DOI: 10.1111/ipd.12346

INTERNATIONAL JOURNAL OF PAEDIATRIC DENTISTRY

REVIEW

Restorations in primary teeth: a systematic review on survival and reasons for failures

LUIZ ALEXANDRE CHISINI[1], KAUÊ COLLARES[1], MARIANA GONZALEZ CADEMARTORI[2], LUÍSA JARDIM CORRÊA DE OLIVEIRA[3], MARCUS CRISTIAN MUNIZ CONDE[4], FLÁVIO FERNANDO DEMARCO[1] & MARCOS BRITTO CORRÊA[1]

[1]Department of Restorative Dentistry, School of Dentistry, Federal University of Pelotas, Pelotas, RS, Brazil, [2]Department of Pediatric Dentistry, School of Dentistry, Federal University of Pelotas, Pelotas, RS, Brazil, [3]School of Dentistry, Catholic University of Pelotas, Pelotas, RS, Brazil, and [4]Department of Graduate Program in Dentistry, School of Dentistry, Univates, Lajeado, RS, Brazil

International Journal of Paediatric Dentistry 2018; 28: 123–139

Background. Several restorative materials with specific indications are used for filling cavities in primary teeth.
Aim. To systematically review the literature in order to investigate the longevity of primary teeth restorations and the reasons for failure.
Design. Electronic databases were screened, and eligible studies were hand-searched to find longitudinal clinical studies evaluating the survival of restorations (class I, class II, and crown) placed with different materials in primary teeth with at least one year of follow-up.
Results. Thirty-one studies were included, and a high bias risk was observed. Overall, 12,047 restorations were evaluated with 12.5% of failure rate. A high variation on annual failure rate (AFR) was detected (0–29.9%). Composite resin showed the lowest AFRs (1.7–12.9%). Stainless steel crowns (SSC) had the highest success rate (96.1%). Class I restorations and restorations placed using rubber dam presented better AFR. The main reason for failure observed was secondary caries (36.5%).
Conclusions. An elevated number of failures were observed due to recurrent caries, highlighting the need for professionals to work with a health-promoting approach. The high variation on failure rate among the materials can be due to children's behavior during the procedure, which demands short dental appointments and a controlled environment.

Introduction

Dental caries is a highly prevalent disease that remains a worldwide public health problem affecting 2.4 billion people with permanent dentition and 621 million children with primary teeth[1]. Dental restorations, or their replacement, are the most common procedure performed by dentists[2–6]. In pediatric dentistry, there are several different options of materials to restore decayed primary teeth, including composites, glass ionomer cements, or steel crowns. Even though these materials have shown satisfactory properties, a large number of failures are still reported, mainly related to secondary caries[2,7,8].

Longevity of restorations relies on a number of factors related to clinical variables, dental materials properties, operator ability, and patients' characteristics[9,10]. Studies on permanent dentition have shown that the main clinical risk factors for failures of restorations are related to extensive cavities, endodontically treated teeth, and type of teeth. On the other hand, caries and bruxism are the principal patient-related risk factors[9–11]. A ten-year retrospective practice-based study investigated the survival of direct class II restorations, and a shorter survival for restorations placed in children was observed, especially in those with higher caries risk[12]. Therefore, individual's age can be a risk factor for lower restoration survival[13,14].

Correspondence to:
Marcos Britto Corrêa, Graduate Program in Dentistry, Federal University of Pelotas, 457, Gonçalves Chaves St. 5th floor, Pelotas 96015-560, Brazil.
E-mail: marcosbrittocorrea@hotmail.com

When dealing with pediatric patients, age and behavior are factors to be observed. A collaborative behavior is needed to carry out a restoration in a short period of time. Composite resin restorations are more technique-sensitive and time-consuming procedures and are seldom substituted by glass ionomer cements that are less technique-sensitive and can be placed in only one increment, favoring clinical management[15]. Survival time variation may also be closely related to the differences in treatment decisions by dentists[12,16], who can adopt a proactive or reactive position in relation to dental intervention[12], and this could be especially critical when attending children.

Although many clinical studies[2–5,7,11,17–24] have addressed the performance of different materials and techniques for restoration of primary teeth, there is no systematic review that summarizes the longevity of these restorations and factors associated with failures. Therefore, we aimed to systematically review the literature and investigate the longevity of posterior restorations of primary teeth using different materials. In addition, we investigated the main reasons for failure.

Materials and methods

Eligibility criteria

This systematic review is reported in accordance with PRISMA Statement guidelines[25]. Longitudinal clinical studies (prospective, retrospective, and randomized clinical trials) evaluating restorations (class I, class II, and crown) placed in primary teeth with composite, amalgam, compomer, glass ionomer cements, stainless steel crown (SSC), resin-modified glass ionomer cements (RMGIC), and metal-reinforced glass ionomer cement (MRGIC) were included. To be eligible, studies should present a follow-up of at least one year and a minimum of 40 restorations included per group. Only studies published in the period from 1996 to 2017 and written in English were considered. Reviews, letters, and studies with different outcomes from restoration survival were not included.

Outcomes

The outcome of this review was the longevity of restorations, which was defined using annual failure rate (AFR), survival rate, or success rate of restorations.

Search strategy

The search strategy followed the structure of each electronic database (SciVerse Scopus, ISIS Web of Science, Cochrane library, National Library of Medicine—MEDLINE/PubMed) and was carried out in February 2017 to answer the questions 'what is the best material for restoring decayed primary teeth?' and 'what are the main related factors associated with restorations failures?'. The PICO framework for this review was as follows:

P: Primary teeth
I: Class I or II, or crown restorations
C: Materials, techniques, and related factors associated with restoration failure
O: Longevity of restorations

The syntax of the search is detailed in the Appendix S1. The references of all eligible studies were screened and cross-referenced. In addition, the gray literature was investigated.

Study selection

Studies were uploaded into Endnote® Basic (www.myendnoteweb.com) to delete duplicates and to build a virtual library. Thus, the title and abstract of identified studies were assessed by two independent reviewers (L.A.C. and K.C.) and evaluated for eligibility criteria. Studies that met the inclusion criteria were selected for full-text reading. Articles were compared between the two reviewers and, in case of disagreement, the articles were discussed to obtain consensus. If no consensus was reached, an experienced researcher (F.F.D.) made the final decision. Papers that met the eligibility criteria were included in the study and processed for double and independent data extraction. The reasons for exclusion were justified and reported in the flowchart (Fig. 1).

Data extraction

Data extraction was performed independently by two reviewers. Disagreements were solved through discussion. The following items were collected: authors names, year of publication, aim of study, study design, clinical setting, number of operators, manufacturers research grant, country of studies, time of follow-up, number of participants and age, number of restoration at baseline and last follow-up, dental materials used, type of restorations, use of rubber dam, evaluation criteria, factors associated with failure, reasons for failures, and participant risk factors. Longevity outcomes (survival rate, success rate, and AFR) were also collected.

Bias risk

The bias risk of included studies was assessed using the Cochrane risk of bias tool based on random sequence generation, allocation concealment, blinding of participants and personnel, blinding of outcome assessment, incomplete outcome data, selective reporting, and other sources of bias[26].

