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Review

Longevity of posterior resin composite restorations in adults – A systematic review

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ABSTRACT

Objective: To conduct a systematic review of the literature on the longevity of posterior resin composite restorations in adults.

Material and methods: A systematic literature search was conducted according to predetermined criteria for inclusion and exclusion. The studies selected were prospective clinical trials with a minimum follow-up time of 4 years, 40 restorations per experimental group and an annual attrition rate of less than 5%. Initially, abstracts and full-text articles were assessed independently and the assessment was subsequently agreed on by five reviewers. The methodological quality of the studies was assessed according to the Swedish Council on Health Technology Assessment (SBU) standard checklist for determining the extent to which studies meet basic quality criteria.

Results: In all, the literature search identified 4275 abstracts and 93 articles were read in full-text. There were eighteen studies which met the criteria for inclusion, eight of which were included in the analysis. There were 80 failures of restorations with a total follow-up time at risk for failure of 62,030 months. The overall incidence rate for all causes of failure was 1.55 lost restorations per 100 restoration years. The most common biological reason for failure (a total of 31 restorations) was secondary caries, with or without fracture of the restoration. The quality of the evidence was low.

Conclusions: In an efficacy setting, the overall survival proportion of posterior resin composite restorations is high. The major reasons for failure are secondary caries and restoration fracture which supports the importance of adequate follow-up time.

Clinical significance: The overall survival proportion of posterior composite restorations was high, but the results cannot be extrapolated to an effectiveness setting. The importance of adequate follow-up time is supported by the finding that secondary caries often occurred after 3 years or later.

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1. Introduction

A range of materials is available for restoration of posterior teeth. In recent years, amalgam, once the predominant restorative material, has successively been replaced by tooth-coloured materials,[1–3] offering such advantages as aesthetics and less invasive preparation techniques. Dental restorations, however, have a limited lifespan and replacement of a failed restoration leads to an increase in cavity size and destruction of tooth substance.[4,5] Placement and replacement of restorations is still the most common procedure in general dentistry, representing an enormous annual expense.[2,6] Improving the longevity of restorations is therefore an important aim in dentistry.

A higher annual failure rate has been reported for posterior resin composite restorations than for amalgam.[1–3,7,8] A recent Cochrane review, evaluating trials which compared resin composite with amalgam restorations in posterior permanent teeth, showed that resin composite restorations had a significantly higher risk of failure than amalgam, with increased risk of secondary caries, but no evidence of increased risk of restoration fracture.[9]

The longevity of restorations is influenced by a number of factors,[10,11] such as the considerable differences in mechanical, physical, adhesive and handling properties of the various resin composites and adhesive systems. The patient, socio-economic factors, the oral environment, including the location and size of the restoration, caries risk and habits such as bruxism also influence the survival of restorations.[10,12] A major factor is the clinician, who makes the decision to restore the tooth or replace a restoration, selects the material and undertakes the treatment.[10,13] Commercially, the life span of restorative materials is limited and in recent years conventional hybrid materials have been superseded by nanohybrid resin composites. At the same time, clinicians are increasingly adopting simplified adhesive systems.[14,15] From a dental material perspective, the generalizability of the results from earlier studies is therefore problematic.

The aim of the present review was to assess systematically the longevity of posterior resin composite restorations in adults, as reported in prospective clinical trials of satisfactory quality.

2. Materials and methods

2.1. Inclusion and exclusion criteria

Inclusion and exclusion criteria for the selection of papers for review were established prior to the literature search and are shown in Table 1. Inclusion criteria consisted of prospective controlled trials of Class I and/or Class II resin composite restorations with follow-up times of 4 years or more, with at least forty restorations per experimental group, in adult patients with dropout rates of less than 5% per year. Retrospective studies and reviews were excluded.

2.2. Literature search and selection of articles

The electronic search included PubMed, Cochrane Library and the databases of the Centre for Reviews and Dissemination from 1990 to December 2011. An updated search of the same databases was conducted in March 2013 and on this occasion the Trip Database was also included.

A combination of free text and MeSH terms was used (Table 2). In PubMed a filter was used to identify randomized controlled trials. No language restrictions were applied. The abstracts were evaluated independently by the 5 reviewers, according to predetermined inclusion criteria. Any disagreement about inclusion was solved by consensus. If a reviewer was co-author of a paper, the evaluations were conducted by other reviewers. Articles in English, German, Danish, Norwegian and Swedish were accepted. Full text articles not fulfilling the inclusion criteria were excluded from further analysis.

Table 1 – Criteria for inclusion and exclusion.

Inclusion criteria	
Study design	Prospective RCT
	Prospective CCT
	Prospective observational study without comparison group
Observation time	≥4 years
Participants (number and age)	≥40 individuals/teeth (18+ years) in each groups
Attrition	≤5%/year and described
Exclusion criteria	
Problem specification	Problem specification not addressed
	Primary outcome not analyzed
Sample characteristics and size	Advanced sample, not treated in GDP
	All teeth endodontically treated
	Sample characteristics unclear
	Number of subjects in each group <40
	Impossible to analyze number of subjects followed for ≥5 years
	Attrition >20% after 4 years and then additionally >5% per year or not described
	Accrual period >5 years or not reported
	Observation time <4 years
Publication issues	Published <1990
	Not original research (editorial, review, etc.)
	Case report

2.3. Rating quality of individual studies

The methodological quality of the studies was assessed according to the Swedish Council on Health Technology Assessment (SBU) standardized checklists for determining the extent to which studies meet basic quality criteria.[16] The criteria assess risk for selection bias, performance bias, detection bias, attrition bias and reporting bias. The quality of included studies (i.e. risk of bias) was rated as high, moderate or low. Only studies with moderate to low risk of bias were considered for grading of scientific evidence and conclusions. Any disagreements on quality rating of individual studies were resolved within the group of reviewers by consensus. Reviewers who were also authors or co-authors of studies under evaluation were excluded from participating in the quality rating process.

2.4. Grading the scientific evidence across studies

The quality of the scientific evidence supporting the reported outcomes was rated on a four-point scale according to GRADE.[17]

Table 2 – Search strategies: (a) PubMed via NLM, (b) Cochrane Library via Wiley, (c) Centre for Reviews and Dissemination followed original literature search on December 14, 2011 and (d) PubMed via NLM, (e) Cochrane Library via Wiley, (f) Centre for Reviews and Dissemination, (g) Trip Database followed update of literature search on March 8, 2013.

	Search terms	Items found
(a) PubMed via NLM		
Intervention		
1.	(''Dental Restoration, Permanent/adverse effects''[Mesh] OR ''Dental Restoration, Permanent/classification''[Mesh] OR ''Dental Restoration, Permanent/economics''[Mesh] OR ''Dental Restoration, Permanent/instrumentation''[Mesh] OR ''Dental Restoration, Permanent/methods''[Mesh] OR ''Dental Restoration, Permanent/psychology''[Mesh] OR ''Dental Restoration, Permanent/statistics and numerical data''[Mesh] OR ''Dental Restoration, Permanent/utilization''[Mesh] OR ''Dental Bonding''[Mesh] OR ''Dental Marginal Adaptation''[Mesh] OR ''Nanocomposites''[Mesh] OR ''ceromer'' [Supplementary Concept] OR ''Composite Resins''[Mesh])	36,164
2.	((resin*[tiab] AND composite*[tiab]) OR (permanent[tiab] AND dental[tiab] AND (restoration*[tiab] OR filling*[tiab])) OR (dental[tiab] AND marginal[tiab] AND (adaptation*[tiab] OR fit*[tiab])) OR nanocomposites[tiab] OR compomer[tiab] OR ceromer[tiab])	14,032
3.	1 OR 2	40,015
Outcome		
4.	''Tooth Fractures''[Majr] OR ''Retreatment''[Mesh] OR ''Recurrence''[Mesh] OR ''Quality of Life''[Mesh] OR ''Patient Satisfaction''[Mesh] OR ''Dentin Sensitivity''[Mesh] OR ''Cost-Benefit Analysis''[Mesh] OR ''adverse effects'' [Subheading] OR ''toxicity'' [Subheading]	1,805,214
5.	Durability[tiab] OR Failure[tiab] OR Fracture[tiab] OR Longevity[tiab] OR Survival[tiab] OR Repair[tiab] OR Replacement[tiab] OR Maintenance[tiab] OR Retreatment[tiab] OR Recurrence[tiab] OR (caries[tiab] AND (recurrent[tiab] OR secondary[tiab])) OR Retreatment[tiab] OR ''Patient satisfaction''[tiab] OR ''Quality of life''[tiab] OR QoL[tiab] OR HRQoL[tiab] OR HQoL[tiab] OR OHIP[tiab] OR GOHAI[tiab] OR Cost[tiab] OR Cost-effectiveness[tiab] OR (Postoperative[tiab] AND sensitivit*[tiab]) OR (Dentin*[tiab] AND sensitivit*[tiab]) OR ''Adverse effects''[tiab] OR Biocompatibility[tiab] OR Toxicity[tiab]	1,969,472
6.	4 OR 5	3,323,428
Combined sets		
7.	3 AND 6	12,921
Study types		
8.	''Randomized Controlled Trials as Topic''[Mesh] OR ''Randomized Controlled Trial'' [Publication Type] OR ''Controlled Clinical Trials as Topic''[Mesh] OR ''Cohort Studies''[Mesh] OR (clinical[tiab] AND trial[tiab]) OR longitudinal[tiab] OR prospective[tiab] OR follow-up[tiab] OR ''randomized controlled trial''[Title/Abstract] OR ''random''[Title/Abstract] OR ''randomly''[Title/Abstract] OR ''randomised''[Title/Abstract] OR ''randomized''[Title/Abstract]	2,084,380
Limits		
9.	Publication date from 1990/01/01 to 2011/12/14	
	7 AND 8 AND 9	**3437**
(b) Cochrane Library via Wiley		
1.	(dental) AND (restoration)	
2.	(dental) AND (bonding)	
3.	(dental) AND (marginal) AND (adaptation)	
4.	(nanocomposites)	
5.	(ceromer)	
6.	(resin*) AND (composite*)	
	1 OR 2 OR 3 OR 4 OR 5 OR 6	**3383** Solely CDSR included
(c) Centre for Reviews and Dissemination		
7.	(dental) AND (restoration)	
8.	(dental) AND (bonding)	
9.	(dental) AND (marginal) AND (adaptation)	
10.	(nanocomposites)	
11	(ceromer)	
12.	(resin*) AND (composite*)	
	1 OR 2 OR 3 OR 4 OR 5 OR 6	**135**

