

Review article

Same, same, but different? A systematic review of protocols for restoration repair

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ABSTRACT

Objectives: While repairs are increasingly recommended to manage partially defective restorations, performing the repair (including bonding to different substrates) can be challenging, and dentists should adhere to established repair protocols. We aimed to systematically assess the consistency and quality of repair protocols.

Data: 808 records were initially identified and 71 repair protocols based on 84 sources included. The number of published sources over time increased exponentially ($p < 0.001$). Recommended treatment steps varied widely. Some treatment steps were only recommended by a minority of protocols, while others were consistently recommended (e.g. surface roughening, hydrofluoric acid etching of silicate ceramics, application of an adhesive/bonding agent). The overall quality of included sources was moderate (mean \pm SD 3.7 \pm 0.9 out of 7 points).

Sources: Electronic databases (Medline via PubMed, Embase) were searched, hand searches using Google and Google Scholar conducted, and the reference lists of included full texts screened and cross-referenced.

Study selection: (Non-)systematic reviews, working instructions, and textbooks with protocols on direct composite repair restorations for partially defective (1) composite, (2) amalgam, (3) porcelain-fused-to-metal (PFMs) with exposed metal base, (4) ceramic/PFMs without exposed metal base, and (5) full metal restorations were included. Data synthesis was performed by tabulation of recommended treatment steps and descriptive statistics. The quality of included sources was assessed based on a checklist for guideline appraisal (MiChe).

Conclusions: The main treatment steps were consistently reported across repair protocols.

Clinical significance: Dentists may want to adopt widely recommended treatment steps when performing repairs of different restoration materials in their daily practice.

1. Introduction

Placement of restorations is one of the most commonly performed treatments by dentists worldwide [1], often to replace already existing, but (partially or totally) failed restorations [2]. As opposed to complete replacement of partially failed restorations, repairing defective areas by placement of a “repair-filling” (usually of resin composite) is associated with a number of advantages like an increase of the restorations’ lifetime [3] and tooth retention time [4], reduced treatment time, and possibly lower long-term costs [5,6].

While almost all dental schools teach repairs within their dental undergraduate curricula [7,8] and dentists are theoretically accepting repairs as a treatment strategy [7], the proportion of performed repairs remains low [7]. One possible reason for the discrepancy between evidence for repairs and dentists’ actual treatment decisions might be

uncertainty regarding the required operative steps. In fact, establishing a sufficient adhesive bond of the repair composite to different substrates, e.g. composites, metals, ceramics, with or without adjacent tooth substrate involvement is complex and requires different operative protocols.

Such protocols may be available from (non-)systematic reviews, working instructions, or textbook chapters. However, it is unclear (1) if the required treatment steps are consistently reported, (2) whether the protocols are available freely to dentists (i.e. free availability of full text online), and (3) what quality repair protocols have. For dentists, consistency, availability and quality are important to assure that repairs are performed according to standards. If inconsistency is present, it would be to identify key treatment steps which are reported within most protocols, as these may be considered as a standard to be recommend for clinical application. Also, an assessment of protocol quality may

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drive improvements in future protocols.

We aimed to systematically review repair protocols for partially defective restorations. Based on this review, we aimed to assess the consistency of the treatment recommendations included in such protocols, as well as protocol availability and quality.

2. Methods

Prior to initiation, the review was registered at PROSPERO (CRD42018094336). The reporting of this study is in accordance with the PRISMA and the ENTREQ statements [9,10].

2.1. Eligibility criteria

(Non-)Systematic reviews, working instructions, and textbook chapters with treatment recommendations on repair restorations for partially defective (1) composite, (2) amalgam, (3) porcelain-fused-to-metal (PFMs) with exposed metal base, (4) ceramic/PFMs without exposed metal base, and (5) full metal restorations in permanent teeth using resin composites were assessed. Publications published in or after 1990 were included. There were no quality restrictions (e.g. mandatory peer-review or journal with impact factor). Case reports, presentation slides, posters, video content, patents, and conference abstracts were excluded, as we assumed information presented there to be too limited to allow synthesis. Dental manufacturers' instructions and dissertations were also excluded as dentists are unlikely to use these sources for continuing education. Furthermore, publications presenting a broad range of potential repair measures rather than clearly defining recommendations of clinical repair procedures for specific materials were also excluded. Moreover, original studies were excluded, as outcomes of these studies might not directly be translated into clinical recommendations. Furthermore, only publications in English and German were assessed. English versions were assessed if textbooks had been published in both languages. Otherwise or in case of multiple editions of textbooks, only the most recent edition was included.

2.2. Outcome

The outcome of this review was recommended treatment steps suggested for repair measures of partially defective (1) composite, (2) amalgam, (3) porcelain-fused-to-metal (PFMs) with exposed metal base, (4) ceramic/PFMs without exposed metal base, and (5) full metal restorations.

2.3. Information sources

Two electronic databases (Medline via PubMed, Embase) were searched in March 2019. In addition, hand searches using Google and Google Scholar were conducted and the reference lists of included full texts screened and cross-referred.

2.4. Search strategy

For the database screening, the following strategy was used for PubMed and adapted for Embase: Search (repair OR refurbish OR repolish OR reseal) AND (dental OR dentists) AND (filling OR fillings OR restoration OR restorations OR crown OR crowns OR resin OR composite OR composites OR amalgam OR amalgams OR metal OR metals OR ceramic OR ceramics OR zirconia) AND (protocol OR protocols OR recommendation OR recommendations OR guideline OR guidelines OR consensus statement OR consensus statements OR instruction OR instructions OR treatment option OR treatment options OR pretreatment OR pretreatments). For non-databases, different combinations of the above mentions terms were used.

2.5. Study records

Two reviewers independently screened the identified records and compared their findings. Data extraction was performed independently by both reviewers (PK and AW) using a pilot-tested spreadsheet. Disagreements were resolved through discussion. Sources without any relevant treatment suggestions and ineligible sources were excluded (appendix Tab. S2).

2.6. Data items

The following data items were collected from each literature source: Authors; year of publication; study type (e.g. (non-)systematic review, working instruction, textbook chapter); language; external peer-review (yes/no); restoration materials repaired; free availability of full text online (yes/no); suggested treatment recommendations (e.g. materials and procedures).

2.7. Data synthesis

For each restoration material to be repaired, the recommended treatment steps from included sources were summarized and collated. Statistical analyses were performed using the software R (version 3.5.3, www.r-project.org). The number of published sources with repair instructions per year and the mean overall quality score of published sources of each year were subjected to metaregression analysis. The distribution of study type, language, the proportion of sources having gone through external peer-review, and the proportion of freely available full texts was compared between different restorative materials using Fisher's exact tests with Bonferroni-Holm-correction. Overall quality scores of sources regarding repair of different restorative materials were compared by Kruskal-Wallis test. Furthermore, protocols' publication years with and without recommendation of specific treatment steps were compared for each restorative material by Wilcoxon rank sum tests with Bonferroni-Holm-correction. The level of significance was set at $\alpha = 0.05$.