Data analysis

Included studies had a high heterogeneity regarding study design, evaluation criteria, and longevity outcomes, contraindicating meta-analysis. Hence, a qualitative analysis was conducted on collected data.

For qualitative analysis, the survival or the success rate was used to compare the included studies. Besides, we also analyzed the results using the AFR. When AFR was not reported, it was calculated according to the formula: $(1-y)^z = (1-x)$, in which 'y' is the mean AFR and 'x' the total failure rate at 'z' years[14].

Results

The flow diagram of the systematic review is shown in Fig. 1. From the initial 776 studies identified after removal of duplicates, 80 full-text articles were assessed for eligibility criteria and 31 studies were included in the qualitative analysis. Excluded studies and reasons for exclusion are displayed in the Appendix S2. The included studies evaluated the clinical performance of class I, class II, and/or crown restorations due to caries with seven different materials: amalgam (six studies), compomer (nine studies), composite (six studies), conventional GIC (five studies), MRGIC (four studies),

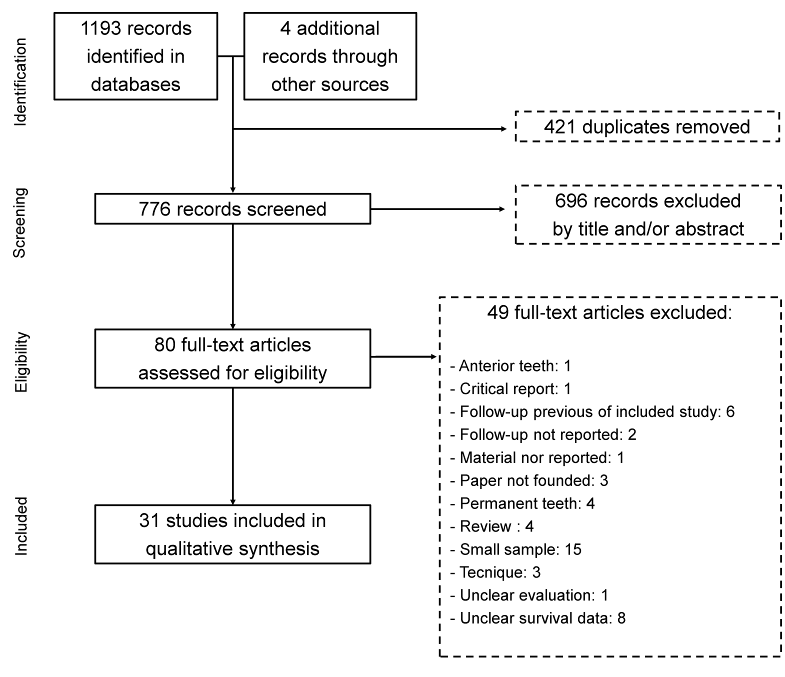

Fig. 1. Flow diagram of the systematic review.

RMGIC (10 studies), and SSC (three studies). The data of the eleven studies that evaluated more than one group of restorative materials were included separately. The follow-up of studies ranged from one to four years, and 12,047 restorations were evaluated.

Overall

Table 1 shows all studies included in the systematic review and the collected variables. Included studies were published between 1996 and 2016, and the follow-up times varied from 1 to 4 years. Most studies were carried out prospectively (83.9%), in European countries (61.3%), with multiple operators doing the restorations (54.8%), and in dental school settings (45.2%). Most of the included studies were randomized clinical trials comparing different restorative materials or techniques, using split-mouth or parallel groups as a design. The number of restorations in the last follow-up varied from 40 to 1834 among studies, with most studies including <100 restorations. Almost 50% of the studies were restricted to the evaluation of class II restorations, and 36% reported that restorations were carried out exclusively using rubber dam. A modified version of the United States Public Health Service (USPHS) criteria[27] was the most often used method to evaluate restorations; eight studies used their own criteria, and two recently published studies used the FDI criteria[28].

Risk factors

Risk factors for failures were assessed in 10 studies, and from those, six found some association between the aspects investigated and failed restorations. The risk factors reported on these studies were as follows: operator[29,30], cavity preparation[2,29], use of rubber dam[29], age[29], adhesive system[29], material[3,5,22], incomplete caries excavation[2], and endodontically treated teeth[5]. Few studies included high caries risk patients[18,31–33].

Survival data of restorative materials

Table 2 shows the results of restoration survival (success rate and AFR) according to restorative material, use of rubber dam, and type of cavity. Considering all included studies, a high variation on AFR was observed, varying from zero to 29.9%. In general, composite resin showed the lowest AFRs (1.7–12.9%) and MRGIC exhibited the highest AFRs (10.0–29.9%). Class I restorations and restorations placed with rubber dam tend to present better results on AFR.

The observed global failure rate was 12.5% (1507 restorations), without taking into consideration the follow-up times (Table 2). SSC was the material with the highest success rate (96.1%) followed by RMGIC (93.6%) and compomer (91.2%), whereas the MRGIC showed the lowest success rate (57.4%). In addition, independently of the material, restorations placed under use of rubber dam showed a greater success rate (93.6%) than those placed without it (77.5%), and class I restorations failed less (7.6%) than class II (14.7%).

Reasons for failure

Table 3 presents the reasons for failure of restorations on primary teeth reported in the included studies. Nine studies did not report specific reasons for failure[5,17,18,21,31,34–37]; thus, they were not included in Table 3. One study did not report the reasons for failure for MRGIC, and this material was excluded from the table[4]. The main reason for failure observed was secondary caries; 86% of studies detected at least one failure caused by caries, varying for 4–100%. Besides, considering all reported reasons for failure, 36.5% occurred due to caries followed by restoration loss (19.6%) and marginal adaptation (15.6%).

Risk of bias assessment

Appendix S3 presents the proportion of studies with low, unclear, or high risk of bias for each item. In general, the included studies presented high bias risk, mainly selection, performance, and detection biases. The item 'Incomplete outcome data' was judged as a low risk of bias in 50% of studies and was the aspect with the lowest bias. The authors' classification for bias risk of each included study is shown in a Appendix S3.

Table 1. Longitudinal clinical studies with at least one year of follow-up evaluating restorations on primary teeth: the systematic review results.