Table 2 (*Continued*)

	Search terms	Items found
(d) PubMed via NLM		
Intervention		
1.	(''Dental Restoration, Permanent/adverse effects''[Mesh] OR ''Dental Restoration, Permanent/classification''[Mesh] OR ''Dental Restoration, Permanent/economics''[Mesh] OR ''Dental Restoration, Permanent/instrumentation''[Mesh] OR ''Dental Restoration, Permanent/methods''[Mesh] OR ''Dental Restoration, Permanent/psychology''[Mesh] OR ''Dental Restoration, Permanent/statistics and numerical data''[Mesh] OR ''Dental Restoration, Permanent/utilization''[Mesh] OR ''Dental Bonding''[Mesh] OR ''Dental Marginal Adaptation''[Mesh] OR ''Nanocomposites''[Mesh] OR ''ceromer'' [Supplementary Concept] OR ''Composite Resins''[Mesh])	38,580
2.	((resin*[tiab] AND composite*[tiab]) OR (permanent[tiab] AND dental[tiab] AND (restoration*[tiab] OR filling*[tiab])) OR (dental[tiab] AND marginal[tiab] AND (adaptation*[tiab] OR fit*[tiab])) OR nanocomposites[tiab] OR compomer[tiab] OR ceromer[tiab])	15,901
3.	2 OR 3	43,483
Outcome		
4.	''Tooth Fractures''[Majr] OR ''Retreatment''[Mesh] OR ''Recurrence''[Mesh] OR ''Quality of Life''[Mesh] OR ''Patient Satisfaction''[Mesh] OR ''Dentin Sensitivity''[Mesh] OR ''Cost-Benefit Analysis''[Mesh] OR ''adverse effects'' [Subheading] OR ''toxicity'' [Subheading]	1,919,329
5.	Durability[tiab] OR Failure[tiab] OR Fracture[tiab] OR Longevity[tiab] OR Survival[tiab] OR Repair[tiab] OR Replacement[tiab] OR Maintenance[tiab] OR Retreatment[tiab] OR Recurrence[tiab] OR (caries[tiab] AND (recurrent[tiab] OR secondary[tiab])) OR Retreatment[tiab] OR ''Patient satisfaction''[tiab] OR ''Quality of life''[tiab] OR QoL[tiab] OR HRQoL[tiab] OR HQoL[tiab] OR OHIP[tiab] OR GOHAI[tiab] OR Cost[tiab] OR Cost-effectiveness[tiab] OR (Postoperative[tiab] AND sensitivit*[tiab]) OR (Dentin*[tiab] AND sensitivit*[tiab]) OR ''Adverse effects''[tiab] OR Biocompatibility[tiab] OR Toxicity[tiab]	2,123,157
6.	4 OR 5	3,581,319
Combined sets		
7.	6 AND 12	14,026
Study types		
8.	''Randomized Controlled Trials as Topic''[Mesh] OR ''Randomized Controlled Trial'' [Publication Type] OR ''Controlled Clinical Trials as Topic''[Mesh] OR ''Cohort Studies''[Mesh] OR (clinical[tiab] AND trial[tiab]) OR longitudinal[tiab] OR prospective[tiab] OR follow-up[tiab] OR ''randomized controlled trial''[Title/Abstract] OR ''random''[Title/Abstract] OR ''randomly''[Title/Abstract] OR ''randomized''[Title/Abstract] OR ''randomized''[Title/Abstract]	2,282,538
Limits		
9.	Publication date from 2011/12/14 to 2013/03/08	
	7 AND 8 AND 9	**319**
(e) Cochrane Library via Wiley		
1.	dental and restoration:ti,ab,kw (Word variations have been searched)	2284
2.	dental and bonding:ti,ab,kw (Word variations have been searched)	1796
3.	dental and marginal and adaptation:ti,ab,kw (Word variations have been searched)	449
3.	nanocomposites:ti,ab,kw (Word variations have been searched)	46
4.	ceromer:ti,ab,kw (Word variations have been searched)	5
5.	resin* and composite*:ti,ab,kw (Word variations have been searched)	1717
	1 OR 2 OR 3 OR 4 OR 5 OR 6	**3564** CDSR 25 DARE 85 HTA 11 EED 19
(f) Centre for Reviews and Dissemination		
1.	(dental) AND (restoration)	141
2.	(dental) AND (bonding)	15
3.	(dental) AND (marginal) AND (adaptation)	2
4.	(nanocomposites)	0
5.	(ceromer)	0
6.	(resin*) AND (composite*)	19
	1 OR 2 OR 3 OR 4 OR 5 OR 6	**155**

Table 2 (*Continued*)

	Search terms	Items found
(g) Trip Database		
1.	"dental restoration"~3 from:1990 area:"Dentistry"	73
2.	""dental bonding"~3 from:1990"	23
3.	""dental marginal adaptation"~3 from:1990"	1
4.	"(nanocomposites) from:1990"	12
5.	"(ceromer) from:1990"	1
6.	"resin composite"~3 from:1990 area:"Dentistry"	340
7.	"resin composites"~3 from:1990	77
	1 OR 2 OR 3 OR 4 OR 5 OR 6 OR 7	**481**

The search result, usually found at the end of the documentation, forms the list of abstracts.
[MeSH] = Term from the Medline controlled vocabulary, including terms found below this term in the MeSH hierarchy.
[MeSH:NoExp] = Does not include terms found below this term in the MeSH hierarchy.
[MAJR] = MeSH major topic.
[TIAB] = Title or abstract.
[TI] = Title.
[AU] = Author.
[TW] = Text word.
Systematic[SB] = Filter for retrieving systematic reviews.
* = Truncation.
" " = Citation marks; searches for an exact phrase.

1. **High quality** (++++) Further research is very unlikely to change our confidence in the estimate of effect.
2. **Moderate quality** (+++0) Further research is likely to have an important impact on our confidence in the estimate of effect and may change the estimate.
3. **Low quality** (++00) Further research is very likely to have an important impact on our confidence in the estimate of effect and is likely to change the estimate.
4. **Very low quality** (+000) Any estimate of effect is very uncertain.

The aim of applying GRADE is firstly to determine the level of confidence one can have in a particular estimate of effect and secondly to decide whether the results are sustainable, or if it is likely that new research findings will change the evidence within the foreseeable future. Initially the rating is usually high, but during the process of analysis, confidence in the evidence may decrease stepwise for several reasons, including limitations in study design, and/or quality (i.e. risk of bias), inconsistency or indirectness of results, imprecise estimates and probability of publication bias. Reviewers who were also authors or co-authors of included studies were excluded from participation in grading the scientific evidence.

2.5. *Statistics*

To make overall calculations on survival of restorations as well as comparisons between the articles, a combined dataset was constructed from data retrieved from the eight studies included in the review. Information on the number of restorations, follow-up time, failures and the timing of failures was included in the dataset. If a failed restoration had been registered at a follow-up appointment the restoration provided time at risk until that time point. The reason for failure of a restoration was also noted from the studies.

Incidence rates with 95% confidence intervals were calculated. The life table method was used to calculate survival proportions at different time points. Differences in hazard rates between the different studies were analyzed with Cox proportional hazards model. The studies were modelled as dichotomous indicator variables. All analyses were performed with STATA 12 SE. Hazard ratios with 95% confidence intervals not including 1 were considered statistically significant.

3. Results

3.1. *Literature identification*

A flow chart showing the results of the literature search and the outcome of the selection procedures is presented in Fig. 1. In all, the literature search identified 4275 records for potential inclusion in the review. No additional trials were identified from ClinicalTrials.gov. After the initial screening of the abstracts, the full-text versions of 93 articles were retrieved and read in full text: 75 were excluded and the quality of the remaining 18 articles was assessed. Ten were deemed to contain high risk of bias and were not tabulated[18–27] (Table 3). The excluded studies and the reasons for exclusion are presented in Table 4. The remaining eight studies fulfilling the quality criteria were included in the analysis.[14,28–34] A flow chart showing the results of the literature search and the outcome of the selection procedures is presented in Fig. 1.