2.8. Quality assessment and confidence in data

Quality assessment of included sources was based on the MiChe framework, a minichcklist for the rapid assessment of guidelines' usefulness and quality for clinical practitioners. The MiChe evaluates 8 criteria focusing on important methodological features (quality of guideline creation, quality of reporting, quality of presentation, quality of evidence synthesis) on a 3-level scale (yes, partly, no). The assessed 8 criteria are then transformed into an overall quality score on a 7-level scale (1: very poor, 7: very good) via the following formula, with the result rounded to an integer:

$$\text{Overall quality rating} = \frac{3}{4} n_{\text{yes}} + \frac{3}{8} n_{\text{partly}} + 1 \quad [11,12]$$

Definitions of the scale are shown in the appendix (appendix Tab. S3). Quality was assessed by one reviewer (GG) and verified by another reviewer (PK). Discrepancies were resolved through discussion.

3. Results

3.1. Search and included sources

In total, 692 records were initially identified via systematic database search (483 via PubMed and 209 via Embase). Additionally, 116 sources were identified via cross-referencing and hand search. From all identified sources, 138 were screened in full-text. A total of 71 repair protocols based on 84 sources were included (Table 1, appendix Fig. S1). Details on excluded sources are presented in the appendix (appendix Tab. S2).

Table 1
Characteristics of included repair protocols and sources.

Repaired restoration	Number of repair protocols	Number of sources	Systematic reviews	Non-systematic reviews	Textbooks	Working instructions	English language	External peer review	Full text freely available online	Overall quality rating
Composite restoration	40	46 (100%)	2 (4.35%)	19 (41.30%)	21 (45.65%)	4 (8.70%)	25 (54.35%) ^{AB}	16 (34.78%)	6 (13.04%)	3.9 ± 1.0
Amalgam restoration	15	17 (100%)	–	7 (41.18%)	9 (52.94%)	1 (5.88%)	11 (64.71%) ^{AB}	6 (35.29%)	2 (11.76%)	4.0 ± 1.0
PFM restoration with exposed metal base	42	44 (100%)	2 (4.55%)	21 (47.73%)	15 (34.09%)	6 (13.64%)	33 (75.00%) ^B	24 (54.55%)	4 (9.09%)	3.6 ± 0.9
Ceramic restoration or PFM restoration without exposed metal base	44	49 (100%)	3 (6.12%)	23 (46.94%)	20 (40.82%)	3 (6.12%)	32 (65.31%) ^B	22 (44.90%)	5 (10.20%)	3.8 ± 0.9
Full metal restoration	12	14 (100%)	–	6 (42.86%)	6 (42.86%)	2 (14.29%)	3 (21.43%) ^A	4 (28.57%)	1 (7.14%)	3.9 ± 1.0
Total	71	84 (100%)	4 (4.76%)	32 (38.10%)	34 (40.48%)	14 (16.67%)	56 (66.67%)	37 (44.05%)	9 (10.71%)	3.7 ± 0.9

Absolute numbers and percentages / means ± SD are shown. Some sources contained information on multiple restorative materials. Different superscript letters indicate significant differences between different restorative materials ($p < 0.05$). Porcelain-fused-to-metal (PFM).

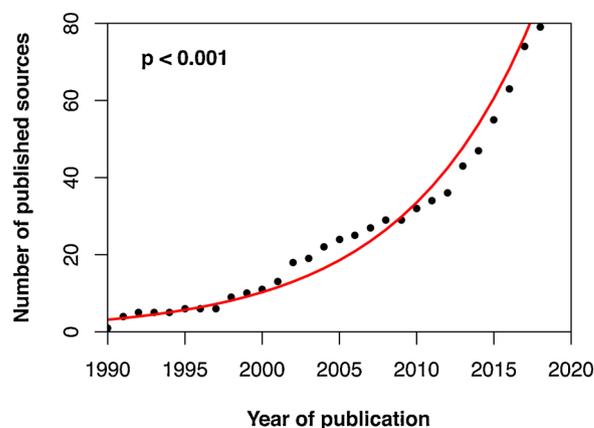


Fig. 1. Number of published sources with recommended repair procedures over time. The number of published sources over time well fitted an exponential model ($p < 0.001$).

Among the included sources, 32 were non-systematic reviews, 34 were chapters from textbooks, 14 were working instructions, and 4 were systematic reviews. Fifty-six of these sources were published in English and 28 in German. The distribution of study type, the proportion of protocols with external peer-review, and the proportion of freely available full texts did not differ significantly between different restorative materials. However, protocols on the repair of full metal restorations were significantly less often published in English than those on the repair of ceramic restorations or PFM restorations without exposed metal base ($p = 0.049$) and PFM restorations without exposed metal base ($p = 0.004$). The number of published protocols increased with each year, following an exponential model ($p < 0.001$, Fig. 1).

3.2. Quality assessment

The mean ± SD overall quality score of the included sources was 3.7 ± 0.9 points (Table 1). Highest MiChe ratings could be found for the domains “Clarity, key recommendations highlighted” (“yes” in 57 sources) and “Different treatment options given” (“yes” in 20 sources). Lowest ratings were found for the domains “Definition of backgrounds, goals and target patients” (“no” in 51 sources) and “Definition of target group/target setting” (“no” in 33 sources). Therefore, the most important drawbacks/limitations are missing definitions of protocols’ backgrounds, suitable target audiences, objectives, and information regarding patients for whom the protocols are relevant. More detailed ratings according to the MiChe criteria can be found in the appendix (appendix Tab. S4). Mean overall quality score of published sources of each year did not change over time (appendix Fig. S2). There were no significant differences between the overall quality scores of repair protocols for (1) composite, (2) amalgam, (3) PFMs with exposed metal base, (4) ceramic/PFMs without exposed metal base, and (5) full metal restorations ($p > 0.05$).

3.3. Recommended treatment steps

The recommended treatment steps varied widely across protocols, regardless of the different materials to be repaired (Tables 2–6). A number of treatment steps were only recommended by a minority of protocols (e.g. phosphoric acid etching of other materials than composite, hydrofluoric acid etching of composite restorations/oxide ceramics), while there were certain steps which were consistently recommended (e.g. surface roughening using a diamond bur, hydrofluoric acid etching of silicate ceramics, application of an adhesive/bonding agent). Further mechanical surface conditioning (i.e. by air abrasion using aluminium oxide or silica coated aluminium oxide) was recommended material-specific. A silane coupling agent / alloy/zirconia

Table 2
Recommended treatment steps when repairing composite restorations (n = 40).