Author, year	Aim[1] Study design Clinical setting (No of operator) Manufacturers financial (yes or no) Country	Follow-up (years)[2]	Included participants [age (years)]	Restoration at baseline/last follow-up	Material (Brand)	Evaluated restoration (use of rubber dam)	Evaluation criteria	Cumulative survival rate* or success rate†/AFR[3]	Factors associated with failure
Abo-Hamar, *et al.*[61], 2015	Nanofilled RMGIC *vs* Conventional RMGIC Split-mouth RCT University (1) No Egypt	2	29 (5–8)	60/60	RMGIC (Ketac Nano/Vitremer)	Class I (Yes)	Modified USPHS	95%/2.5%†	
Andersson-Wenckert, *et al.*[6], 1995	Design cavity effect on longevity Multicentered NRCT (PBR) Public dental health service (2) No Sweden	1‡	25 (6–10)	56/48	GIC (ChemFill II)	Class II (No)	Modified USPHS	93.8%/6.2%†	
Andersson-Wenckert, *et al.*[62], 1997	Clinical performance of Compomer Multicentered NRCT (PBR) Public dental health service (6) No Sweden	2	79 (5–12)	159/148	Compomer (Dyract)	Class II (No)	Modified USPHS	78%/11.7%*	
Attin, *et al.*[7], 2001	Compomer *vs* Composite Parallel group RCT Private practice (3) § Germany	3	52 (3–10)	96/46 94/46	Compomer (Compoglass) Composite (TPH spectrum)	Class II (No)	Ryge	79.5%/7.4% Compomer* 85.8%/5.0% Composite*	
Buecher, *et al.*[29], 2015	Clinical performance of Composite Secondary data University (8) No Germany	2	667 (1–13)	1834/1834	Composite (§)	416 Class I 1418 Class II (Yes and No)	FDI	79.0%/11.1% Class I† 75.0%/13.4% Class II†	Age Cavity operator Use of rubber dam adhesive system
Croll, *et al.*[33], 2001	Clinical performance of RMGIC Secondary data Private practice (1) § USA	Mean 4.2	306 (NR)	799/799	RMGIC (Vitremer)	393 Class I 406 Class II (§)	Modified USPHS	92.6% Class I/1.8%† 93.3% Class II/1.6%†	

(Continued)

Table 1 (Contd.)

Author, year	Aim[1] Study design Clinical setting (No of operator) Manufacturers financial (yes or no) Country	Follow-up (years)[2]	Included participants [age (years)]	Restoration at baseline/ last follow-up	Material (Brand)	Evaluated restoration (use of rubber dam)	Evaluation criteria	Cumulative survival rate* or success rate† /AFR[3]	Factors associated with failure
de Amorim, *et al.*[59], 2014	Amalgam *vs* ART¶ Parallel group NRCT Primary schools (3) Yes Brazil	2	284 (mean 6.8)	364/258	Amalgam (§)	Class I Class II (No)	Own	77.3%/12.1%*	
Duggal, *et al.*[34], 2002	Amalgam *vs* compomer Split-mouth RCT Private practice and University (§) No England	2	60 (4–7)	78/60 78/60	Amalgam (Contour) Compomer (Dyract)	Class II (No)	Modified USPHS	66.6%/18.4% Amalgam† 71.6/15.4% Compomer†	
Dutta, *et al.*[17], 2002	Amalgam *vs* RMGIC Parallel group RCT § (1) § India	1	120 (4–9)	120/100 360/290	Amalgam (Solila) RMGIC (Fuji II LC)	Class II (No)	Modified USPHS	72.0%/28.0% Amalgam* 83.1%/16.9% RMGIC*	
Espelid, *et al.*[22], 1999	MRGIC *vs* RMGIC Split-mouth RCT § (§) § Norway	3	43 (5.5–11)	49/49 49/49	RMGIC (Vitremer) MRGIC (Ketac-silver)	Class II (§)	Modified USPHS	73.0/10.0% MRGIC† 97.0/1.0% RMGIC†	
Folkesson, *et al.*[63], 1999	Clinical performance of RMGIC Multicentered (PBR) Public dental health service (6) No Sweden	3	85 (4–12)	174/174	RMGIC (Vitremer)	Class II (No)	Modified USPHS	80.2%/7.1%*	
Franzon, *et al.*[2], 2015	Total caries removal (TCR) *vs* Partial caries removal (PCR)†† Parallel group RCT University (3) § Brazil	2	48 (3–8)	54/39 TCR 66/65 PCR	Composite (Filtek Z350)	Class I Class II (Yes)	Modified USPHS	86%/7.3% TCR* 66%/18.8% PCR*	Incomplete excavation Occlusoproximal restoration

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Table 1 (Contd.)

Author, year	Aim[1] Study design Clinical setting (No of operator) Manufacturers financial (yes or no) Country	Follow-up (years)[2]	Included participants [age (years)]	Restoration at baseline/ last follow-up	Material (Brand)	Evaluated restoration (use of rubber dam)	Evaluation criteria	Cumulative survival rate* or success rate† /AFR[3]	Factors associated with failure
Gross, *et al.*[60], 2001	Clinical performance of Compomer Split-mouth RCT § (2) Yes USA	2	49 (5–8)	86/58	Compomer (Hytac/Dyract)	Class II (Yes)	Own	89.7%/5.3%†	
Holst[32], 1996	Clinical performance of MRGIC NRCT Private practice (1) No Sweden	3	48 (4–7)	172/119	MRGIC (Ketac-silver)	Class I Class II (§)	Modified USPHS	46%/22.8%†,**	
Hubel and Mejare[3], 2003	Conventional GIC *vs* RMGIC Split-mouth RCT University (1) No Sweden	3	40 (4–7)	62/61 53/53	GIC (Fuji II)RMGIC (Vitremer)	Class II (No)	Modified USPHS	81%/6.8% GIC* 94%/2.0% RMGIC*	
Kavvadia, *et al.*[4], 2004	Amalgam *vs* Compomer Split-mouth RCT Private practice (2) Yes Greece	2	75 (6–9)	75/57 75/57	Amalgam (Dispersalloy) Compomer (F2000)	Class II (Yes)	Ryge	98%/1.0% Amalgam† 98%/1.0% Compomer†	
Kilpatrick, *et al.*[21], 1995	Conventional GIC *vs* MRGIC Split-mouth NRCT § (1) No England	Mean 1.5	37 (4–10)	46/46 46/46	GIC (Ketac Fill) MRGIC (Ketac-silver)	Class II (§)	Modified USPHS	76.1%/16.6% GIC† 58.7%/29.9% MRGIC†	
Kitty and Wei[20], 1997	Compomer *vs* Composite Split-mouth RCT University (1) No Hong Kong	1	36 (4–7)	59/59 59/59	Compomer (Dyract) Composite (Prisma TPH)	76 Class I 42 Class II (Yes)	Ryge	98.3%/1.7% Compomer† 98.3%/1.7% Composite†	
Kotsanos and Arizos[23], 2011	Clinical performance of RMGIC‡‡ Parallel group NRCT Private practice (1) § Greece	Mean 2.7	58 (3.5–8.5)	86/86	RMGIC (Vitremer)	Class II (Yes)	Modified USPHS	88.4%/4.5%†	

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Table 1 (Contd.)