3.2. *Interpretation of data*

The eight studies included in the analysis had been published between 2005 and 2013. All but one were conducted by the same research group. In all, the studies were based on 910 restorations in 420 patients. The number of restorations per study varied between 63 and 165. All studies used

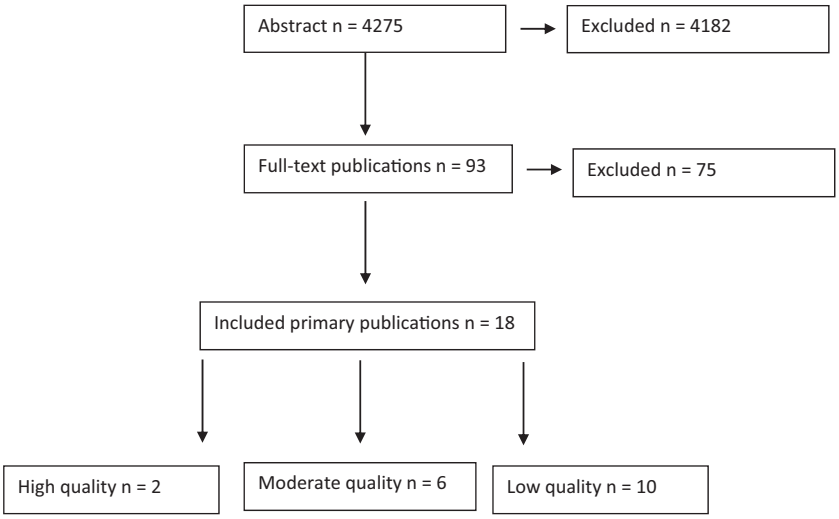

Fig. 1 – Selection process for study inclusion.

intra-individual comparisons and modified USPHS criteria for evaluation. The follow-up times ranged from 4 to 12 years. The characteristics of the included studies are presented in Table 5. Because of the variety of materials used, the results could not be interpreted in relation to the specific resin composite material or bonding material used. Thus, data from the included studies were used as cohorts in the analysis of survival and reasons for failure.

3.3. *Failure rates*

There were 80 failures of restorations in total, ranging from 2 to 17 per study. Sixty percent of the fractures of the restoration or the tooth and endodontic complications occurred during the first 3 years of follow-up. Caries occurred later, more than 75% after 3 years in service. The total follow-up time at risk for failure was 62,030 months, ranging from 2736 to 13,820 months. The overall incidence rate for all causes of failure was 1.55 lost restorations per 100 restoration years (Table 6).

Comparison of the failure rates by visual inspection of Kaplan Meier curves disclosed that overall, the studies seemed quite similar, with one exception: a study reporting a significantly lower incidence rate, by van Dijken[32] (Fig. 2). The comparison of studies with Cox proportional hazards model showed a similar result, with the same study

Table 3 – Studies with low study quality.

First author, year, reference	Main reason for low quality assessment (types of bias)
Andersson-Wenckert IE, van Dijken JW, Kieri C. Durability of extensive Class II open-sandwich restorations with a resin-modified glass ionomer cement after 6 years. *American Journal of Dentistry* 2004;**17**:43–50	Selection bias Assessment bias Loss to follow-up bias
Demirci M, Sancakli HS. Five-year clinical evaluation of Dyract in small Class I cavities. *American Journal of Dentistry* 2006;**19**:41–6	Selection bias Assessment bias
Demircia M. Clinical evaluation of a polyacid-modified resin composite (Dyract AP) in Class I cavities: 5-year results. *Journal of Adhesive Dentisty* 2007;**9**:547–53	Assessment bias
Gordan VV, Mondragon E, Watson RE, Garvan C, Mjör IA. A clinical evaluation of a self-etching primer and a giomer restorative material: results at eight years. *JADA* 2007;**138**:621–7	Selection bias
Kiremitci A, Alpaslan T, Gurgan S. Six-year clinical evaluation of packable composite restorations. *Operative Dentistry* 2009;**34**:11–7	Assessment bias
Köhler B, Rasmusson CG, Odman P. A five-year clinical evaluation of Class II composite resin restorations. *Journal of Dentistry* 2000;**28**:111–6	Selection bias Assessment bias
Lange RT, Pfeiffer P. Clinical evaluation of ceramic inlays compared to composite restorations. *Operative Dentistry* 2009;**34**:263–72	Selection bias
Lundin SA, Koch G. Class I and II posterior composite resin restorations after 5 and 10 years. *Swedish Dental Journal* 1999;**23**:165–71	Selection bias Treatment bias Assessment bias Loss to follow-up bias
Mair LH. Ten-year clinical assessment of three posterior resin composites and two amalgams. *Quintessence International* 1998;**29**:483–90	Selection bias
Raskin A, Michotte-Theall B, Vreven J, Wilson NH. Clinical evaluation of a posterior composite 10-year report. *Journal of Dentistry* 1999;**27**:13–9	Loss to follow-up bias

Table 4 – Excluded studies.

First author, year, reference	Main reason for exclusion
Akimoto N, Takamizu M, Momoi Y. 10-year clinical evaluation of a self-etching adhesive system. *Operative Dentistry* 2007;**32**:3–10	Number of participants
Antony K, Genser D, Hiebinger C, Windisch F. Longevity of dental amalgam in comparison to composite materials. *GMS Health Technology Assessment* 2008;**4**:Doc12	Systematic review
Baratieri LN, Ritter AV. Four-year clinical evaluation of posterior resin-based composite restorations placed using the total-etch technique. *Journal of Esthetic Restorative Dentistry* 2001;**13**:50–7	Loss to follow-up
Barnes DM, Blank LW, Thompson VP, Holston AM, Gingell JC. A 5- and 8-year clinical evaluation of a posterior composite resin. *Quintessence International* 1991;**22**:143–51	Number of participants
Bernardo M, Luis H, Martin MD, Leroux BG, Rue T, Leitão J, DeRouen TA. Survival and reasons for failure of amalgam versus composite posterior restorations placed in a randomized clinical trial. *Journal of the American Dental Association* 2007;**138**:775–83	Participants <18 years
Boeckler, A., Boeckler, L., Eppendorf, K., Schaller, H.G., Gernhardt, C.R. A prospective, randomized clinical trial of a two-step self-etching vs two-step etch-and-rinse adhesive and SEM margin analysis: four-year results, *Journal of Adhesive Dentistry* 2012;**14**:585–92	Loss to follow-up
Bottenberg P, Jacquet W, Alaerts M, Keulemans F. A prospective randomized clinical trial of one bis-GMA-based and two ormocer-based composite restorative systems in Class II cavities: five-year results. *Journal of Dentistry* 2009;**37**:198–203	Loss to follow-up
Brunthaler A, König F, Lucas T, Sperr W, Schedle A. Longevity of direct resin composite restorations in posterior teeth. *Clinical Oral Investigation* 2003;**7**:63–70	Review
Busato AL, Loguercio AD, Reis A, Carrilho MR. Clinical evaluation of posterior composite restorations: 6-year results. *American Journal of Dentistry* 2001;**14**:304–8	Outcome measure not relevant
Cetin AR, Unlu N, Cobanoglu N. A five-year clinical evaluation of direct nanofilled and indirect composite resin restorations in posterior teeth. *Operative Dentistry* 2013;**38**:E1–11	Number of participants
Collins CJ, Bryant RW, Hodge KL. A clinical evaluation of posterior composite resin restorations: 8-year findings. *Journal of Dentistry* 1998;**26**:311–7	Loss to follow-up
da Rosa Rodolpho PA, Cenci MS, Donassollo TA, Loguércio AD, Demarco FF. A clinical evaluation of posterior composite restorations: 17-year findings. *Journal of Dentistry* 2006;**34**:427–35	Retrospective design
Effective health care: dental restoration-what type of filling. The University of York, NHS Centre for Reviews and Dissemination 1999; Vol. 5 No. 2, ISSN: 0965-0288	Systematic review
el-Mowafy OM, Lewis DW, Benmergui C, Levinton C. Meta-analysis on long-term clinical performance of posterior composite restorations. *Journal of Dentistry* 1994;**22**:33–43	Meta analysis
Fagundes TC, Barata TJ, Carvalho CA, Franco EB, van Dijken JW, Navarro MF. Clinical evaluation of two packable posterior composites: a five-year follow-up. *Journal of the American Dental Association* 2009;**140**:447–54	Number of participants
Fernandez EM, Martin JA, Angel PA, Mjör IA, Gordan VV, Moncada GA. Survival rate of sealed, refurbished and repaired defective restorations: 4-year follow-up. *Brazilian Dental Journal* 2011;**22**:134–9	Loss to follow-up
Fokkinga WA, Kreulen CM, Bronkhorst EM, Creugers NH. Composite resin core-crown reconstructions: an up to 17-year follow-up of a controlled clinical trial. *International Journal of Prosthodontics* 2008;**21**:109–15	Subject not relevant
Gaengler P, Hoyer I, Montag R. Clinical evaluation of posterior composite restorations: the 10-year report. *Journal of Adhesive Dentistry* 2001;**3**:185–94	Loss to follow-up
Garcia-Godoy F, Kramer N, Feilzer AJ, Frankenberger R. Long-term degradation of enamel and dentin bonds: 6-year results in vitro vs. in vivo. *Dental Materials* 2010;**26**:1113–8	Loss to follow-up
Geurtsen W, Schoeler U. A 4-year retrospective clinical study of Class I and Class II composite restorations. *Journal of Dentistry* 1997;**25**:229–32	Retrospective design
Goldstein GR. The longevity of direct and indirect posterior restorations is uncertain and may be affected by a number of dentist-, patient-, and material-related factors. *Journal of Evidence Based Dental Practice* 2010;**10**:30–1	Summary of systematic review Manhart et al. (2004)
Gordan VV, Shen C, Watson RE, Mjör IA. Four-year clinical evaluation of a self-etching primer and resin-based restorative material. *American Journal of Dentistry* 2005;**18**:45–9	Loss to follow-up
Hawthorne WS, Smales RJ. Factors influencing long-term restoration survival in three private dental practices in Adelaide. *Australian Dental Journal* 1997;**42**:59–63	Retrospective design
Hayashi M, Wilson NH. Marginal deterioration as a predictor of failure of a posterior composite. *European Journal of Oral Sciences* 2003;**111**:155–62	Retrospective design
Heintze SD, Rousson V. Clinical effectiveness of direct Class II restorations – a meta-analysis. *Journal of Adhesive Dentistry* 2012;**14**:407–31	Meta analysis
Hickel R, Manhart J, García-Godoy F. Clinical results and new developments of direct posterior restorations. *American Journal of Dentistry* 2000;**13**:41D–54D	Review
Hickel R, Manhart J. Longevity of restorations in posterior teeth and reasons for failure. *Journal of Adhesive Dentistry* 2001;**3**:45–64	Review
Hondrum SO. The longevity of resin-based composite restorations in posterior teeth. *General Dentistry* 2000;**48**:398–404	Review
Huth KC, Manhart J, Selbertinger A, Paschos E, Kaaden C, Kunzelmann KH, Hickel R. 4-year clinical performance and survival analysis of Class I and II compomer restorations in permanent teeth. *American Journal of Dentistry* 2004;**17**:51–5	Loss to follow-up

