental schools teaching repairs



(3) Proportion of failed restorations having been repaired

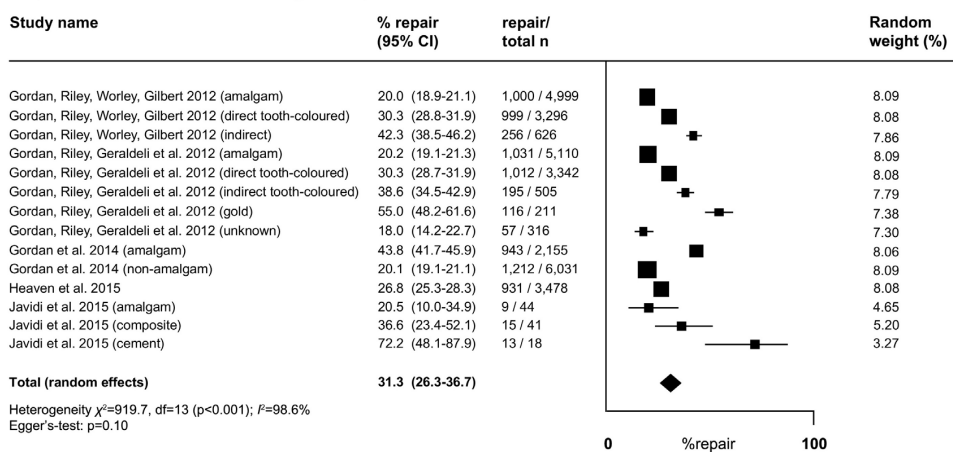


Fig. 1. The proportion (%) of (1) dentists stating to perform repairs, (2) dental schools teaching repairs, and (3) failed restorations having actually been repaired. Wherever possible, subgroups of dentists (students/faculty, different countries, or different restoration materials) were separately entered into meta-analyses. Pooled proportions and 95% confidence intervals (bold) from random-effects meta-analyses are shown as diamonds. Heterogeneity was assessed using χ^2 -test and I^2 -statistics and publication bias or small-study effects were evaluated using Egger's regression intercept test. * = 761/5175 of all treatment decision by 115 students were in favor of repairs, ** = 124/855 of all treatment decision by 19 faculty members were in favor of repairs, n = total sample sizes.



Fig. 2. Association between the year of study publication and the share of dentists stating to perform repairs. The regression line indicates a significantly increased share in recent years ($p = 0.004$), with a mean (95% CI) slope of 1.32% (1.09-1.58%), i.e., the share increased with 1.3% per year in mean.

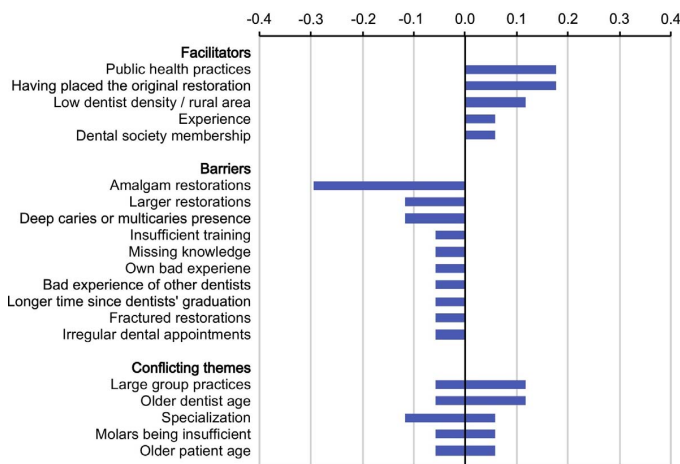


Fig. 3. Frequency effect sizes of extracted barriers and facilitators. Relative importance of identified barriers and facilitators are expressed as frequency effect sizes by dividing the number of studies containing a particular theme by the total number of included studies.

restorations, guidelines towards when and how to repair should be established and reinforced. The promotion by peers (with presumably higher peer pressure in large groups practices or practice research networks) could be used on mid-level to improve implementation of repairs. Healthcare services should establish financial incentives and regulations to increase the number of performed repairs.

5. Conclusion

Dental schools teach repairs widely, but only about two-thirds of dentists state to perform repairs. However, in recent years this proportion seems to increase. Dentists' decision-making regarding repairs

is affected by a range of factors, from their knowledge, over contextual factors to systemic and oftentimes economic reinforcement mechanisms. Future studies should use also include qualitative elements to yield a deeper understanding of barriers and facilitators towards repairs. A number of interventions like establishing financial incentives, altering healthcare regulation, or promotion by peers could be used to facilitate repairs in dental practice.

Conflict of interest

The authors declare no conflict of interest.