Author, year	Aim[1] Study design Clinical setting (No of operator) Manufacturers financial (yes or no) Country	Follow-up (years)[2]	Included participants [age (years)]	Restoration at baseline/ last follow-up	Material (Brand)	Evaluated restoration (use of rubber dam)	Evaluation criteria	Cumulative survival rate* or success rate† /AFR[3]	Factors associated with failure
Kramer and Frankenberger[24], 2001	Clinical performance of MRGIC NRCT University (1) § Germany	2	17 (3–11)	42/42	MRGIC (Hi-dense)	Class I Class II (§)	Modified USPHS	92.0%/4.1% Class I* 66.0%/18.8% Class II*	
Leith and O'Connell[31], 2011	Clinical performance of SSC Split-mouth RCT University (2) § Ireland	1	18 (2–9)	48/48	SSC (NuSmile Kinder Krown)	SSC (Yes)	Own	81%/19.0%†	
Papagiannoulis, *et al.*[8], 1999	Clinical performance of Compomer NRCT Private practice (2) § Greece	2	25 (6–9)	68/55	Compomer (Dyract)	Class II (Yes)	Ryge	90%/5.1%†	
Peters, *et al.*[37], 1996	Clinical performance of Compomer NRCT Private practice and University (3) § The Netherlands	1	55 (4–9)	91/86	Compomer (Dyract)	11 Class I80 Class II (No)	Ryge	96.5%/3.5%†	
Pinto, *et al.*[5], 2014	Clinical performance of Composite, RMGIC, and GIC Secondary data University (§) No Brazil	Up to 4	329 (mean 8.4)	129/129 354/354 175/175	Composite (§) GIC (§) RMGIC (§)	Class I Class II (Yes and No)	Own	NR/9.5% Composite NR/12.9% GIC NR/12.2% RMGIC	Material Pulp intervention
Roberts, *et al.*[19], 2005	MRGIC *vs* SSC Secondary data (PBR) Private practice (1) § England	Mean 2.1 Class I 1.7 Class II 2.1 SSC	NR (NR)	1506/1506 1010/1010	RMGIC (Photac Fill)	544 Class I 962 Class II 1010 SSC (Yes and No)	Own	98.3%/0.8% Class I† 97.3%/1.6% Class II† 97.0%/ 1.4% SSC†	
Rutar, *et al.*[36], 2002	Clinical performance of GIC NRCT University (1) No Australia	1‡	69 (NR)	129/129	GIC (Fuji IX GP)	48 Single Surface 65 Multiple Surface (§)	Modified USPHS	100% Single surface/0.0%† 98.6% Multiple surface/1.4%†	

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Table 1 (Contd.)

Author, year	Aim[1] Study design Clinical setting (No of operator) Manufacturers financial (yes or no) Country	Follow-up (years)[2]	Included participants [age (years)]	Restoration at baseline/ last follow-up	Material (Brand)	Evaluated restoration (use of rubber dam)	Evaluation criteria	Cumulative survival rate* or success rate† /AFR[3]	Factors associated with failure
Schueler, *et al.*[42], 2014	Clinical performance of SSC NRCT § (1) No Germany	3	171 (1.1–8.6)	56/56	SSC (3M ESPE)	SSC (§)	Own	89.3%/3.7%†	
Sengul and Gurbuz[18], 2015	Clinical performance of Composite, RMGIC, compomer, and giomer§§ Parallel group RCT University (1) § Turkey	2	41 (5–7)	40/40	Composite (Valux Plus)	Class II (Yes)	FDI	77.5%/12.0%†	
Soncini, *et al.*[11], 2007	Amalgam *vs* compomer Multicentered parallel group RCT Private practice, public dental health service, and university (6) No England and USA	2.8	461 (6–10)	954/954 1088/1088	Amalgam (Dispersalloy) Compomer (Dyract)	Small, Medium or Large restoration (Yes)	Own	96%/1.4% Amalgam† 94.2%/2.1% Compomer†	
Taifour, *et al.*[30], 2002	Amalgam *vs* ART¶ Parallel group NRCT Primary schools (8) Yes Syria	3	253 (6–7)	805/§	Amalgam (Avalloy)	380 Single Surface 425 Multiple Surface (No)	Frencken *et al.*, 1996 (REF)	79.6% Single surface/7.3%* 42.9% Multiple surface/24.6%*	Operator
Webman, *et al.*[35], 2016	Clinical performance of RMGIC NRCT Private practice (1) No USA	3	NR (2.7–11)	427/427	RMGIC (Vitremer)	Class II (Yes)	Own	97.4%/0.9%†	

*Cumulative survival rate.
†Success rate.
‡The total follow-up was 3 years but it was included only 1 year of observation due sample size.
§Data not informed in the study.
¶ART group was not included.
**Exfoliated and extracted teeth were excluded.
††Clinical longevity of composite restoration as outcome.
‡‡Clinical performance of RMGIC as indirect pulp therapy and as restorative material.
§§Only composite groups were included.

Table 2. Annual failure rates, success rate, and total of restorations evaluated from included studies distributed by materials, use of rubber dam, and type of cavity.

	AFR(%) Follow-up time				Overall AFR (%)/No of studies	Total restorations evaluated	Total failures	Total success rate (%)
	1 year	2 years	3 years	4 years				
Material								
Amalgam	28.0 (dutta - high caries)	1.0–12.10–18.4	1.40–16.3		1.00–28.0%/6	2360	425	82.0
Composite	1.7	7.30–12.00–12.9	5.0	9.5	1.70–12.9%/6	2266	470	79.3
Conventional GIC	0.80–6.2	16.6	6.8	12.9	0.80–16.6%/5	639	72	88.7
Compomer	1.70–3.5	1.00–5.10–5.30–11.70–15.4	2.10–7.4		1.70–15.4%/9	1723	152	91.2
RMGIC	16.9	1.30–2.5	0.90–1.00–2.00–4.50–7.1	1.70–12.2	0.90–16.9%/10	3689	235	93.6
MRGIC		11.50–29.9	10.00–22.8		10.00–29.9%/4	256	109	57.4
SSC	19.0	1.4	3.7		1.40–19.0%/3	1114	44	96.1
Use of rubber dam								
No	3.50–6.20–16.90–28.0	11.70–12.10–15.40–18.4	2.00–5.00–6.80–7.10–7.40–16.4		2.00–28.0%/14	2498	562	77.5
Yes	1.70–1.70–19.0	1.00–1.00–2.50–5.10–5.30–7.30–12.0	0.90–1.40–2.10–4.5		0.90–19.0%/14	3158	202	93.6
Not differentiated or not reported	0.8	1.30–1.40–11.50–12.90–16.60–29.9	1.00–3.70–10.00–22.8	1.70–9.50–12.20–12.9	0.80–29.9%/15	6391	742	88.4
Cavity								
Class I	0.0	0.80–0–2.50–4.10–11.1	7.3	1.8	0.00–11.1/7	1377	105	92.4
Class II	1.40–6.20–16.90–28.9	1.00–1.00–1.60–5.10–5.30–11.70–12.00–13.40–15.40–16.60–18.40–18.80–29.9	0.90–1.00–2.00–4.50–5.00–6.80–7.10–7.40–10.00–24.6	1.6	0.90–29.9/28	4049	595	85.3
Class I and Class II	1.70–1.70–3.50–19.0	1.40–7.30–12.1	1.40–2.10–3.70–22.8	9.50–12.20–12.9	1.40–22.8/14	6627	807	87.8

Discussion

Restorations placed in primary teeth due to dental caries are the most common procedures in pediatric dentistry presenting a wide range of materials and techniques[2–5]. Several reviews have evaluated the survival of restorations in permanent teeth[9,14,38–41]. This is, however, the first study to systematically review the literature evaluating the longevity of several restorative materials and techniques in children and addressing the main reasons for failure. From the 31 papers included in the review, evaluating 12,047 posterior restorations in primary teeth, a 12.5% rate of failed restorations was observed, mainly due to secondary caries (36.5%). Moreover, it was possible to identify a decrease in the AFRs of restorations performed without rubber dam and in restorations with more than one tooth surface involved.