Table 4 (*Continued*)

First author, year, reference	Main reason for exclusion
Kopperud, S.E., Tveit, A.B., Gaarden, T., Sandvik, L., Espelid, I. Longevity of posterior dental restorations and reasons for failure. *European Journal of Oral Sciences* 2012;**120**:539–48	Participants <18 years
Krämer N, García-Godoy F, Reinelt C, Feilzer AJ, Frankenberger R. Nanohybrid vs. fine hybrid composite in extended Class II cavities after six years. *Dental Materials* 2011;**27**:455–64	Number of participants
Krämer N, García-Godoy F, Reinelt C, Frankenberger R. Clinical performance of posterior compomer restorations over 4 years. *American Journal of Dentistry* 2006;**19**:61–6	Loss to follow-up
Kubo S, Kawasaki A, Hayashi Y. Factors associated with the longevity of resin composite restorations. *Dental Materials* 2011;**30**:374–83	Retrospective design
Letzel H. Survival rates and reasons for failure of posterior composite restorations in multicentre clinical trial. *Journal of Dentistry* 1989;**17**(Suppl. 1):S10–7; discussion S26–8	Publication date
Lu H, Koh H, Rasines Alcaraz MG, Schmidlin PR, Davis D. Direct composite resin fillings versus amalgam fillings for permanent or adult posterior teeth. *Cochrane Database of Systematic Reviews* 2006, Issue 1. Art. No.: CD005620. http://dx.doi.org/10.1002/14651858.CD005620	Systematic review
Lund RG, Sehn FP, Piva E, Detoni D, Moura FR, Cardoso PE, Demarco FF. Clinical performance and wear resistance of two compomers in posterior occlusal restorations of permanent teeth: six-year follow-up. *Operative Dentistry* 2007;**32**:118–23	Loss to follow-up
Lundin SA. Studies on posterior composite resins with special reference to Class II restorations. *Swedish Dental Journal* 1990;**73**(Suppl.):1–41	Thesis
Mandari GJ, Frencken JE, van't Hof MA. Six-year success rates of occlusal amalgam and glass-ionomer restorations placed using three minimal intervention approaches. *Caries Research* 2003;**37**:246–53	Participants <18 years
Manhart J, Chen H, Hamm G, Hickel R. Buonocore Memorial Lecture. Review of the clinical survival of direct and indirect restorations in posterior teeth of the permanent dentition. *Operative Dentistry* 2004;**29**:481–508	Review, update of Hickel and Manhart (2000, 2001)
Mannocci F, Qualtrough AJ, Worthington HV, Watson TF, Pitt Ford TR. Randomized clinical comparison of endodontically treated teeth restored with amalgam or with fiber posts and resin composite: five-year results. *Operative Dentistry* 2005;**30**:9–15	Endodontically treated teeth
Mazer RB, Leinfelder KF. Evaluating a microfill posterior composite resin. A five-year study. *Journal of the American Dental Association* 1992;**123**:32–8	Loss to follow-up
Mjör IA, Jokstad A. Five-year study of Class II restorations in permanent teeth using amalgam, glass polyalkenoate (ionomer) cement and resin-based composite materials. *Journal of Dentistry* 1993;**21**:338–43	Loss to follow up
Nikaido T, Takada T, Kitasako Y, Ogata M, Shimada Y, Yoshikawa T, et al. Retrospective study of five-year clinical performance of direct composite restorations using a self-etching primer adhesive system. *Dental Materials* 2006;**25**:611–5	Retrospective design
Nikaido T, Takada T, Kitasako Y, Ogata M, Shimada Y, Yoshikawa T, et al. Retrospective study of the 10-year clinical performance of direct resin composite restorations placed with the acid-etch technique. *Quintessence International* 2007;**38**:e240–6	Retrospective design
Nordbø H, Leirskar J, von der Fehr FR. Saucer-shaped cavity preparations for posterior approximal resin composite restorations: observations up to 10 years. *Quintessence International* 1998;**29**:5–11	Study design unclear
Norman RD, Wright JS, Rydberg RJ and Felkner LL. A 5-year study comparing a posterior composite resin and an amalgam. *Journal of Prosthetic Dentistry* 1990;**64**:523–9	Amalgam preparation technique
Opdam NJ, Bronkhorst EM, Loomans BA, Huysmans MC. 12-year survival of composite vs. amalgam restorations. *Journal of Dental Research* 2010;**89**:1063–7	Retrospective design
Opdam NJ, Bronkhorst EM, Roeters JM, Loomans BA. A retrospective clinical study on longevity of posterior composite and amalgam restorations. *Dental Materials* 2007;**23**:2–8	Retrospective design
Opdam NJ, Bronkhorst EM, Roeters JM, Loomans BA. Longevity and reasons for failure of sandwich and total-etch posterior composite resin restorations. *Journal of Adhesive Dentistry* 2007;**9**:469–75	Retrospective design
Opdam NJ, Loomans BA, Roeters FJ, Bronkhorst EM. Five-year clinical performance of posterior resin composite restorations placed by dental students. *Journal of Dentistry* 2004;**32**:379–83	Retrospective design
Palaniappan S, Elsen L, Lijnen I, Peumans M, Van Meerbeek B, Lambrechts P. Nanohybrid and microfilled hybrid versus conventional hybrid composite restorations: 5-year clinical wear performance. *Clinical Oral Investigation* 2012;**16**:181–90	Number of participants
Pallesen U, Qvist V. Composite resin fillings and inlays. An 11-year evaluation. *Clinical Oral Investigation* 2003;**7**:71–9	Number of participants
Pallesen U, van Dijken JWV, Halken J, Hallonsten AL, Höigaard R. Longevity of posterior resin composite restorations in permanent teeth in Public Dental Health Service: a prospective 8 years follow up. *Journal of Dentistry* 2013;**41**:297–306	Participants <18 years
Raskin A, Setcos JC, Vreven J, Wilson NH. Influence of the isolation method on the 10-year clinical behaviour of posterior resin composite restorations. *Clinical Oral Investigation* 2000;**4**:148–52	Loss to follow-up
Rasmusson CG, Lundin SA. Class II restorations in six different posterior composite resins: five-year results. *Swedish Dental Journal* 1995;**19**:173–82	Loss to follow-up
Rowe AH. A five year study of the clinical performance of a posterior composite resin restorative material. *Journal of Dentistry* 1989;**17**(Suppl. 1):S6–9; discussion S26–8	Publication date
Schirrmeister JF, Huber K, Hellwig E, Hahn P. Four-year evaluation of a resin composite including nanofillers in posterior cavities. *Journal of Adhesive Dentistry* 2009;**11**:399–404	Loss to follow-up

Table 4 (*Continued*)