Protocol	Isolation			Physical repair measures				Chemical repair measures				Repair composite		Finishing technique
	Diamond bur	Air abrasion using aluminium oxide	Silica coating	Phosphoric acid	Hydrofluoric acid	Silane coupling agent / universal primer	Adhesive / bonding agent	Repair composite	Finishing technique					
Roeters, de Kloet 1992 [21] Goldstein, White 1995 [20]	Yes dam	Yes	–	Yes	–	Yes	Yes	Yes	Not specified	Not specified	Not specified	Not specified	Not specified	
Denehy et al. 1998 [22]	–	Yes, fine grit	–	Yes, 15 s	–	Yes	Yes	Hybrid composite (large fractures), microfilled composite (non-functional areas or smaller fractures)	Finishing burs, discs, strips, polishing paste					
Edelhoff et al. 1999 [23]	Yes	–	Yes	–	–	Yes	–	Incremental application of hybrid composite	Arkansas stones, polishing disks, and polishing brushes					
Wolfart, Kern 2000 [24]	Yes, rubber dam	Yes, 10 s, 2.5 bar	–	–	–	–	–	Hybrid composite	Not specified					
Albers 2002 [25] Brunton 2002 [26]	Yes dam	Yes	–	Yes, 15 s	Yes, 5 s	Yes	Yes	Not specified	Not specified					
Hahn 2003 [27]	–	Yes	–	Yes	–	Yes	Yes	Same composite as the original restoration	Not specified					
Besek et al. 2004 [28]	Yes, rubber dam	Yes, 40-25 µm	–	Yes	–	Yes	Yes	Not specified	Not specified					
Foitzik, Aitın 2004 [29]	Yes, rubber dam	Yes, > 4 s, 4.5 bar	–	–	–	–	–	Not specified	Not specified					
Wiegand et al. 2005 [30]	Yes, rubber dam	Yes	Yes, 5 s, 2.3 bar	–	–	Yes, only in case of silica coating	Yes	Not specified	Not specified					
Ahlers 2006 [31]	–	Yes, 177-210 µm	–	Yes	–	–	Yes	Not specified	Not specified					
Frankenberger 2007 [32]	Yes, rubber dam	Yes, > 100 µm	Yes, only if no dentin is involved	Yes	–	–	Yes	A thin layer of flowable composite	Not specified					
Blum 2008 [33]; Blum, Lynch 2014 [34]	Yes	–	Yes	Yes, 15-30 s, only if no silica coating was applied	–	Yes, only in case of silica coating	Yes	Incremental application	Not specified					
Hugo 2008 [35]	Yes, rubber dam	Yes, ≥ 4 s, 4.1-4.8 bar	–	–	–	–	Yes	Not specified	Not specified					
Frankenberger et al. 2010 [36]; Frankenberger 2013 [37]; Frankenberger 2013 [38]; Frankenberger, Blunck 2013 [39]	–	Yes, > 80 µm	Yes, only if no dentin is involved	–	–	–	Yes	A thin layer of flowable composite (0.1-0.5 mm)	Not specified					
Willhite 2010 [40] Blum et al. 2011 [41]	Yes, rubber dam	Yes	Yes, 5 s	Yes, 15-30 s	–	–	Yes	Incremental application	Not specified					
Malhotra, Acharya 2012 [42] Zimmerli, Strub 2012 [43] Blunck 2013 [44] Hickel et al. 2013 [5] Blum et al. 2014 [45] Banerjee, Watson 2015 [46] Frankenberger et al. 2015 [47]	– – – Yes – –	Yes Yes Yes – – –	– Yes Yes – – –	– – Yes, 5-10 s – Yes, 15-30 s –	Yes, 20 s – – – – –	– Yes Yes – – –	– Yes Yes – – –	– Yes Yes – – –	Not specified Not specified Not specified Incremental application Incremental application A thin layer of flowable composite	Not specified Not specified Not specified Not specified Not specified Not specified				
Garg, Garg 2015 [48]	–	Yes	–	–	–	–	Yes	Not specified	Not specified					

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Table 2 (continued)

Protocol	Isolation			Physical repair measures			Chemical repair measures				Repair composite		Finishing technique
	Diamond bur	Air abrasion using aluminium oxide	Silica coating	Phosphoric acid	Hydrofluoric acid	Silane coupling agent / universal primer	Adhesive / bonding agent	Flowable	Incremental application	Not specified	Not specified		
Lührs 2015 [49]	Yes, rubber dam	Yes	-	-	-	-	Yes	Flowable	Not specified	Not specified	Not specified		
Staeble et al. 2015 [50]; Staehle et al. 2016 [51]	Yes, rubber dam	Yes	-	Yes	-	-	Yes	Not specified	Not specified	Not specified	Not specified		
Göstemeyer, Blunck 2016 [52]; Gostemeyer, Blunck 2017 [53]	-	Yes, 10 s	-	Yes, 30 s	-	Yes	Yes	Not specified	Not specified	Not specified	Not specified		
Hattrick, Eakle 2016 [54]	-	Yes	-	Yes	-	-	Yes	Not specified	Not specified	Not specified	Not specified		
Loomans, Özcan 2016 [55]	-	Yes, fine-grit	-	-	Yes, 5 or 9.6 %, 20-90 s	Yes	-	Incremental application	Not specified	Not specified	Not specified		
Banerji, Mehta 2017 [56]	Yes, rubber dam	Yes	-	Yes, 15 s	-	-	Yes	Not specified	Diamond or aluminium oxide polishing paste, glazing agent	Not specified	Not specified		
Leprince et al. 2017 [57]	-	Yes	-	-	-	Yes	Yes	Not specified	Not specified	Not specified	Not specified		
Powers, Wataha 2017 [58]	Yes	Yes	-	-	-	Yes	-	Not specified	Not specified	Not specified	Not specified		
Salamonowicz and Choromanska 2017 [59]	-	Yes	-	Yes	-	Yes, only if no tooth tissue is affected	Yes	Not specified	Not specified	Not specified	Not specified		
Foxton 2018 [60]	Yes, rubber dam	Yes	-	Yes	-	-	Yes	Not specified	Not specified	Not specified	Not specified		
Hellwig et al. 2018 [61]	Yes, rubber dam	Yes, ≥ 4 s, 4.5 bar	-	-	-	-	Yes	Hybrid composite	Not specified	Not specified	Not specified		
Ritter et al. 2019 [62]	Yes, rubber dam	-	-	Yes	-	-	Yes	Not specified	Not specified	Not specified	Not specified		
Rothmeier et al. 2019 [63]	Yes, rubber dam	Yes, 10-15 s	Yes, 10-15 s	Yes	-	Yes	Yes	Not specified	Not specified	Not specified	Not specified		
Sakaguchi et al. 2019 [64]	-	Yes	-	-	-	-	Yes	Not specified	Not specified	Not specified	Not specified		
Number of protocols recommending this step	19/40	28/40	11/40	20/40	3/40	21/40	34/40	-	-	-	-		

Table 3
Recommended treatment steps when repairing partially defective amalgam restorations (n = 15).