Concerning the survival of dental materials, we found a wide variation in AFR among the included studies. SSC was the material that presented the highest success rate without presenting secondary caries as reason for failure; however, only three studies with high bias risk evaluated the performance of this material[19,31,42]. The reasons for failure when using SSC were tooth fracture, restoration loss, and endodontic complication. Roberts and Attari *et al.*[19] assessed SSC failure as 'true' and 'false' failures. Crown loss following cement failure or perforation of the occlusal surface as a result of wear was considered true failures, and failures related to endodontic treatment were considered false failures. It is important to highlight that cases in which interventions on the tooth did not lead to replacement or removal of the crown (endodontic treatment or dislodgement of the crown), the status at the end of the observation time was considered as 'survived'[43]. Therefore, an overestimation of failures in the other materials compared to SSC might have occurred, as endodontic complication or fractured tooth was classified as a failure. In addition, the occurrence of failures due to caries in teeth with SSC was not reported, which contributed to the lower AFRs observed for SSC, despite the fact that one study showed a 19% AFR mainly due to small fractures of occlusal and buccal surfaces[31]. Although our results corroborate previous studies that SSCs are the most reliable and durable restorative material for primary molars,[19,31,44–46] this technique should be indicated carefully. Tooth preparation for SSCs in several class II cases requires the removal of high amount of sound tissue, and, therefore, alternative materials and techniques should be considered[19].

Resin-modified glass ionomer cements and compomer also presented good performance with more than 90% of success rate. A wide variation, however, in performances was observed between the studies. In most studies that compared RMGIC with other materials, favorable results for RMGIC were observed[3,4,11,17,20,22,34], although some studies showed different results[5,7,21]. Hubel and Mejare[3] showed a cumulative survival rate of 94% for RMGIC (*Vitremer*) compared to 81% of GIC (Fuji II). In the other hand, MRGIC showed lower performance, with AFR ranging from 10% to 29.9%[21,22,32].

Although composite resin has been the main choice of material for direct restorations of permanent teeth, presenting AFR ranging from 1% to 3%[9,14,47], this study found a different clinical behavior in primary teeth. The overall success rate for composite resin was 79.3%, and the AFR ranged from 1.7% to 12.9%. In pediatric dentistry, patient-related factors can play an important role when considering behavior management. Thus, restoration performance can vary among patients, due to different conditions affecting the execution of the technique[48,49]. Composite resin success is highly sensitive to the technique. The performance of composite resins is completely affected by presence of water or saliva. Therefore, in noncooperative children, and in cases where moisture control is critical, the correct restoration can be jeopardized and a low performance can be expected. This can explain the significant 'loss of restorations' observed in the included studies considering all materials. Therefore, in some studies, a better performance was observed for RMGIC, compomer, and GIC (in contrast to composite resin) due to the easier and faster application technique of these materials. Importantly,

Table 3. Reasons for failures by included studies and by patient caries risk.

Author, year	Patient Risk	Material	Failures (n)	Reasons for failure: Fracture teeth	Fracture restoration	Caries	Endodontic complication	Restoration lost	Marginal adaptation	Aesthetic	Unknown reason
Abo-Hamar, *et al.*[61], 2015	NS	RMGIC	3	–	–	3 (100%)	–	–	–	–	–
Andersson-Wenckert, *et al.*[6], 1995	NS	GIC	3	1 (33.4%)	–	1 (33.3%)	–	1 (33.3%)	–	–	–
Andersson-Wenckert, *et al.*[62], 1997	NS	Compomer	32	2 (6.3%)	–	14 (43.8%)	–	12 (37.5%)	3 (9.4%)	–	1 (3.1%)
Attin, *et al.*[7], 2001	NS	Compomer	14	1 (7.1%)	–	13 (92.9%)	–	–	–	–	–
		Composite	10	–	–	10 (100%)	–	–	–	–	–
Buecher, *et al.*[29], 2015	NS	Composite	410	–	–	212 (51.7%)	–	–	–	–	196 (47.8%)
Croll, *et al.*[33], 2001	Were include high and low caries	RMGIC (Class I)	29	–	–	–	–	–	29 (100%)	–	–
		RMGIC (Class II)	28	–	–	1 (3.6%)	–	–	27 (96.4%)	–	–
de Amorim, *et al.*[59], 2014	NS	Amalgam	67	3 (4.5%)	2 (2.9%)	24 (35.8%)	–	23 (34.4%)	15 (22.4%)	–	–
Espelid, *et al.*[22], 1999	NS	MRGIC	18	–	–	6 (33.4%)	–	–	12 (66.6%)	–	–
		RMGIC	1	–	–	1 (100%)	–	–	–	–	–
Folkesson, *et al.*[63], 1999	NS	RMGIC	26	4 (15.4%)	–	11 (42.3%)	–	8 (30.8%)	3 (11.5%)	–	–
Franzon, *et al.*[2], 2015	NS	TCR + Composite	8	–	–	7 (87.5%)	–	–	1 (12.5%)	–	–
		PCR + Composite	20	–	–	12 (60%)	–	5 (25%)	3 (15%)	–	–
Gross, *et al.*[60], 2001	NS	Compomer	6	1 (16.7%)	–	4 (66.7%)	–	–	1 (16.7%)	–	–
Holst[32], 1996	Caries risk	MRGIC	64	–	–	10 (15.6%)	–	32 (50%)	12 (18.8%)	10 (15.6%)	–
Hubel and Mejare[3], 2003	NS	RMGIC	2	1 (50%)	–	–	–	1 (50%)	–	–	–
		GIC	11	1 (9.1%)	–	4 (36.4%)	–	6 (54.5%)	–	–	–
Kavvadia, *et al.*[4], 2004	Low risk	Compomer	1	–	–	1 (100%)	–	–	–	–	–
		Amalgam	1	–	–	–	–	1 (100%)	–	–	–
Kitty and Wei[20], 1997	NS	Compomer	1	–	–	–	–	1 (100%)	–	–	–
		Composite	1	–	–	–	–	1 (100%)	–	–	–
Kotsanos and Arizos[23], 2011	NS	RMGIC	18	5 (27.8%)	–	1 (5.6%)	3 (16.7%)	–	1 (5.6%)	8 (44.5)	–
Kramer and Frankenberger[24], 2001	NS	MRGIC	8	–	–	–	1 (12.5%)	5 (62.5%)	–	–	2 (25%)
Papagiannoulis, *et al.*[8], 1999	Low risk	Compomer	15	5 (33.3)	–	10 (66.6)	–	–	–	–	–
Roberts, *et al.*[19], 2005	NS	RMGIC (Class I)	9	–	–	4 (44.4%)	–	–	5 (65.6)	–	–
		RMGIC (Class II)	26	2 (7.7%)	–	12 (46.2%)	1 (3.8%)	–	11 (42.3)	–	–
		SSC	30	21 (70%)	–	–	–	9 (30%)	–	–	–

(Continued)

Table 3 (Contd.)