First author, year, reference	Main reason for exclusion
Scholtanus JD, Huysmans MC. Clinical failure of class-II restorations of a highly viscous glass-ionomer material over a 6-year period: a retrospective study. *Journal of Dentistry* 2007;**35**:156–62	Retrospective design
Sikorska-Bochinska J. Long-term evaluation of filling from selected composite materials and their effect on tooth pulp. *Annales Academiae Medicae Stetinenses* 2002;**48**:317–30	In Polish
Smales RJ, Hawthorne WS. Long-term survival and cost-effectiveness of five dental restorative materials used in various classes of cavity preparations. *International Dental Journal* 1996;**46**:126–30	Retrospective design
Smales RJ, Hawthorne WS. Long-term survival of extensive amalgams and posterior crowns. *Journal of Dentistry* 1997;**25**:225–7	Retrospective design
Soncini JA, Maserejian NN, Trachtenberg F, Tavares M, Hayes C. The longevity of amalgam versus compomer/composite restorations in posterior primary and permanent teeth: findings From the New England Children's Amalgam Trial. *Journal of the American Dental Association* 2007;**138**:763–72	Participants < 18 years
Sturdevant JR, Lundeen TF, Sluder TB, Wilder AD and Taylor DF (1988) Five-year study of two light-cured posterior composite resins. *Dental Materials* 1988;**4**:105–10	Publication date
Thomason JM, Heydecke G, Feine JS, Ellis JS. How do patients perceive the benefit of reconstructive dentistry with regard to oral health-related quality of life and patient satisfaction? A systematic review. *Clinical Oral Implants Research* 2007;**18**(Suppl. 3):168–88	Systematic review
Tobi H, Kreulen CM, Vondeling H, van Amerongen WE. Cost-effectiveness of composite resins and amalgam in the replacement of amalgam Class II restorations. *Community Dental Oral Epidemiology* 1999;**27**:137–43	Preparation design
Trachtenberg F, Maserejian NN, Tavares M, Soncini JA, Hayes C. Extent of tooth decay in the mouth and increased need for replacement of dental restorations: the New England Children's Amalgam Trial. *Pediatric Dentistry* 2008;**30**:388–92	Participants <18 years
Türkün LS, Aktener BO, Ateş M. Clinical evaluation of different posterior resin composite materials: a 7-year report. *Quintessence International* 2003;**34**:418–26	Lost to follow up
Tyas MJ, Wassenaar P. Clinical evaluation of four composite resins in posterior teeth. Five-year results. *Australian Dental Journal* 1991;**36**:369–73	Number of participants
van Dijken JWV. A 6-year evaluation of a direct composite resin inlay/onlay system and glass ionomer cement-composite resin sandwich restorations. *Acta Odontologica Scandinavica* 1994;**52**:368–76	More recent report included
van Dijken JWV. Direct resin composite inlays/onlays: an 11 year follow-up. *Journal of Dentistry* 2000;**28**:299–306	Number of participants
Van Nieuwenhuysen JP, D'Hoore W, Carvalho J, Qvist V. Long-term evaluation of extensive restorations in permanent teeth. *Journal of Dentistry* 2003;**31**:395–405	Loss to follow-up
Wassell RW, Walls AW, McCabe JF. Direct composite inlays versus conventional composite restorations: 5-year follow-up. *Journal of Dentistry* 2000;**28**:375–82	Loss to follow-up
Welbury RR, Walls AW, Murray JJ, McCabe JF. The management of occlusal caries in permanent molars. A 5-year clinical trial comparing a minimal composite with an amalgam restoration. *British Dental Journal* 1990;**169**:361–6	Participants <18 years
Wilder AD, Jr., May KN, Jr., Bayne SC, Taylor DF, Leinfelder KF. Seventeen-year clinical study of ultraviolet-cured posterior composite Class I and II restorations. *Journal of Esthetic Dentistry* 1999;**11**:135–42	Amalgam preparation technique
Wilson NH, Wilson MA, Wastell DG and Smith GA A clinical trial of a visible light cured posterior composite resin restorative material: five-year results. *Quintessence International* 1988;**19**:675–81	Publication date

significantly different from the others ($p < 0.05$) (Fig. 3). This was the sole study investigating Class I restorations only.[32]

3.4. *Survival proportions*

Survival proportions with 95% confidence intervals at specific time points are presented in Table 7. The four year survival proportion retrieved from the life table calculations, including data from all eight studies, was 0.93. At the five year follow-up, three studies no longer provided data and the survival proportion had decreased to 0.91. There was a similar decrease until the nine year follow-up. Thereafter, only one study provided data and no further restorations failed until the end of the follow-up at 12 years.

3.5. *Reasons for failure*

When the incidence rate was stratified according to type of complication, the incidence rate for biological complications was close to twofold higher than for technical complications. The most common biological reason for failure (a total of 31 restorations) was secondary caries, with or without fracture of the restoration. Other biological reasons for failure were tooth fracture (15 restorations) and endodontic complications such as pulpitis or apical periodontitis (7 restorations). The technical complications reported were fractured or lost restoration material (26 restorations) and a colour match problem for one restoration.

3.6. *Level of evidence*

With respect to the overall incidence rate, the risk of selection- and detection bias resulted in downgrading of the level of evidence of studies. On the other hand, strong effect size strengthened the evidence to a total low level of evidence (Table 6).

With respect to survival proportion, the risk of selection- and detection bias resulted in downgrading of the level of evidence of studies. On the other hand, strong effect size strengthened the evidence to a total low level of evidence.

Table 5 – Included studies, extracted data and outcomes.

First author Reference Year Country	Study design Sample selection and characteristics Inclusion period Evaluation method Follow-up	Interventions Sample	Control Sample	Outcome Interventions	Outcome Control	Comparison	Study quality	Comments
Lindberg 2007 Sweden[28]	RCT Intra individual comparison Consecutive patients treated at public dental health clinic Operators: 2 Evaluators: 1–2 Modified USPHS Follow up: 9 years evaluated at 6, 12, 24, 36 months and 9 years	*Class II hybrid resin composite* (1) Resin composite (Prisma TPH) with PAMRC (compomer: Dyract) base as open sandwich, $n = 75$ (2) Resin composite without PAMRC, $n = 75$ *Adhesive system* 2-step etch and rinse (Prime & Bond 2.1) Cavity form: Mainly Black type Most cavities enamel bordered No rubber dam No $Ca(OH)_2$ or GIC cavity base Patients: 57 Women: 31 Men: 26 Mean age: 34.6 (range 17–68) Premolars: 68 Molars: 82 2 surfaces: 86 $\geq$3 surfaces: 64 Caries risk evaluation *Lost to follow up* Restorations: 15		*CSR (cumulative survival rate)* Tot: 89.6% (1) 90.9% (2) 88.4% *Postoperative sensitivity* 2 restorations with pulpitis *Reasons for failure* Caries: 8 (5.9%) Material fracture: 2 (1.5%) Tooth fracture: 1 (0.7%) Endodontic treatment: 3 (2.2%) *Failure localization* Premolars: 8.8% Molars: 9.8% 2 surfaces: 10.5% $\geq$3 surfaces: 7.8% 51.7% patients were estimated as high caries risk		CSR No statistical difference between the two groups ($p = 0.604$) *Annual failure rate* (1) 1.0% (2) 1.37%	Moderate	Selection period not reported Calibrated evaluators but inter-observer agreement not reported Part of restorations were evaluated by two evaluators

Table 5 (*Continued*)

First author Reference Year Country	Study design Sample selection and characteristics Inclusion period Evaluation method Follow-up	Interventions Sample	Control Sample	Outcome Interventions	Outcome Control	Comparison	Study quality	Comments
Manhart 2010 Germany[29]	RCT Intra-individual comparison Operators: 3 Evaluators: 2 Modified USPHS Follow up: 4 years evaluated at baseline, 3, 6, 18 months and 3 and 4 years	*Class I and II hybrid resin composite restorations* (1) Transluscent bulk-fill resin composite (Quixfil; $n = 46$) (2) Microhybrid resin composite (Tetric Ceram; $n = 50$) *Adhesive system* (1) 1-step self-etch (Xeno III) (2) 4-step etch-and-rinse (Syntac Classic) Cavity form: Both Black and saucer shaped type Both with and without rubber dam Patients: 43 Mean age: 44.3 (range 19–67) In patients with more than one restoration both resin composites were randomly placed Premolars: 0 Molars: 96 1 surface: 13 2 surfaces: 40 ≥3: 30 *Lost to follow up* Patients: 7 Restorations: (1) 9 (2) 4	CSR Tot: 94% (1) 89.2% (2) 97.8% *Reasons for failure* (1) Restoration fracture: 1 (2.17%) Tooth fracture: 2 (4.35%) Post op sensitivity: 1 (2.17%) (2) Tooth fracture: 1 (2.0%)	CSR No statistical difference between the two groups ($p = 0.120$) *Annual failure rate* (1) 2.7% (2) 0.6%	Moderate	Selection not described Selected patients: high level of oral hygiene Cavity sizes at baseline not indicated Inter-observer agreement kappa value >0.65 except colour match kappa 0.34 Post-operative sensitivity not indicated except for one failure

van Dijken 2005 Sweden[30]	RCT Intra-individual comparison Consecutive patients treated at public dental clinic from November 1999 to April 2000 Operator: 1 Evaluators: 2 Modified USPHS Follow up: 4 years, annual recalls	*Class II and Class I micro hybrid resin composite and calcium-aluminate cement restorations* (1) Microhybrid resin composite (Tetric Ceram), Class II 61, Class I 10 (2) Ca-aluminate cement (Doxadent) Class II 61, Class I 10 *Adhesive system* (1) 2-step etch-and-rinse (Exite) (2) none Cavity form: Black type Minimum 1 pair of restorations per patient 50% of cervical margin apical to cement–enamel junction No rubber dam No base Patients: 63 Women: 31 Men: 32 Mean age: 51.7 (30–85) Premolars: 72 Molars: 70 Caries risk evaluation *Lost to follow up* (1) Patients: 3, Restorations: 4 (2) Patients: 3, Restorations: 4	CSR (1) 92.5% (2) 43.1% (at 3 years) *Postoperative sensitivity* (1–3 weeks biting forces and/or cold stimuli) (1) 2 (2) 3 *Reasons for failure* Material fracture: 2 (3.0%) Tooth fracture: 2 (3.0%) Endodontic reasons 1 (1.5%) 19.2% high-risk caries patients	Trial of Ca-Aluminate discontinued at year 3 due to high failure rate All group (1) failures in Class II restorations Group 1: No difference in failure rate between restorations with enamel- or dentine-bordered margins *Annual failure rate* (1) 1.9% (2) 19.0% (at 3 years)	Moderate	Calibrated evaluators Inter-examiner agreement not stated