Protocol	Isolation	Physical repair measures			Chemical repair measures			Repair composite	Finishing technique
		Diamond bur	Air abrasion using aluminium oxide	Silica coating	Phosphoric acid	Hydrofluoric acid	Silane coupling agent / alloy primer / universal primer		
Roeters, de Kloet 1992 [21]	–	Yes	–	–	–	–	–	Not specified	Not specified
Goldstein, White 1995 [20]	Yes, rubber dam	–	Yes	–	–	–	–	Not specified	Not specified
Brunton 2002 [26]	Yes, rubber dam	Yes	–	–	–	–	–	Not specified	Not specified
Foitzik, Attin 2004 [29]	Yes, rubber dam	Yes	Yes, > 4 s, 4.5 bar	–	–	–	–	Not specified	Not specified
Frankenberger 2007 [32]	Yes, rubber dam	Yes, > 100 µm	Yes	Yes, only if no dentin is affected	Yes	–	–	A thin layer of flowable composite	Not specified
Blum 2008 [33]; Blum, Lynch 2014 [34]	Yes	Yes	Yes	–	–	–	Yes, alloy primer	Opaquer, incremental application	Not specified
Zimmerli, Strub 2012 [43]	–	Yes	Yes	–	–	–	–	Not specified	Not specified
Blum et al. 2014 [45]	Yes	Yes	Yes	–	–	–	Yes, alloy primer	Opaquer, incremental application	Not specified
Banerjee, Watson 2015 [46]	–	Yes	–	–	–	–	–	Incremental application	Not specified
Lührs 2015 [49]	Yes, rubber dam	–	–	Yes	–	–	Yes, silane coupling agent or universal primer	Flowable	Not specified
Harrick, Eakle 2016 [65]	–	–	–	–	Yes	–	–	Flowable	Not specified
Özcan, Valpato 2016 [66]; Özcan 2017 [67]	Yes, rubber dam	–	–	Yes, 5 s, 2.5 bar	Yes, 30 s	–	Yes, silane coupling agent	Opaquer, incremental application	Rubber tips, brushes, polishing pastes
Staeble et al. 2016 [51]	Yes, rubber dam	–	–	–	Yes	–	–	Opaquer	Not specified
Foxton 2018 [60]	Yes, rubber dam	Yes	–	–	–	–	–	Opaquer	Not specified
Hellwig et al. 2018 [61]	Yes, rubber dam	Yes	Yes, ≥ 4 s, 4.5 bar	–	Yes	–	Yes, alloy primer (only if tooth tissue is affected) or silane coupling agent	Hybrid composite	Not specified
Number of protocols recommending this step	11/15	10/15	7/15	3/15	5/15	0/15	10/15	–	–

Table 4
Suggested treatment steps when repairing partially defective PFM restorations with exposed metal base (n = 42).

Protocol	Physical repair measures			Chemical repair measures			Repair composite	Finishing technique		
	Isolation	Diamond bur	Air abrasion using aluminium oxide	Silica coating	Phosphoric acid	Hydrofluoric acid			Silane coupling agent / alloy/zirconia primer / universal primer	Adhesive / bonding agent
Rosen 1990 [68]	Yes, rubber dam	Yes	Yes	-	-	Yes, 9 %, 5 min	Yes, silane coupling agent	Yes	OPAquer, incremental application	After 24 hours
Brönnimann 1991 [19]	Yes, rubber dam	Yes	Yes	-	-	Yes, 9.5 %, 2-3 min	Yes, silane coupling agent + alloy primer	Yes	OPAquer, hybrid composite	Not specified
Fan 1991 [69]	Yes	Yes	Yes	-	-	Yes, 4-5 min	-	-	Incremental application, macrofilled or hybrid repair composite	After 24 hours
Rada 1991 [70]	Yes, rubber dam	Yes	-	-	-	Yes, 5 min	Yes, silane coupling agent	Yes	OPAquer	Not specified
Goldstein, White 1995 [20]	Yes, rubber dam	Yes	Yes	-	-	Yes	Yes, silane coupling agent	Yes	OPAquer	Not specified
Denehy et al. 1998 [22]	Yes	Yes, fine grit	Yes, 5.5 bar	Yes	-	Yes, 1 min	Yes, silane coupling agent	Yes	OPAquer, hybrid composite (large fractures), microfilled composite (non-functional areas or smaller fractures)	Finishing burs, discs, strips, polishing paste
Niedermeier et al. 1998 [71]	Yes, rubber dam	-	-	Yes, 10 s, 2.3 bar	-	-	Yes, silane coupling agent	-	OPAquer	Not specified
Robbins 1998 [72]	Yes, rubber dam	-	Yes	-	-	Yes	Yes, silane coupling agent	Yes	OPAquer, hybrid composite (if strength is required)	Not specified
Edelhoff et al. 1999 [23]; Edelhoff et al. 2001 [73]	Yes	-	-	Yes	-	-	Yes, silane coupling agent	-	OPAquer, incremental application of hybrid composite	Arkansas stones, polishing discs, and polishing brushes
Wolfart, Kern 2000 [24]	Yes, rubber dam	-	Yes, 10 s, 2.5 bar	Yes	-	-	Yes, alloy primer	Yes	OPAquer, hybrid composite	Not specified
Ferracane 2001 [74]	Yes, rubber dam	Yes	Yes	-	-	Yes, 10 %, 2-3 min	Yes, silane coupling agent	Yes	OPAquer	Not specified
Ahmad 2002 [75]	-	Yes	Yes	-	-	Yes, 9.5 %	Yes, silane coupling agent	Yes	Initial application of highly filled composite, incremental application of hybrid composite, final layer of microfilled composite	Not specified
Özcan 2002 [76]	Yes, rubber dam	-	-	Yes, 13 s, 2.3 bar	-	-	Yes, silane coupling agent	Yes	OPAquer, incremental application	Carbide and extra-fine diamond burs or stones and a diamond paste
Yanikoglu 2004 [77]	-	Yes	-	-	-	-	Yes, silane coupling agent	Yes	OPAquer	Not specified
Bartlett, Brunton 2005 [78]	Yes, rubber dam	-	-	Yes, 13 s, 2-3 bar	-	-	Yes, silane coupling agent	Yes	OPAquer, incremental application	Microfine high-speed water-cooled burs
Frankenberger 2007 [32]	Yes, rubber dam	Yes, < 40 µm	-	Yes	-	-	Yes, silane coupling agent	Yes	OPAquer, a thin layer of flowable composite	Not specified