Author, year	Patient Risk	Material	Failures (n)	Reasons for failure: Fracture teeth	Fracture restoration	Caries	Endodontic complication	Restoration lost	Marginal adaptation	Aesthetic	Unknown reason
Schueler, *et al.*[42], 2014	Caries risk evaluate by dmft	SSC	6	–	–	–	3 (50%)	3 (50%)	–	–	–
Soncini, *et al.*[11], 2007	NS	Amalgam	38	4 (11%)	–	23 (60%)	–	10 (26%)	–	–	1 (3%)
		Compomer	63	7 (11%)	–	46 (73%)	–	8 (13%)	–	–	2 (3%)
Taifour, *et al.*[30], 2002	NS	Amalgam (Single surface)	64	4 (6.3%)	7 (10.9%)	9 (14.1%)	–	24 (37.5%)	12 (18.8%)	–	8 (12.5%)
		Amalgam (Multiple surface)	201	5 (2.5%)	27 (13.4%)	11 (5.5%)	–	92 (45.8%)	58 (28.9%)		8 (4%)
Total			1234	67 (5.4%)	36 (2.9%)	450 (36.5%)	8 (0.6%)	242 (19.6%)	193 (15.6%)	18 (1.5%)	218 (17.7%)

Not specified: NS; studies did not specify failures reasons: Duggal, *et al.*[34]; Dutta, *et al.*[17]; Webman, *et al.*[35]; Sengul and Gurbuz[18]; Rutar, *et al.*[36]; Pinto, *et al.*[5]; Leith and O'Connell[31, 37]; Kilpatrick, *et al.*[21].

such materials can remain biologically suitable until the natural exfoliation of the tooth, which is usually a short period of time in relation to the permanent teeth restorations.

The use of rubber dam for placing composite and amalgam restorations (class I and class II) has increased the longevity of restorations after 10 years of follow-up[39]. A recent Cochrane review has found that the use of rubber dam can lead to a decrease in restoration failure in relation to use of cotton rolls[50]. In agreement with such results observed in permanent teeth, our findings show a substantial decrease in failures when the restorations were performed with rubber dam isolation. The rubber dam provides a dry operatory field, preventing saliva contamination that can impair adhesive properties, while allowing a better view of the field. Due to the young age of pediatric patients associated with difficulties with behavior management, it is sometimes impossible to properly isolate teeth to perform composite restorations, however[33]. In such situations, GIC, RMGIC, and compomer are alternatives[33,51] because they are less sensitive to humidity.

Some authors have suggested that the fluoride released from GIC materials can prevent caries[52,53], as GIC can reduce the demineralization of adjacent surfaces[54–56]. Despite *in vitro* and *in situ* studies demonstrating the capacity of these materials to release fluoride and prevent demineralization, there is no strong clinical evidence showing that fluoride-releasing materials prevent the occurrence of secondary caries[54]. Only the use of dentifrices combined with toothbrushing presented strong evidence in the caries reduction[57]. In our review, secondary caries was the main reason for failures for composite or for glass ionomer materials, suggesting that the release of fluoride by GIC did not affect the longevity of restorations.

The individual caries risk has been demonstrated to affect the longevity of restorations in permanent teeth. This could be even more challenging in pediatric patients, when oral health habits and behaviors are being established. Poor oral hygiene and increased sugar intake are frequent in high caries risk pediatric patients and can contribute to caries development. As secondary caries or caries adjacent to restorations are subjected to the same factors as primary caries, the difficulty of the dentist or of the patients and their families to change behaviors could contribute to the early failure of restorations in pediatric dentistry. This highlights the need for professionals to work with a health-promoting approach, which should improve treatment longevity[58]. Considering that in the majority of studies patients presented a minimum of two decayed posterior teeth (split-mouth design to compare the materials), we can hypothesize that most patients had a significant caries risk, once they presented active caries disease. This can explain the elevated number of failures observed due to recurrent carries, with 86% of studies reporting at least one failure due to this reason.

The different evaluation criteria adopted in the studies was one of the factors contributing for the heterogeneity of AFR. Although some studies adopted their own criteria[31,59,60], considering failure as the need of a new intervention (loss of restoration, pulp necrosis, or extraction)[5], other studies used more rigorous criteria, such as the FDI[18] or modified USPHS[21,34,61–63], influencing the results. The cutoff point for determining whether the restorations should be maintained, repaired, or replaced varies in different evaluation methods, and this could impact the longevity observed across studies[58].

The current literature discusses the possibility of treatments that require smaller interventions such as the maintenance of opened cavities without restorations[64], the atraumatic restorative treatment (ART)[65], or the Hall technique[66]. Such options, however, were not included in our systematic review because our aim was to investigate the survival of restorative materials in conventionally prepared cavities. It is important to highlight that the calculation of total success rate was used to summarize data, without considering the follow-up time, which is a strong limitation of these results. This is reinforced by the wide range of AFR among studies, which considered time in their calculation. Thus, the results of total success rate should be carefully interpreted.

Randomized clinical trials (RCTs) are the best study design for comparing different treatment alternatives. Nevertheless, due to the high cost to conduct these studies and the difficulty to recruit and follow the patients with similar characteristics, few studies with appropriate methodological approach and adequate sample size are available in the literature. Thus, a systematic review including only randomized and controlled trials would include few studies (limiting the number of evaluated restorations). In addition, when including only RCTs another bias can occur, based on patient selection. Usually, only patients with low caries risk are included in RCTs. Therefore, we have included also prospective and retrospective clinical trials carried out in settings closer to clinical reality. With such strategy, an expressive number of restorations (12,047) were available for analysis, even though the risk of bias for the included studies was high. Another important limitation of our study was the data analysis, which in general was a single-level analysis (restoration). A better analytical approach would be a multilevel analysis, taking into account the fact that all the restorations in a patient share the same risks, leading to misinterpretations of data.

Considering the results of this systematic review, we conclude that there is a large variation in longevity of posterior restorations in primary teeth. Composite resin exhibited the lowest AFRs, whereas MRGIC exhibited the highest. SSC had the highest success rare. Higher success rates were observed in restorations of a single tooth surface and those performed with rubber dam isolation. Secondary caries was the main reason for failure.

Why this paper is important to paediatric dentists

- Composite resin showed the lowest AFRs (1.7–12.9%) and stainless steel crown were the material with the highest success rate (96.1%).
- Class I restorations and restorations placed using a rubber dam presented better results on AFR; the main reason for failure was secondary caries (36.5%).
- A large number of failures were due to recurrent caries, highlighting the need for professionals to take a health-promoting approach in their daily work. The high variation among the materials can be due to children's behavior, which affects the quality of the procedure as it demands a short appointment and a controlled environment.