Table 4
Mapping of identified themes to the COM-B system (capability, opportunity, motivation) of the Wheel of Change [20] and TDF domains and constructs [17].

COM-B	TFD domain	TDF constructs	Identified facilitators (+), barriers (–), or conflicting themes (?)	Explanation	References
Capability	Knowledge	<ul style="list-style-type: none"> - Knowledge (including knowledge of condition/scientific rationale) - Procedural knowledge - Knowledge of task environment 	<ul style="list-style-type: none"> - (+) fewer years since dental school graduation - (?) age 	Dentists with fewer years since dental school have different knowledge and were taught repair restorations in dental school	[4,23,31,46]
	Skills	<ul style="list-style-type: none"> - Skills - Skills development - Competence - Ability - Interpersonal skills - Practice - Skill assessment 	<ul style="list-style-type: none"> - (+) experience - (–) insufficient training - (–) missing knowledge regarding the necessary conditioning of surfaces to be treated 	Experienced dentists are more aware of repair restorations	[5,30]
	Memory, Attention and Decision Processes	<ul style="list-style-type: none"> - Memory - Attention - Attention control - Decision making - Cognitive overload/tiredness 	<ul style="list-style-type: none"> - (+) having been the dentist who placed the original restoration - (–) own bad experience with repair restorations - (–) bad experience of other dentists 	Dentists who placed the original restoration have greater knowledge regarding the clinical circumstances and might be more confident in their own work	[5,32,46,47]
Opportunity	Social influences	<ul style="list-style-type: none"> - Social pressure - Social norms - Group conformity - Social comparisons - Group norms - Social support - Power - Intergroup conflict - Alienation - Group identity - Modelling 	<ul style="list-style-type: none"> - (+) low dentist density - (?) large group practices (dentists participating in large group practices or public health practices choose repairs more often than dentists who participate in solo or small group private practices) 	Low dentist density leads to less financial competition, larger practices drive a different group dynamics and facilitates change	[4,7,23,46]
	Environmental Context and Resources	<ul style="list-style-type: none"> - Environmental stressors - Resources/material resources - Organisational culture/climate - Salient events/critical incidents - Person x environment interaction - Barriers and facilitators 	<ul style="list-style-type: none"> - (+) public health practices 	Being paid for new restorations might set an incentive to replace in private practices	[7,23,46]
Motivation	Social/Professional Role and Identity	<ul style="list-style-type: none"> - Beliefs - Professional identity - Professional role - Social identity - Identity - Professional boundaries - Professional confidence - Group identity - Leadership - Organisational commitment 	<ul style="list-style-type: none"> - (+) dental society membership - (?) specialization 	Dentists who are society members might have different professional identity which could act as facilitator.	[4,5]
	Beliefs about Consequences	<ul style="list-style-type: none"> - Beliefs - Outcome expectancies - Characteristics of outcome expectancies - Anticipated regret - Consequents 	<ul style="list-style-type: none"> - (+) older patient age - (?) affected tooth - (–) increasing size of defect (there is a maximum size suitable for repair) - (–) larger restorations - (–) deep caries or multicares presence - (–) amalgam restorations - (–) fractured restorations - (–) irregular dental appointments 	The expected outcome might drive some decisions (decisions are tailored to teeth or patients based on different expectations)	[4,5,32,46–48]
	Reinforcement	<ul style="list-style-type: none"> - Rewards (proximal/distal, valued/not valued, probable/improbable) - Incentives - Punishment - Consequents - Reinforcement - Contingencies - Sanctions 	<ul style="list-style-type: none"> - (–) financial aspects, practice settings 	see above	[4,7,23,46]

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Appendix A. Supplementary data

Supplementary data associated with this article can be found, in the online version, at <http://dx.doi.org/10.1016/j.jdent.2017.09.010>.

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Lebenslauf

Mein Lebenslauf wird aus datenschutzrechtlichen Gründen in der elektronischen Version meiner Arbeit nicht veröffentlicht.

Komplette Publikationsliste

- Dissertation: **Zirkulierende Nukleinsäuren im zellfreien Plasma von LTx-Patienten als Frühmarker einer Schädigung des Spenderorgans**
Institut für Klinische Chemie, Universitätsmedizin Göttingen
(ehemaliger Direktor: Prof. Dr. med. Dr. h.c. M. Oellerich),
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- Masterarbeit: **Betriebswirtschaftliche Bewertung einer Zahnarztpraxis in der heutigen Zeit – Retrospektive Analyse anhand von zwei Praxiskäufen**
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– **National Academy of Clinical Biochemistry (NACB) 2013 Distinguished Abstract Award** –

IF = Impactfaktor, jeweils für das Erscheinungsjahr der Arbeiten angegeben (soweit bereits verfügbar, gemäß ISI Journal Citation Reports®).

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