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Table 4 (continued)

Protocol	Isolation			Physical repair measures			Chemical repair measures			Repair composite	Finishing technique
		Diamond bur	Air abrasion using aluminium oxide	Silica coating	Phosphoric acid	Hydrofluoric acid	Silane coupling agent / zirconia primer	Silane coupling agent / alloy/zirconia primer	Adhesive / bonding agent		
Smith, Howe 2007 [79] Hugo 2008 [35]	- Yes, rubber dam	- Yes	Yes -	- Yes, 15 s, 2 bar	- -	- -	Yes, silane coupling agent Yes, silane coupling agent	Yes, silane coupling agent Yes, silane coupling agent	- Yes	Opaquer Opaquer	Not specified Not specified
Bücking 2010 [80]	-	Yes	-	-	-	Yes, 9.5 %, 60 s	Yes, alloy/zirconia primer	-	-	Not specified	Finishing burs, rubber polishers, Occlubrashes
Gutmann, Lovdahl 2011 [81]	-	Yes	-	-	-	Yes, 10 %	-	-	Yes	Not specified	Not specified
Malhotra, Acharya 2012 [42]	Yes, rubber dam	Yes	-	Yes	Yes, 10 s	Yes, 30 s	Yes, silane coupling agent + alloy/zirconia primer	Yes	Yes	Opaquer, incremental application	Not specified
Zimmerli, Strub 2012 [43]	Yes, rubber dam	Yes	-	Yes	-	Yes	Yes, silane coupling agent	Yes	Yes	Opaquer	Not specified
Al-Moaleem et al. 2013 [82]	dam	-	Yes	-	-	Yes	Yes, silane coupling agent	-	-	Opaquer	Not specified
Hickel et al. 2013 [5]	-	-	-	-	Yes	-	Yes, silane coupling agent	-	-	Opaquer	Not specified
Kimmich, Stappert 2013 [83]	Yes, rubber dam	-	Yes, 0.5 bar	Yes	-	Yes, 2.5-10 %, 60 s	Yes, silane coupling agent + alloy primer	-	-	-	Not specified
Özcan 2014 [84]; Özcan 2017 [67]	Yes, rubber dam	Yes, fine grit	-	Yes, 5 s, 2.5 bar	-	Yes, 5 or 9.6 %, 20 or 90 s	Yes, silane coupling agent	Yes	Yes	Opaquer, incremental application	Not specified
Özcan 2014 [85]	Yes, rubber dam	Yes, fine grit	-	Yes	-	Yes, 5 or 9.6 %, 20 or 90 s	Yes, silane coupling agent or universal adhesive	Yes	Yes	Not specified	Not specified
Black, Trushkowsky 2015 [86]	Yes	Yes, coarse	Yes	-	-	Yes, 9.5 %, 90 s	Yes, silane coupling agent + alloy primer	-	-	Opaquer, incremental application	Not specified
Frankenberger et al. 2015 [47]	-	-	-	Yes	-	-	Yes, silane coupling agent	-	-	Opaquer	Not specified
Garg, Garg 2015 [87]	Yes	Yes	-	-	Yes	-	-	Yes	Yes	Opaquer, incremental application	Not specified
Burke 2016 [88]	Yes, rubber dam	-	-	Yes, 2.5 bar	-	-	Yes, silane coupling agent	-	-	Opaquer	Abrasive discs, impregnated rubber points
Hatrick, Eakle 2016 [54]	Yes, rubber dam	Yes	Yes, low pressure	-	-	Yes, 60 s	Yes, silane coupling agent	Yes	Yes	Opaquer	Not specified
Loomans, Özcan 2016 [55]	-	Yes, fine grit	Yes	-	-	Yes, 5 or 9.6 %, 20-90 s	Yes, silane coupling agent	-	-	Opaquer, incremental application	Not specified
Burke 2017 [89]	Yes, rubber dam	-	-	Yes, 2.5 bar	-	-	Yes, universal adhesive	Yes, universal adhesive	Yes, universal adhesive	Opaquer	Not specified
Ho 2017	Yes, rubber dam	-	-	Yes	-	-	Yes, silane coupling agent with phosphate monomers	-	-	Opaquer	Not specified
Kern et al. 2017 [90]	Yes, rubber dam	-	-	Yes	-	-	Yes, silane coupling agent	Yes	Yes	Opaquer, incremental application of hybrid or nano-composite	Arkansas stones, polishing rubber, polishing disks, and polishing brushes

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Table 4 (continued)

Protocol	Isolation			Physical repair measures			Chemical repair measures			Repair composite		Finishing technique
	Diamond bur	Air abrasion using aluminium oxide	Silica coating	Phosphoric acid	Hydrofluoric acid	Silane coupling agent / alloy/zirconia primer / universal primer	Adhesive / bonding agent	Flowable	Incremental application nano/hybrid composite or fiber-reinforced composite	Opaque, hybrid composite	Not specified	
Terry 2017 [91]	-	Yes	-	-	Yes, 4-9.8 %	Yes, silane coupling agent + alloy primer	-	Flowable	-	-	Not specified	
Aslam et al. 2018 [92]	Yes	Yes, 2-3 bar	Yes	-	Yes, 2.5-10 %, 60 s	Yes, silane coupling agent (only in case of silica coating) or alloy primer	-	Incremental application nano/hybrid composite or fiber-reinforced composite	-	-	Not specified	
Hellwig et al. 2018 [61]	Yes, rubber dam	-	Yes	-	-	Yes, silane coupling agent	Yes	Opaque, hybrid composite	-	-	Not specified	
Özcan et al. 2018 [93]	Yes	Yes, fine grit	Yes, 5 s, 2.5 bar	-	Yes, 5 or 9 %, 20-180 s	Yes, silane coupling agent	Yes	Opaque, incremental application	-	-	Rubber tips, polishing pastes	
Sakaguchi et al. 2019 [64]	Yes, rubber dam	Yes	Yes	-	Yes	Yes, silane coupling agent	-	Not specified	-	-	Not specified	
Samuel et al. 2019 [94]	-	Yes, coarse	-	-	-	Yes, silane coupling agent	Yes	Opaque	-	-	Not specified	
Number of protocols recommending this step	32/42	18/42	22/42	3/42	24/42	39/42	26/42	-	-	-	-	

Porcelain-fused-to-metal (PFM).

primer / universal primer was also generally recommended except for repairs of amalgam restorations. In case of exposed metal bases, an opaquer might be used to mask the exposed metal.