Table 5 (*Continued*)

First author Reference Year Country	Study design Sample selection and characteristics Inclusion period Evaluation method Follow-up	Interventions Sample	Control Sample	Outcome Interventions	Outcome Control	Comparison	Study quality	Comments
van Dijken 2009 Sweden[31]	RCT Intra-individual comparisons Consecutive patients treated at dental school clinic and public dental clinic during a 3-month period Operators: 2 Evaluators: 2–3 Modified USPHS Follow up: 5 years, annual recalls	*Class II hybrid resin composite restorations* (1) Low shrinkage RC (In-Ten-S; $n = 53$) (2) Microhybrid resin composite (Point 4; $n = 53$) *Adhesive system* (1) 2-step etch and rinse (Exite) (2) 2-step etch and rinse (Optibond Solo Plus) Cavity form: Black type No rubber dam No base used One or two pair resin composite per patient Patients: 50 Women: 22 Men: 28 Mean age 43 (range 17–64) Premolars: 33 Molars: 73 Caries risk evaluation *Lost to follow up* Patients: 4 Restorations: 8 Extraction due to periodontal reasons: 1		CSR Tot: 87.6% (1) 89.6% (2) 85.7% *Postoperative sensitivity Over a 2-week period* (1) Cold and air: 2 (2) Biting forces: 1 *over a 2-week period* *Reasons for failure* (1) Caries: 3 (6.3%) Material fracture and caries: 1 (2.1%) Tooth fracture: 1 (2.1%) (2) Caries: 4 (8.2%) Material fracture: 2 (4.1%) Tooth fracture: 1 (2.0%) 26.7% were estimated as high caries risk patients 5 of 8 caries lesions were observed in caries risk patients		CSR No statistical difference between the two groups. *Annual failure rates* (1) 2.1% (2) 2.9%	Moderate	Calibrated evaluators Inter-observer agreement not reported Cavity sizes at baseline not indicated Most caries occurred in high caries risk patients

van Dijken 2010 Sweden[32]	RCT Intra-individual comparison Consecutive patient treated at public dental clinic Operators: 1 Evaluators: 1–2 Modified USPHS Follow up: 12 years, annual recalls	*Class I hybrid resin composite (Prisma TPH)* (1) Resin composite with PAMRC (compomer: Dyract) base (closed sandwich), *n* = 45 (2) Resin composite without PAMRC, *n* = 45 *Adhesive system* 2-step etch and rinse (Prime & Bond 2.1) Cavity form: Black type No rubber dam $Ca(OH)_2$ base used for 1 restoration Indirect/direct light curing technique Patients: 29 Women: 11, Men: 18 Mean age: 43.3 (range 26–72) Premolars: 23 Molars: 67 Maxilla: 35 Mandible: 55 Caries risk evaluation *Lost to follow up* Patients: 6 Restorations: 14	CSR Tot: 97.4% (1) 97.4% (2) 97.4% *Postoperative sensitivity* 1 patient (moderate symptoms during flying first 2 years in both types of restorations) *Reasons for failure* (1) Non acceptable colour match: 1 (2.6%) (2) Material fracture: 1 (2.6%) *Replacement due to primary approximal caries* 2 molars and 1 premolar, all in high caries risk patients 27.6% were estimated as high caries risk patients at baseline and 26.1% at 12 years	CSR No statistical difference between groups *Annual failure rate* (1) 0.2% (2) 0.2%	Moderate	One or two evaluators Inter-observer agreement not reported Most caries occurred in high caries risk patients

Table 5 (*Continued*)

First author Reference Year Country	Study design Sample selection and characteristics Inclusion period Evaluation method Follow-up	Interventions Sample	Control Sample	Outcome Interventions	Outcome Control	Comparison	Study quality	Comments
van Dijken 2011 Sweden, Denmark[33]	RCT Intra-individual comparison Consecutive patients treated at public dental clinic over 1 year Operators: 2 Evaluators: 1–2 Modified USPHS Follow up: 7 years, annual recalls	*Class II microhybrid resin composite restorations* (1) With cervical flowable RC (Tetric Ceram/Tetric flow) $n = 59$ (2) Without cervical flowable RC, $n = 59$ *Adhesive system* 2-step step etch and rinse (Exite) Cavity form: Black type No $Ca(OH)_2$ base No rubber dam Patients: 48 Women: 22 Men: 26 Mean age: 57.0 (range 21–85) Premolars: 62 Molars: 56 2 surfaces: 108 $\geq$3: 10 Maxilla: 56 Mandible: 62 86% of cervical margins located below cement–enamel junction Caries risk evaluation *Lost to follow up* Patients: 2 Restorations: 4	*CSR* Tot: 85.1% (1) 86.0% (2) 84.2% *Postoperative sensitivity* 7 patients symptoms over 1–3 weeks, biting forces and/or cold stimuli (1) 3 (2) 4 *Reasons for failure* (1) Caries: 2 (3.5%) Material fracture: 5 (8.8%) Tooth fracture: 1 (1.8%) (2) Caries: 2 (3.5%) Material fracture: 4 (7.0%) Tooth fracture: 2 (3.5%) Material fracture and caries: 1 (1.8%) 39.1% were estimated as high caries risk patients	*CSR* No statistical difference between restorations with and without cervical flowable RC layer *Annual failure rates* (1) 2.0% (2) 2.3%	High	Calibrated evaluators Inter-observer agreement not reported

van Dijken 2011 Sweden, Denmark[34]	RCT Intra-individual comparison Consecutive patients treated at public dental clinic and in private dental practice, 7 months during 2004–2005 Operators: 4 Evaluators: 2–3 Modified USPHS Follow up: 4 years, annual recalls	*Class II restoration with ormocer nano-hybrid resin composite (Ceram X)* *Adhesive system* (1) 1-step self-etch (Xeno III), $n = 92$ (2) 2-step etch and rinse (Exite), $n = 73$ Cavity form: Black type No $Ca(OH)_2$ base No rubber dam Patients: 78 Women: 44 Men: 34 Mean age 52.7 (range 28–86) Premolars: 62 Molars: 103 2-surfaces: 101 $\geq$3: 64 Maxilla: 101 Mandible: 64 *Lost to follow up* Patients: 2 Restorations: 3	CSR Tot: 93.2% (1) 92.3% (2) 94.4% *Postoperative sensitivity* (1–3 weeks biting forces and/or cold stimuli) (1) 3 (2) 3 *Reasons for failure* (1) Caries: 1 (1.1%) Material fracture: 5 (5.5%) Tooth fracture: 1 (1.1%) (2) Material fracture: 2 (2.8%) material fracture and caries: 1 (1.4%) Endodontic reasons: 1 (1.4%)	CSR No statistical difference between the two groups *Annual failure rates* Tot: 1.7% (1) 1.9% (2) 1.4%	High	Calibrated evaluators Inter-observer agreement not reported

Table 5 (*Continued*)

First author Reference Year Country	Study design Sample selection and characteristics Inclusion period Evaluation method Follow-up	Interventions Sample	Control Sample	Outcome Interventions	Outcome Control	Comparison	Study quality	Comments
van Dijken 2013 Sweden, Denmark[14]	RCT Intra-individual comparison Consecutive patients treated at public l and private dental clinics during September–December 2003 Operators: 2 Evaluators: 1–2 Modified USPHS Follow up: 6 years annual recalls	*Class II resin composite restorations* (1) Conventional microhybrid RC (Tetric Ceram) $n = 61$ (2) Nanohybrid RC (Tetric Evo Ceram), $n = 61$ *Adhesive system* 2-step step etch and rinse (Exite) Cavity form: Black type No $Ca(OH)_2$ base No rubber dam Patients: 52 Women: 27 Men: 25 Mean age: 53.0 (range 29–82) Premolars: 49 Molars: 73 Maxilla: 66 Mandible: 56 Caries risk evaluation *Lost to follow up* Patients: 2 Restorations: 4		CSR Tot: 88.1% (1) 89.8% (2) 86.4% *Postoperative sensitivity* (1) 1 patient extraction at 4 years due to pain (2) 1 patient mild symptoms during first weeks, cold and hot stimuli) *Reasons for failure* (1) Caries: 3 (5.3%) Material fracture and caries: 1 (1.8%) Fracture: 1 (1.8%) Pain: 1 (1.8%) (2) Caries: 3 (5.3%) Material fracture and caries: 1 (1.8%) Tooth fracture: 2 (3.6%) Lost: 1 (1.8%) Lost and tooth fracture 1 (1.8%) 30.8% patients were estimated as high caries risk		CSR: No statistical difference between the two groups Annual failure rates (1) 1.7% (2) 2.3%	High	Calibrated evaluators Cohen–Kappa > 85% Most caries occurred in high caries risk patients

Table 6 – Overall survival.

Outcome	Study design No. of teeth (No. of studies)	Loss of filling/100 survival filling years (95% CI)	Scientific evidence	Comments
Overall incidence rate	Cohort 910 (8)	1.55 (1.24;1.93)	(⊕⊕OO)	Risk of bias −1 Effect size +1

However at 12 years, studies were downgraded due to imprecision in the data, resulting in very low scientific evidence at this specific time point (Table 7).