Author contributions

L.A.C., K.C., and M.C.G conceived the ideas, analyzed the data, collected the data, and wrote the manuscript. L.J.C.O. and M.C.M.C. conceived the ideas and analyzed the data. F.F.D. and M.B.C conceived the idea, analyzed the data, and reviews the manuscript.

Conflict of interest

The rest of the authors declare no conflict of interests.

References

1 Kassebaum NJ, Bernabe E, Dahiya M, Bhandari B, Murray CJ, Marcenes W. Global burden of untreated caries: a systematic review and metaregression. *J Dent Res* 2015; **94**: 650–658.

2 Franzon R, Opdam NJ, Guimarães LF *et al.* Randomized controlled clinical trial of the 24-months survival of composite resin restorations after one-step incomplete and complete excavation on primary teeth. *J Dent* 2015; **43**: 1235–1241.

3 Hubel S, Mejare I. Conventional versus resin-modified glass-ionomer cement for Class II restorations in primary molars. A 3-year clinical study. *Int J Paediatr Dent* 2003; **13**: 2–8.

4 Kavvadia K, Kakaboura A, Vanderas AP, Papagiannoulis L. Clinical evaluation of a compomer and an amalgam primary teeth class II restorations: a 2-year comparative study. *Pediatr Dent* 2004; **26**: 245–250.

5 Pinto GDS, Oliveira LJC, Romano AR *et al.* Longevity of posterior restorations in primary teeth: results from a paediatric dental clinic. *J Dent* 2014; **42**: 1248–1254.

6 Andersson-Wenckert IE, van Dijken JW, Stenberg R. Effect of cavity form on the durability of glass ionomer cement restorations in primary teeth: a three-year clinical evaluation. *ASDC J Dent Child* 1995; **62**: 197–200.

7 Attin T, Opatowski A, Meyer C, Zingg-Meyer B, Buchalla W, Monting JS. Three-year follow up assessment of Class II restorations in primary molars with a polyacid-modified composite resin and a hybrid composite. *Am J Dent* 2001; **14**: 148–152.

8 Papagiannoulis L, Kakaboura A, Pantaleon F, Kavvadia K. Clinical evaluation of a polyacid-modified resin composite (compomer) in Class II restorations of primary teeth: a two-year follow-up study. *Pediatr Dent* 1999; **21**: 231–234.

9 Demarco FF, Correa MB, Cenci MS, Moraes RR, Opdam NJ. Longevity of posterior composite restorations: not only a matter of materials. *Dent Mater* 2012; **28**: 87–101.

10 van de Sande FH, Collares K, Correa MB, Cenci MS, Demarco FF, Opdam N. Restoration survival: revisiting patients' risk factors through a systematic literature review. *Oper Dent* 2016; **41**: S7–S26.

11 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. *J Am Dent Assoc* 2007; **138**: 763–772.

12 Laske M, Opdam NJ, Bronkhorst EM, Braspenning JC, Huysmans MC. Longevity of direct restorations in Dutch dental practices. Descriptive study out of a practice based research network. *J Dent* 2016; **46**: 12–17.

13 van de Sande FH, Opdam NJ, Rodolpho PA, Correa MB, Demarco FF, Cenci MS. Patient risk factors' influence on survival of posterior composites. *J Dent Res* 2013; **92**: 78S–83S.

14 Opdam NJ, van de Sande FH, Bronkhorst E *et al.* Longevity of posterior composite restorations: a systematic review and meta-analysis. *J Dent Res* 2014; **93**: 943–949.

15 Casagrande L, Dalpian DM, Ardenghi TM *et al.* Randomized clinical trial of adhesive restorations in primary molars. 18-month results. *Am J Dent* 2014; **26**: 351–355.

16 Kopperud SE, Tveit AB, Opdam NJ, Espelid I. Occlusal caries management: preferences among dentists in Norway. *Caries Res* 2016; **50**: 40–47.

17 Dutta BN, Gauba K, Tewari A, Chawla HS. Silver amalgam versus resin modified GIC class-II restorations in primary molars: twelve month clinical evaluation. *J Indian Soc Pedod Prev Dent* 2002; **19**: 118–122.

18 Sengul F, Gurbuz T. Clinical evaluation of restorative materials in primary teeth class II lesions. *J Clin Pediatr Dent* 2015; **39**: 315–321.

19 Roberts JF, Attari N, Sherriff M. The survival of resin modified glass ionomer and stainless steel crown restorations in primary molars, placed in a specialist paediatric dental practice. *Br Dent J* 2005; **198**: 427–431.

20 Kitty MY, Wei SHY. Clinical evaluation of compomer in primary teeth: 1-year results. *J Am Dent Assoc* 1997; **128**: 1088–1096.

21 Kilpatrick NM, Murray JJ, McCabe JF. The use of a reinforced glass-ionomer cermet for the restoration of primary molars – a clinical-trial. *Br Dent J* 1995; **179**: 175–179.

22 Espelid I, Tveit AB, Tornes KH, Alvheim H. Clinical behaviour of glass ionomer restorations in primary teeth. *J Dent* 1999; **27**: 437–442.

23 Kotsanos N, Arizos S. Evaluation of a resin modified glass ionomer serving both as indirect pulp therapy and as restorative material for primary molars. *Eur Arch Paediatr Dent* 2011; **12**: 170–175.

24 Kramer N, Frankenberger R. Clinical performance of a condensable metal-reinforced glass ionomer cement in primary molars. *Br Dent J* 2001; **190**: 317–321.