For all materials, the recommendation of specific treatment steps did not change over time ($p > 0.05$).

A summary of the more or less often recommended treatment steps can be found in Fig. 2.

4. Discussion

If repair protocols provide inconsistent or conflicting information, dentists may not be able to make sound decisions when planning and performing repairs. Inconsistency may further lead to uncertainty and, consequently, rejection of repairs. This review identified a high number of different repair protocols. A number of treatment steps were consistently reported; some steps were – as expected – material-specific; some steps, however, were reported only by very few protocols and there seems to be uncertainty towards their need.

This uncertainty may be the result of a lack of evidence for repair of restorations. Although the overall number of publications on restoration repair has increased over the last decades [5], there is only limited evidence from randomized-controlled trials [13–15]. Given the lack of high-quality trials, one can assume that recommendations which are widely accepted as a standard might merely be based on studies with low level of evidence [16] or *in-vitro* research. In *in-vitro* studies, comparisons among different studies is difficult to be made as used substrates, simulated surface treatments, aging protocols, and approaches for measuring bond strengths differ widely. These parameters might lead to conflicting results. Lack of evidence might also partly explain the finding from our qualitative analysis, where a high number of recommendations from assessed protocols have not been linked to evidence from studies. Furthermore, lack of emerging evidence might explain why recommendation of specific treatment steps did not change over time. However, it should be noted that most repair protocols have been published as non-systematic reviews or as book chapters, where linking of recommendations to underlying evidence is not always common.

A further limitation was that target patients and indications for repairs have not always been reported. Again, this is most likely due to a lack of evidence for the clinical effectiveness of restoration repair. Further trials should not only assess the effectiveness of different repair strategies, but also the comparative effectiveness of restoration repair versus replacement of restorations in different situations [4].

Regardless of these evidence gaps, the number of published repair protocols have exponentially increased during the past decades, indicating a growing demand to guide dentists on how to perform restoration repair. The overall quality of these repair protocols did not increase over time, which can be partially explained by the lack of evidence, as discussed, but possibly also as protocol developers may not be aware as to how to increase the quality of their protocol. Notably, some quality criteria of the MiChe can be met with limited efforts only (e.g. conflict of interest statement, systematic search for evidence, linking recommendations to evidence if evidence exists). Given the overall moderate quality of published repair protocols, there is a need for the systematic development of guidelines. These guidelines could transparently inform dentists on the usefulness of different approaches for restoration repair aligned with the underlying strength of evidence. Guidelines could also be used to inform the research community on where evidence gaps exist.

Repair protocols from 1990 onwards have been included within our analyses. With the development of new bonding strategies and improvement of adhesive systems, approaches for repairing restorations have changed over time: While older sources favour laboratory produced repair overcastings (e.g. [17,18], studies have been excluded) or recommend intraoral tin plating [19,20], more recent sources utilize both physical and chemical repair measures for intraoral repairs using

Table 5
Recommended treatment steps when repairing partially defective ceramic restorations or PFM restorations without exposed metal base (n = 44).

Protocol	Isolation			Physical repair measures				Chemical repair measures				Repair composite	Finishing technique
	Isolation	Diamond bur	Air abrasion using aluminium oxide	Silica coating	Phosphoric acid	Hydrofluoric acid	Silane coupling agent / alloy/zirconia primer / universal primer	Adhesive / bonding agent	Repair composite	Finishing technique			
Rosen 1990 [68]	Yes, rubber dam	Yes	-	-	-	Yes, 9 %, 5 min	-	Yes	Incremental application	After 24 hours			
Brönnimann 1991 [19]	Yes, rubber dam	Yes	Yes	-	-	Yes, 9.5 %, 2-3 min	Yes, silane coupling agent	Yes	Hybrid composite	Not specified			
Fan 1991 [69]	Yes	Yes	-	-	-	Yes, 4-5 min	-	-	Incremental application, macrofilled or hybrid repair composite	After 24 hours			
Roeters, de Kloet 1992 [21]	-	-	Yes	-	-	Yes, 2 %, 2-6 min	-	Yes	Not specified	Not specified			
Goldstein, White 1995 [20]	Yes, rubber dam	Yes	Yes	-	-	Yes	-	Yes	Not specified	Not specified			
Denehy et al. 1998 [22]	Yes	Yes, fine grit	-	Yes	-	Yes, 1 min	Yes, silane coupling agent	Yes	Hybrid composite (large fractures), microfilled composite (non-functional areas or smaller fractures)	Finishing burs, discs, strips, polishing paste			
Niedermeier et al. 1998 [71]	Yes, rubber dam	-	-	Yes, 10 s, 2,3 bar	-	-	Yes, silane coupling agent	-	Opaque	Not specified			
Robbins 1998 [72]	Yes, rubber dam	-	Yes	-	-	Yes	Yes, silane coupling agent	Yes	Hybrid composite (if strength is required)	Not specified			
Edelhoff et al. 1999 [23]; Edelhoff et al. 2001 [73]	Yes	-	-	Yes	-	-	Yes, silane coupling agent	-	Incremental application of hybrid composite	Arkansas stones, polishing disks, and polishing brushes			
Wolfart, Kern 2000 [24]	Yes, rubber dam	-	Yes, 10 s, 2.5 bar	-	-	-	Yes, silane coupling agent	-	Hybrid composite	Not specified			
Ferracane 2001 [74]	Yes, rubber dam	Yes	Yes	-	-	Yes, 10 %, 2-3 min	Yes, silane coupling agent	Yes	Not specified	Not specified			
Ahmad 2002 [75]	-	Yes	Yes	-	-	Yes, 9.5 %	Yes, silane coupling agent	-	Incremental application of hybrid composite, final layer of microfilled composite	Not specified			
Magne, Belser 2002 [95]	Yes, rubber dam	-	Yes, 10-15 s, 2.1-2.9 bar	-	Yes, 60 s	-	Yes, silane coupling agent	-	Incremental application	Not specified			
Hahn 2003 [27]	-	Yes	-	Yes	-	Yes	Yes, silane coupling agent	Yes	Not specified	Not specified			
Foitzik, Attin 2004 [29]	Yes, rubber dam	Yes	-	Yes, 15 s, 2.5 bar	-	-	Yes, silane coupling agent	-	Flowable	Not specified			
Bartlett, Brunton 2005 [78]	Yes, rubber dam	-	-	Yes, 13 s, 2-3 bar	-	-	Yes, silane coupling agent	Yes	Incremental application	Microfine high-speed water-cooled burs			
Smith, Howe 2007 [79]	-	-	Yes	-	-	-	Yes, silane coupling agent	-	Not specified	Not specified			