4. Discussion

The purpose of the study was to review the durability of posterior resin composites in adult participants. The reason to investigate adult participants (≥18 years) was based on the clinical difference in reasons for placement and ability of own dental care in adult participants compared to children populations. Restorations in permanent posterior teeth in children are almost always placed because of primary caries. In adult participants the reasons for placement are beside primary caries above all replacement of old restorations resulting in moderate to large new resin composite restorations.

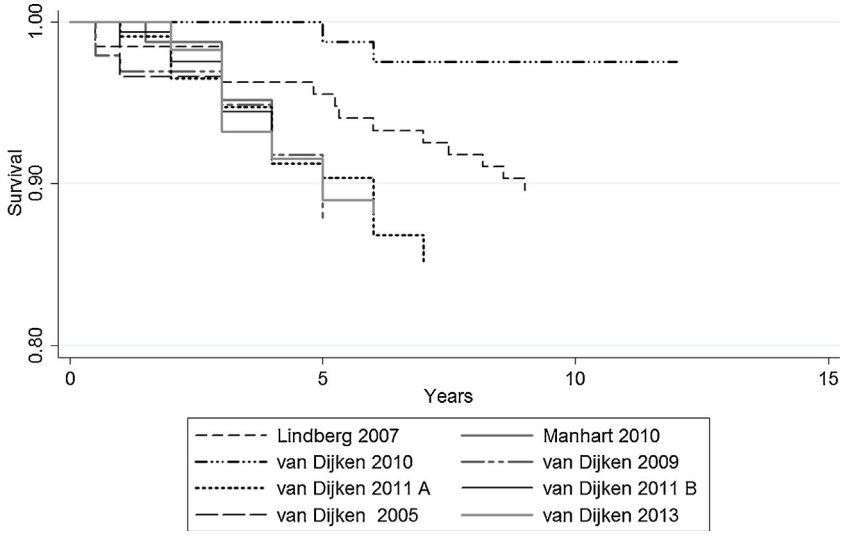

Fig. 2 – Kaplan Meier survival estimates of the studies included in the analysis.

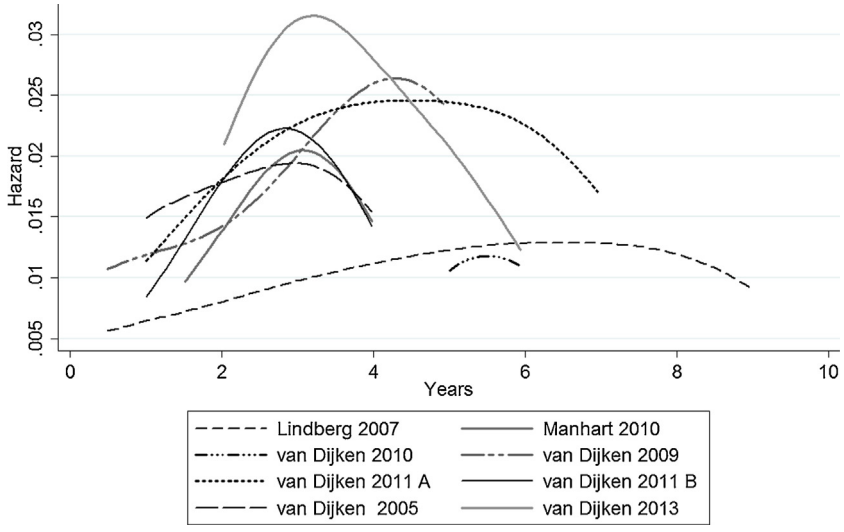

Fig. 3 – Smoothed hazard estimates displaying the changes in incidence rate of filling failure per filling year over the study period for the included studies.

Table 7 – Survival proportions with 95% confidence intervals and scientific evidence at specific time points.

Outcome	Study design No. of teeth (No. of studies)	Survival rate (95% CI)	Scientific evidence	Comments
Survival proportion 4 years	Cohort 808 (8)	0.93 (0.91;0.95)	(⊕⊕OO)	Risk of bias −1 Effect size +1
Survival proportion 5 years	Cohort 511 (5)	0.91 (0.89;0.93)	(⊕⊕OO)	Risk of bias −1 Effect size +1
Survival proportion 6 years	Cohort 415 (4)	0.89 (0.86;0.91)	(⊕⊕OO)	Risk of bias −1 Effect size +1
Survival proportion 7 years	Cohort 298 (3)	0.88 (0.85;0.91)	(⊕⊕OO)	Risk of bias −1 Effect size +1
Survival proportion 9 years	Cohort 195 (2)	0.86 (0.82;0.89)	(⊕⊕OO)	Risk of bias −1 Effect size +1
Survival proportion 12 years	Cohort 74 (1)	0.86 (0.82;0.89)	(⊕OOO)	Risk of bias −1 Effect size +1 Imprecision −1

The duration of follow-up is of major importance, as a short RCT may overestimate clinical effectiveness.[10] The minimum follow-up time was therefore set at 4 years. As posterior resin composite restorations were not standard clinical procedures prior to 1990, the literature search was limited to publications since then, in order to exclude old materials. The number of restorations was set to at least 40 in each cohort. Patient attrition was set at a maximum of 20% at 4 years and thereafter at less than 5% per year.

In general practice, the decision to replace a restoration is based on subjective criteria. Intra- and inter-examiner variability among clinicians is high.[5,13] Studies using non-standardized criteria for decision-making reflect how long a clinician allows a restoration to last, rather than true restoration failure. Guidelines and standardized criteria improve the diagnosis of failure.[10,13]

Among the eight papers fulfilling the inclusion criteria, seven originated from the same research group. In order to eliminate bias, the review author (JvD) who was also author of seven of the included papers, did not participate in the evaluation and analysis of the results.

All the included studies presented an efficacy setting and study design. Therefore the results should be interpreted with caution and not be extrapolated to an effectiveness setting.

The definition of secondary caries in the included studies was based on the modified USPHS criteria: ''caries is evident contiguous with the margin of the restoration''. This means that these caries lesions are related to the primary restoration. There is no distinction of caries associated with defects in fillings. Marginal adaptation and anatomical form are also rated, but the association between lower scores for these variables and the presence of secondary caries have not been presented in the selected studies.

In descending order, the reasons for failure were secondary caries, fractured or lost restoration, fractured tooth, and endodontic complications. Fractures of the restoration or the tooth and endodontic complications occurred earlier during follow up, more than 60% during the first 3 years. Caries occurred later, more than 75% after 3 years in service. This finding is in accordance with earlier reviews[35] and highlights the importance of adequate follow-up time. A meta-analysis by Heintze and Rousson[36] of solely Class II resin composite restorations showed that marginal caries occurred no earlier than at 2 years. In the present study, the failure rates for single-surface restorations were significantly lower than for multi-surface ones, confirming the clinically significant greater durability of Class I restorations.[12]

In many countries, resin composite has displaced amalgam as a posterior restoration material. A recent systematic review[9] reported randomized controlled clinical trials comparing posterior resin composite and amalgam restorations in the permanent teeth of children. The authors concluded that there was low-quality evidence to suggest that higher failure rates and higher risk of secondary caries are associated with resin composite than with amalgam restorations. However, in studies comparing the longevity of resin composite and amalgam restorations, the risk of performance and detection bias is high. In studies with parallel group design, the risk of allocation bias is high, i.e. there is a risk that the patient groups and operators are unequal.[9]

In a recent meta-analysis of longevity of resin composite restorations by Opdam et al.,[11] the annual failure rates were slightly higher (1.8% at 5 years and 2.4% at 10 years) than the overall restoration failure incidence rate of 1.55% disclosed in the present study. This disparity is probably attributable primarily to inclusion of retrospective studies, which introduces the risk of bias with respect to the outcome measure ''failure''. However Opdam et al.[11] used original data sets, which made it possible to analyze variables that may affect restoration longevity, such as caries activity, thus confirming

that caries risk is an important determinant of restoration survival.

The performance of posterior resin composite restorations has improved since they were more common used by the general practitioners during the nineties. This was probably caused by material developments like improved handling characteristics, introduction of amphyphylic bonding systems and especially improved clinical handling of resin composites. Recent material developments are low shrinkage and/or reduced polymerization stress composites, bulk fill and more biocompatible materials as well as simplified bonding systems. Clinical short term evaluations of some of these developments showed similar, not statistically significant different, longevity compared to the control restorations performed with traditional hybrid resin composites placed with etch-and-rinse adhesives.[14,37,38] A recent 30 years clinical evaluation of Class II restorations performed with conventional resin composites and enamel bonding showed annual failure rates comparable with the ones published in the 8 selected studies in the present systemic review.[39] This indicates probably that handling of the material, placed in a proper way, is a more important variable for clinical effectiveness than material characteristics.

It is very well possible that AFR rates observed in future studies of posterior resin composites will become lower than these found in the present review. This as a result of improvements expected for several of the variables related to the failing of posterior restorations. The ongoing shift to smaller cavities in the coming patient generations will increase. A better understanding of patients for and an improved prevention of risk factors involved, especially secondary caries, is necessary. Development of materials with improved fracture toughness and more durable bonding techniques will together with improved handling techniques and diagnostics influence durability.