25 Moher D, Liberati A, Tetzlaff J, Altman DG, Group P. Preferred reporting items for systematic reviews and meta-analyses: the PRISMA statement. *PLoS Med* 2009; **6**: e1000097.
26 Higgins J, Green S. Cochrane Handbook for Systematic Reviews of Interventions, version 5.1.0. London: The Cochrane Collaboration, 2011.
27 Barnes DM, Blank LW, Gingell JC, Gilner PP. A clinical evaluation of a resin-modified. Glass ionomer restorative material. *J Am Dent Assoc* 1995; **126**: 1245–1253.
28 Hickel R, Peschke A, Tyas M *et al.* FDI World Dental Federation - clinical criteria for the evaluation of direct and indirect restorations. Update and clinical examples. *J Adhes Dent* 2010; **12**: 259–272.
29 Buecher K, Metz I, Pitchika V, Hickel R, Kuehnisch J. Survival characteristics of composite restorations in primary teeth. *Clin Oral Investig* 2015; **19**: 1653–1662.
30 Taifour D, Frencken JE, Beiruti N, van 'HM, Truin GJ. Effectiveness of glass-ionomer (ART) and amalgam restorations in the deciduous dentition: results after 3 years. *Caries Res* 2002; **36**: 437–444.
31 Leith R, O'Connell AC. A clinical study evaluating success of 2 commercially available preveneered primary molar stainless steel crowns. *Pediatr Dent* 2011; **33**: 300–306.
32 Holst A. A 3-year clinical evaluation of Ketac-Silver restorations in primary molars. *Swed Dent J* 1996; **20**: 209–214.
33 Croll TP, Bar-Zion V, Segura A, Donly KJ. Clinical performance of resin-modified glass ionomer cement restorations in primary teeth – A retrospective evaluation. *J Am Dent Assoc* 2001; **132**: 1110–1116.
34 Duggal MS, Toumba KJ, Sharma NK. Clinical performance of a compomer and amalgam for the interproximal restoration of primary molars: a 24-month evaluation. *Br Dent J* 2002; **193**: 339–342.
35 Webman M, Mulki E, Roldan R, Arevalo O, Roberts JF, Garcia-Godoy F. A retrospective study of the 3-year survival rate of resin-modified glass-ionomer cement class ii restorations in primary molars. *J Clin Pediatr Dent* 2016; **40**: 8–13.
36 Rutar J, McAllan L, tyas MJ. Three-year clinical performance of glass ionomer cement in primary molars. *Int J Paediatr Dent* 2002; **12**: 146–147.
37 Peters TC, Roeters JJ, Frankenmolen FW. Clinical evaluation of Dyract in primary molars: 1-year results. *Am J Dent* 1996; **9**: 83–88.
38 Demarco FF, Collares K, Coelho-de-Souza FH *et al.* Anterior composite restorations: a systematic review on long-term survival and reasons for failure. *Dent Mater* 2015; **31**: 1214–1224.
39 Heintze SD, Rousson V. Clinical effectiveness of direct class II restorations - a meta-analysis. *J Adhes Dent* 2012; **14**: 407–431.
40 Moraschini V, Fai CK, Alto RM, Dos Santos GO. Amalgam and resin composite longevity of posterior restorations: a systematic review and meta-analysis. *J Dent* 2015; **43**: 1043–1050.
41 Heintze SD, Rousson V, Hickel R. Clinical effectiveness of direct anterior restorations–a meta-analysis. *Dent Mater* 2015; **31**: 481–495.
42 Schueler IM, Hiller M, Roloff T, Kuehnisch J, Heinrich-Weltzien R. Clinical success of stainless steel crowns placed under general anaesthesia in primary molars: an observational follow up study. *J Dent* 2014; **42**: 1396–1403.
43 Anusavice KJ. Standardizing failure, success, and survival decisions in clinical studies of ceramic and metal-ceramic fixed dental prostheses. *Dent Mater* 2012; **28**: 102–111.
44 Roberts JF, Sherriff M. The fate and survival of amalgam and preformed crown molar restorations placed in a specialist paediatric dental practice. *Br Dent J* 1990; **169**: 237–244.
45 Innes NP, Ricketts D, Chong LY, Keightley AJ, Lamont T, Santamaria RM. Preformed crowns for decayed primary molar teeth. *Cochrane Database Syst Rev* 2015; CD005512.
46 Attari N, Roberts JF. Restoration of primary teeth with crowns: a systematic review of the literature. *Eur Arch Paediatr Dent* 2006; **7**: 58–62; discussion 3.
47 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. *Oper Dent* 2004; **29**: 481–508.
48 Waggoner WF. Restoring primary anterior teeth: updated for 2014. *Pediatr Dent* 2015; **37**: 163–170.
49 Goettems ML, Zborowski EJ, Costa FD, Costa VP, Torriani DD. Nonpharmacologic intervention on the prevention of pain and anxiety during pediatric dental care: a systematic review. *Acad Pediatr* 2017; **17**: 110–119.
50 Wang Y, Li C, Yuan H *et al.* Rubber dam isolation for restorative treatment in dental patients. *Cochrane Database Syst Rev* 2016; **9**: CD009858.
51 Donly KJ. Restorative dentistry for children. *Dent Clin North Am* 2013; **57**: 75–82.
52 Raggio DP, Tedesco TK, Calvo AF, Braga MM. Do glass ionomer cements prevent caries lesions in margins of restorations in primary teeth? A systematic review and meta-analysis. *J Am Dent Assoc* 2016; **147**: 177–185.
53 Hara AT, Magalhaes CS, Serra MC, Rodrigues AL Jr. Cariostatic effect of fluoride-containing restorative systems associated with dentifrices on root dentin. *J Dent* 2002; **30**: 205–212.
54 Cury JA, de Oliveira BH, dos Santos AP, Tenuta LM. Are fluoride releasing dental materials clinically effective on caries control? *Dent Mater* 2016; **32**: 323–333.
55 Cenci MS, Tenuta LM, Pereira-Cenci T, Del Bel Cury AA, ten Cate JM, Cury JA. Effect of microleakage and fluoride on enamel-dentine demineralization around restorations. *Caries Res* 2008; **42**: 369–379.
56 Yengopal V, Mickenautsch S. Caries-preventive effect of resin-modified glass-ionomer cement (RM-GIC)

versus composite resin: a quantitative systematic review. *Eur Arch Paediatr Dent* 2011; **12**: 5–14.
57 Marinho VC, Higgins JP, Sheiham A, Logan S. Combinations of topical fluoride (toothpastes, mouthrinses, gels, varnishes) versus single topical fluoride for preventing dental caries in children and adolescents. *Cochrane Database Syst Rev* 2004; CD002781.
58 Demarco FF, Collares K, Correa MB, Cenci MS, Moraes RR, Opdam NJM. Should my composite restorations last forever? Why are they failing? *Braz Oral Res* 2017; **31**: e56.
59 de Amorim RG, Leal SC, Mulder J, Creugers NHJ, Frencken JE. Amalgam and ART restorations in children: a controlled clinical trial. *Clin Oral Investig* 2014; **18**: 117–124.
60 Gross LC, Griffen AL, Casamassimo PS. Compomers as Class II restorations in primary molars. *Pediatr Dent* 2001; **23**: 24–27.
61 Abo-Hamar SE, El-Desouky SS, Abu Hamila NA. Two-year clinical performance in primary teeth of nano-filled versus conventional resin-modified glass-ionomer restorations. *Quintessence Int* 2015; **46**: 381–388.
62 Andersson-Wenckert IE, Folkesson UH, Van Dijken JWV. Durability of a polyacid-modified composite resin (compomer) in primary molars – A multicenter study. *Acta Odontol Scand* 1997; **55**: 255–260.
63 Folkesson UH, Andersson-Wenckert IE, van Dijken JW. Resin-modified glass ionomer cement restorations in primary molars. *Swed Dent J* 1999; **23**: 1–9.
64 Innes NP, Clarkson JE, Speed C, Douglas GV, Maguire A, Fi CTC. The FiCTION dental trial protocol – filling children's teeth: indicated or not? *BMC Oral Health* 2013; **13**: 25.
65 Frencken JE. The state-of-the-art of ART restorations. *Dent Update* 2014; **41**: 218–220, 22–4.
66 Welbury RR. The Hall Technique 10 years on: its effect and influence. *Br Dent J* 2017; **222**: 421–422.

Supporting Information

Additional Supporting Information may be found in the online version of this article:

Appendix S1. Structured search strategy carried out in MEDLINE/PubMed database.

Appendix S2. Excluded studies and reasons for exclusion.

Appendix S3. Bias risk of the included studies.