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Table 5 (continued)

Protocol	Physical repair measures			Chemical repair measures			Repair composite	Finishing technique
	Isolation	Diamond bur using aluminium oxide	Silica coating	Phosphoric acid	Hydrofluoric acid	Silane coupling agent / alloy/zirconia primer / universal primer		
Hugo 2008 [35]	Yes, rubber dam	–	Yes, 15 s, 2 bar	–	–	Yes, silane coupling agent	Opaquer	Not specified
Frankenberger et al. 2010 [36]; Frankenberger 2013 [37]; Frankenberger 2013 [38]	–	–	Yes	–	–	–	Not specified	Not specified
Malhotra, Acharya 2012 [42]	–	Yes, only in case of oxide ceramic	Yes, only in case of oxide ceramic	–	Yes, 2–2.5 min (Feldspathic), 60 s (Leucite-based), 20 s (Lithium disilicate-based)	Yes, silane coupling agent	Not specified	Not specified
Zimmerli, Strub 2012 [43]	Yes, rubber dam	–	Yes	–	Yes	Yes, silane coupling agent	Not specified	Not specified
Al-Moaleem et al. 2013 [82]	Yes	Yes	–	–	Yes	Yes, silane coupling agent	Not specified	Not specified
Hickel et al. 2013 [5]	–	–	–	–	Yes, 5 %	Yes, silane coupling agent or universal adhesive	Not specified	Not specified
Kimmich, Stappert 2013 [83]	Yes, rubber dam	Yes, 0.5 bar, only in case of silicate ceramic	Yes, only in case of oxide ceramic	–	Yes, 2.5–10 %, 60 s, only in case of silicate ceramic	Yes, silane coupling agent	Not specified	Not specified
Özcan 2014 [84]; Özcan 2017 [67]	Yes, rubber dam	Yes, fine grit	–	–	Yes, 5 or 9.6 %, 20 or 90 s	Yes, silane coupling agent	Incremental application	Not specified
Özcan 2014 [85]	Yes, rubber dam	Yes, fine grit	–	–	Yes, 5 or 9.6 %, 20 or 90 s	Yes, silane coupling agent	Not specified	Not specified
Black, Trushkowsky 2015 [86]	Yes	Yes, coarse	–	–	Yes, 9.5 %, 90 s	Yes, silane coupling agent	Incremental application	Not specified
Frankenberger et al. 2015 [47]	–	–	Yes	–	–	Yes, silane coupling agent	Not specified	Not specified
Garg, Garg 2015 [87]	Yes	–	–	–	Yes, 10 %	Yes, silane coupling agent	Not specified	Not specified
Lührs 2015 [49]	Yes, rubber dam	–	Yes	–	Yes	Yes, silane coupling agent	Flowable	Not specified
Özcan 2015 [96]	Yes, rubber dam	Yes, fine grit	Yes, 20 s, 2.5 bar, only in case of oxide ceramic	–	Yes, 5 or 9.6 %, 20 or 90 s, only in case of silicate ceramic	Yes, silane coupling agent	Incremental application	Not specified
Staeble et al. 2015 [50]; Staeble et al. 2016 [51]	Yes, rubber dam	Yes	–	–	Yes, only in case of silicate ceramic	Yes, silane coupling agent	Not specified	Not specified
Hattrick, Eakle 2016 [54]	Yes, rubber dam	Yes, low pressure	–	–	Yes, 60 s	Yes, silane coupling agent	Not specified	Not specified
Loomans, Özcan 2016 [55]	–	Yes, fine grit	–	–	Yes, 5 or 9.6 %, 20 or 90 s, only in case of silicate ceramic	Yes, silane coupling agent	Incremental application	Not specified
Ho 2017	Yes, rubber dam	Yes, fine grit	Yes, 2 bar	–	Yes, 2.5–10 %, 20–60 s, only in case of silicate ceramic	Yes, silane coupling agent or (in case of oxide ceramic and air abrasion) silane coupling agent with phosphate monomers	Not specified	Delayed finishing, fine diamond burs, polishing rubbers

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Table 5 (continued)

Protocol	Physical repair measures			Chemical repair measures			Repair composite	Finishing technique		
	Isolation	Diamond bur	Air abrasion using aluminium oxide	Silica coating	Phosphoric acid	Hydrofluoric acid			Silane coupling agent / alloy/zirconia primer / universal primer	Adhesive / bonding agent
Kern et al. 2017 [90]	Yes, rubber dam	-	-	Yes	-	-	Yes, silane coupling agent	Yes	Incremental application of hybrid or nano-composite	Arkansas stones, polishing rubber, polishing disks, and polishing brushes
Leprince et al. 2017 [57]	-	Yes	Yes	-	-	Yes	Yes, silane coupling agent	Yes	Not specified	Not specified
Powers, Wataha 2017 [58]	-	-	-	-	-	-	Yes, silane coupling agent or (in case of oxide ceramic) alloy/zirconia primer containing phosphate monomers	-	Not specified	Not specified
Terry 2017 [91]	-	-	Yes, only in case of oxide ceramic	Yes, only in case of oxide ceramic	-	Yes, 4-9.8 %, only in case of silicate ceramic	Yes, silane coupling agent or (in case of oxide ceramic and air abrasion) alloy/zirconia primer containing phosphate monomers	-	Flowable	Not specified
Agingu et al. 2018 [97]	Yes	Yes, fine grit	Yes, only in case of silicate ceramic	Yes, 10-20 s, 2.5 bar, only in case of oxide ceramic	-	Yes, 6-10 %, 90-180 s, only in case of silicate ceramic	Yes, silane coupling agent or (in case of oxide ceramic and air abrasion) alloy/zirconia primer containing phosphate monomers	Yes	Incremental application	Intraoral polishing kits and diamond polishing pastes
Aslam et al. 2018 [92]	Yes	Yes	Yes, 2-3 bar	Yes	-	Yes, 2.5-10 %, 60 s	Yes, silane coupling agent (in case of feldspathic and Lithium disilicate-based ceramics) or (in case of oxide ceramic and air abrasion) alloy/zirconia primer containing phosphate monomers	-	Incremental application nanohybrid composite	Not specified
Hellwig et al. 2018 [61]	Yes, rubber dam	Yes	-	Yes	-	Yes	Yes, silane coupling agent	Yes	Hybrid composite	Not specified
Özcan et al. 2018 [93]	Yes	Yes, fine grit	-	Yes, only in case of oxide ceramic	-	Yes, 2-3 min (Feldspathic), 60 s (Leucite-based), 20 s (Lithium disilicate-based)	Yes, silane coupling agent	Yes	Incremental application	Rubber tips, polishing pastes
Heymann et al. 2019 [98]	Yes, rubber dam	Yes	Yes	-	-	Yes, ~ 10%	Yes, silane coupling agent	Yes	Not specified	Not specified
Number of protocols recommending this step	32/44	25/44	21/44	21/44	1/44	32/44	38/44	26/44	-	-

Porcelain-fused-to-metal (PFM).