Despite the attempts to improve the quality of reporting RCTs which led to the publication of the CONSORT (Consolidated Standards of Reporting Trials) statement in 1996, RCTs are still not being reported adequately.[40] RCTs will give solid information on efficacy. However, restorative materials and techniques will continue to develop and improve and there is a continuous need to evaluate their long-term effectiveness. This is probably best achieved by obtaining data in health care quality registers and national health data registers.

5. Conclusion

In an efficacy setting, the overall survival proportion of posterior resin composite restorations is high. The major reasons for failure are secondary caries and restoration fracture which supports the importance of adequate follow-up time.

6. Clinical significance

The overall survival proportion of posterior resin composite restorations was high, but the results cannot be extrapolated to an effectiveness setting. The importance of adequate follow-up time is supported by the finding that secondary caries often occurred after 3 years or later.

Conflict of interest

Professor Jan W.V. van Dijken is the author or co-author of seven of the included studies.

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REFERENCES

1. Forss H, Widstrom E. Reasons for restorative therapy and the longevity of restorations in adults. *Acta Odontologica Scandinavica* 2004;**62**:82–6.
2. Sunnegardh-Gronberg K, van Dijken JWV, Funegard U, Lindberg A, Nilsson M. Selection of dental materials and longevity of replaced restorations in Public Dental Health clinics in northern Sweden. *Journal of Dentistry* 2009;**37**:673–8.
3. Kopperud SE, Tveit AB, Gaarden T, Sandvik L, Espelid I. Longevity of posterior dental restorations and reasons for failure. *European Journal of Oral Sciences* 2012;**120**:539–48.
4. Brantley CF, Bader JD, Shugars DA, Nesbit SP. Does the cycle of rerestoration lead to larger restorations? *Journal of the American Dental Association* 1995;**126**:1407–13.
5. Elderton RJ, Nuttall NM. Variation among dentists in planning treatment. *British Dental Journal* 1983;**154**:201–6.
6. Clarkson JE, Worthington HV, Davies RM. Restorative treatment provided over five years for adults regularly attending general dental practice. *Journal of Dentistry* 2000;**28**:233–9.
7. Soncini JA, Maserejian NN, Trachtenberg F, Tavares M, Hayes C. The longevity of amalgam versus compomer/composite restorations in posterior primary and permanent teeth: findings From the New England Children's Amalgam Trial. *Journal of the American Dental Association* 2007;**138**:763–72.
8. Bernardo M, Luis H, Martin MD, Leroux BG, Rue T, Leitao J, *et al.* Survival and reasons for failure of amalgam versus composite posterior restorations placed in a randomized clinical trial. *Journal of the American Dental Association* 2007;**138**:775–83.
9. Rasines Alcaraz MGV-KA, Sharmann P, Schmidlin PR, Davis D, Iheozor-Ejiofor Z. Direct composite resin fillings versus amalgam fillings for permanent or adult posterior teeth. Review. *Cochrane Database of Systematic Reviews*)2014;(3). http://dx.doi.org/10.1002/14651858.CD005620.pub2. Art. No.: CD005620.
10. Demarco FF, Correa MB, Cenci MS, Moraes RR, Opdam NJ. Longevity of posterior composite restorations: not only a matter of materials. *Dental Materials* 2012;**28**:87–101.
11. Opdam NJ, van de Sande FH, Bronkhorst E, Cenci MS, Bottenberg P, Pallesen U, *et al.* Longevity of posterior composite restorations: a systematic review and meta-analysis. *Journal of Dental Research* 2014;**93**:943–9.
12. van Dijken JWV, Pallesen U. Fracture frequency and longevity of fractured resin composite, polyacid-modified resin composite, and resin-modified glass ionomer cement Class IV restorations: an up to 14 years of follow-up. *Clinical Oral Investigation* 2010;**14**:217–22.

13. Chadwick B, Treasure E, Dummer P, Dunstan F, Gilmour A, Jones R, *et al.* Challenges with studies investigating longevity of dental restorations – a critique of a systematic review. *Journal of Dentistry* 2001;**29**:155–61.
14. van Dijken JWV. A 6-year prospective evaluation of a one-step HEMA-free self-etching adhesive in Class II restorations. *Dental Materials* 2013;**29**:1116–22.
15. van Dijken JWV. A randomized controlled 5-year prospective study of two HEMA-free adhesives, a 1-step self etching and a 3-step etch-and-rinse, in non-carious cervical lesions. *Dental Materials* 2013;**29**:e271–80.
16. SBU. Utvärdering av metoder i hälso- och sjukvården: En metodbok: Statens beredning för medicinsk utvärdering. Stockholm, Sweden: SBU; 2013.
17. Guyatt GH, Oxman AD, Vist GE, Kunz R, Falck-Ytter Y, Alonso-Coello P, *et al.* GRADE: an emerging consensus on rating quality of evidence and strength of recommendations. *BMJ* 2008;**336**:924–6.
18. Andersson-Wenckert IE, van Dijken JW, Kieri C. Durability of extensive Class II open-sandwich restorations with a resin-modified glass ionomer cement after 6 years. *American Journal of Dentistry* 2004;**17**:43–50.
19. Demirci M, Sancakli HS. Five-year clinical evaluation of Dyract in small Class I cavities. *American Journal of Dentistry* 2006;**19**:41–6.
20. Demircia M. Clinical evaluation of a polyacid-modified resin composite (Dyract AP) in Class I cavities: 5-year results. *Journal of Adhesive Dentisty* 2007;**9**:547–53.
21. Gordan VV, Mondragon E, Watson RE, Garvan C, Mjör IA. A clinical evaluation of a self-etching primer and a giomer restorative material: results at eight years. *JADA* 2007;**138**:621–7.
22. Kiremitci A, Alpaslan T, Gurgan S. Six-year clinical evaluation of packable composite restorations. *Operative Dentistry* 2009;**34**:11–7.
23. Köhler B, Rasmusson CG, Odman P. A five-year clinical evaluation of Class II composite resin restorations. *Journal of Dentistry* 2000;**28**:111–6.
24. Lange RT, Pfeiffer P. Clinical evaluation of ceramic inlays compared to composite restorations. *Operative Dentistry* 2009;**34**:263–72.
25. Lundin SA, Koch G. Class I and II posterior composite resin restorations after 5 and 10 years. *Swedish Dental Journal* 1999;**23**:165–71.
26. Mair LH. Ten-year clinical assessment of three posterior resin composites and two amalgams. *Quintessence International* 1998;**29**:483–90.
27. Raskin A, Michotte-Theall B, Vreven J, Wilson NH. Clinical evaluation of a posterior composite 10-year report. *Journal of Dentistry* 1999;**27**:13–9.
28. Lindberg A, van Dijken JWV, Lindberg M. Nine-year evaluation of a polyacid-modified resin composite/resin composite open sandwich technique in Class II cavities. *Journal of Dentistry* 2007;**35**:124–9.
29. Manhart J, Chen HY, Hickel R. Clinical evaluation of the posterior composite Quixfil in Class I and II cavities: 4-year follow-up of a randomized controlled trial. *The Journal of Adhesive Dentistry* 2010;**12**:237–43.
30. van Dijken JWV, Sunnegardh-Gronberg K. A four-year clinical evaluation of a highly filled hybrid resin composite in posterior cavities. *The Journal of Adhesive Dentistry* 2005;**7**:343–9.
31. van Dijken JWV, Lindberg A. Clinical effectiveness of a low-shrinkage resin composite: a five-year evaluation. *The Journal of Adhesive Dentistry* 2009;**11**:143–8.
32. van Dijken JWV. Durability of resin composite restorations in high C-factor cavities: a 12-year follow-up. *Journal of Dentistry* 2010;**38**:469–74.
33. van Dijken JWV, Pallesen U. Clinical performance of a hybrid resin composite with and without an intermediate layer of flowable resin composite: a 7-year evaluation. *Dental Materials* 2011;**27**:150–6.
34. van Dijken JWV, Pallesen U. Four-year clinical evaluation of Class II nano-hybrid resin composite restorations bonded with a one-step self-etch and a two-step etch-and-rinse adhesive. *Journal of Dentistry* 2011;**39**:16–25.
35. Brunthaler A, Konig F, Lucas T, Sperr W, Schedle A. Longevity of direct resin composite restorations in posterior teeth. *Clinical Oral Investigations* 2003;**7**:63–70.
36. Heintze SD, Rousson V. Clinical effectiveness of direct Class II restorations – a meta-analysis. *The Journal of Adhesive Dentistry* 2012;**14**:407–31;
Begg C, Cho M, Eastwood S, Horton R, Moher D, Olkin I. Improving the quality of reporting of randomized controlled trials. The CONSORT statement. *JAMA* 1996;**276**:637–9.
37. van Dijken JWV, Pallesen U. A randomized controlled three year evaluation of bulk-filled posterior resin restorations based on stress decreasing resin technology. *Dental Materials* 2014;**30**:e229–37.
38. Dijken JWV, Pallesen U. Randomized 3 year clinical evaluation of Class I and Class II posterior resin restorations placed with a bulk-filled resin composite and a 1-step self-etch adhesive. *The Journal of Adhesive Dentistry* 2015;**17**:81–8.
39. Pallesen U, van Dijken JWV. A randomized controlled 30 years follow up of three conventional resin composites in Class II restorations. *Dental Materials* 2015. [submitted for publication].
40. Moher D, Schulz KF, Altman DG. The CONSORT statement: revised recommendations for improving the quality of reports of parallel-group randomised trials. *Clinical Oral Investigations* 2003;**7**:2–7.