Table 6
Recommended treatment steps when repairing partially defective full metal restorations (n = 12).

Protocol	Isolation		Physical repair measures			Chemical repair measures			Repair composite	Finishing technique
	Diamond bur	Air abrasion using aluminium oxide	Silica coating	Phosphoric acid	Hydrofluoric acid	Silane coupling agent / alloy primer / universal primer	Adhesive / bonding agent	Composite		
Roeters, de Kloet 1992 [21]	–	–	–	–	–	–	–	–	Not specified	Not specified
Goldstein, White 1995 [20]	Yes	Yes	–	–	–	–	–	–	Hybrid composite	Finishing burs, fine diamond paste
Brunton 2002 [26]	Yes, rubber dam	Yes	–	–	–	–	–	–	Not specified	Not specified
Hahn 2003 [27]	–	Yes	Yes	–	–	–	–	–	Opaque	Not specified
Foitzik, Attin 2004 [29]	Yes, rubber dam	–	Yes, 15 s, 2.5 bar	–	–	–	–	–	Not specified	Not specified
Gutmann, Lovdahl 2011 [81]	–	–	–	Yes	–	–	–	–	Not specified	Not specified
Frankenberger 2015 [47]	–	–	Yes, 10 s	Yes	–	–	–	–	Opaque flowable	Not specified
Lührs 2015 [49]	Yes, rubber dam	–	Yes	–	–	–	–	–	Flowable	Not specified
Staeble et al. 2015 [50]; Staeble et al. 2016 [51]	–	Yes	–	–	–	–	–	–	Not specified	Not specified
Göstemeyer, Blunck 2016 [99]; Göstemeyer, Blunck 2017 [100]	–	Yes, 10s	–	–	–	–	–	–	Not specified	Not specified
Leprince et al. 2017 [57]	–	–	Yes	–	–	–	–	–	Not specified	Not specified
Hellwig et al. 2018 [61]	Yes, rubber dam	Yes, only if tooth tissue is affected	Yes, only if no tooth tissue is affected	–	–	–	–	–	Hybrid composite	Not specified
Number of protocols recommending this step	5/12	6/12	6/12	2/12	0/12	8/12	8/12	8/12	–	–

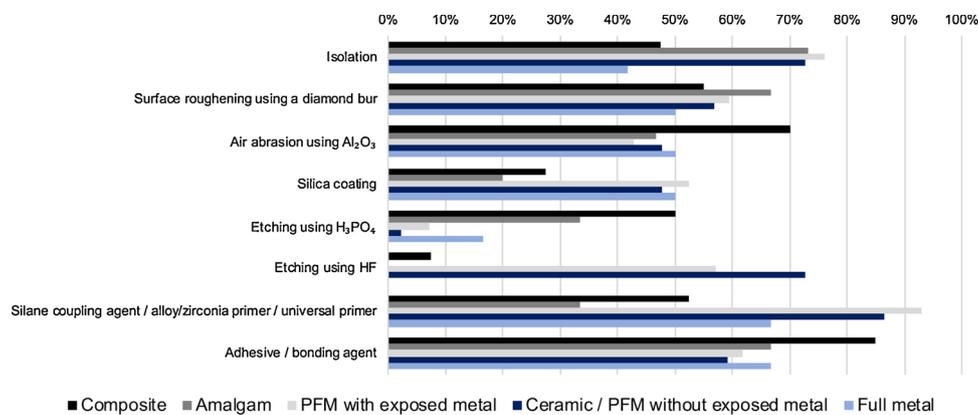


Fig. 2. The frequency of each treatment step being recommended (for each restorative material). Porcelain-fused-to-metal (PFM).

composites.

The growing demand for restoration repair is also reflected by the fact that numerous manufacturers have recently marketed universal primers (e.g. G-Multi Primer, GC Dental Products, Japan; Monobond Plus, Ivoclar Vivadent, Liechtenstein), designed to simplify the procedure to establish adhesive bonding to numerous dental materials. Universal primers contain different chemicals, each specific for adhesion to certain substrates: Silane methacrylate for the formation of Si-O-Si-bonds on silicate ceramics or silica coated surfaces, phosphoric acid methacrylate (e.g. 10-methacryloyloxydecyl dihydrogen phosphate, 10-MDP) for adhesion to oxide ceramics or non-noble metals such as amalgam, and sulfur-containing monomers (e.g. disulfide methacrylate) for adhesion to noble metals. Introduction of these primers might facilitate repairs in practice, thereby simplifying the bonding procedure.

Our study has a number of limitations. First, we included repair protocols from a number of different sources, with some of them generally having a low level of evidence (e.g. book chapters, non-peer-reviewed articles). These sources usually do not aim to systematically compile research data, but can also reflect the opinions of the authors. However, we aimed to collect all sources of information available for dentists irrespective of a preliminary defined quality of the publication type in order to assess on which recommendations performed treatment steps in dental practice are based on.

Second, we used the MiChe to assess the quality of included guidelines, which is a tool originally designed for guideline appraisal. However, no guideline has been identified for the purpose of our study. As there is also no tool available for quality assessment of recommendations stemming from other sources than guidelines, we had to apply some rules and adaptations to the MiChe for the purpose of our study (appendix Tab. S3). As discussed, the moderate quality of the repair protocols might partly be explained by the fact that recommendations from included sources (e.g. book chapters) usually do not aim to give recommendations at the same high level of transparency and quality like in guidelines.

Third, the degree of detail in describing treatment steps differed widely between protocols; some recommendations had only been provided within a short paragraph in a (book) chapter and others had been extensively discussed in a specific article. The short descriptions most likely reported only on essential treatment steps that differ from placement of a complete replacement of a restoration as they did not aim at giving a complete treatment protocol. This incomplete reporting might also partially explain some reasons for the found heterogeneity of repair protocols.

5. Conclusion

The main treatment steps were consistently reported across repair protocols. Dentists may want to adopt these treatment steps when

performing repairs of different restoration materials in their daily practice. The included protocols were mainly based on studies with low level of evidence. High quality trials are needed to systematically develop guidelines which transparently inform dentists on how to perform repairs.

Declarations of interest

None.

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Appendix A. Supplementary data

Supplementary material related to this article can be found, in the online version, at doi:10.1016/j.jdent.2019.05.021.

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