Clinical performance of direct anterior composite restorations: a systematic literature review and critical appraisal

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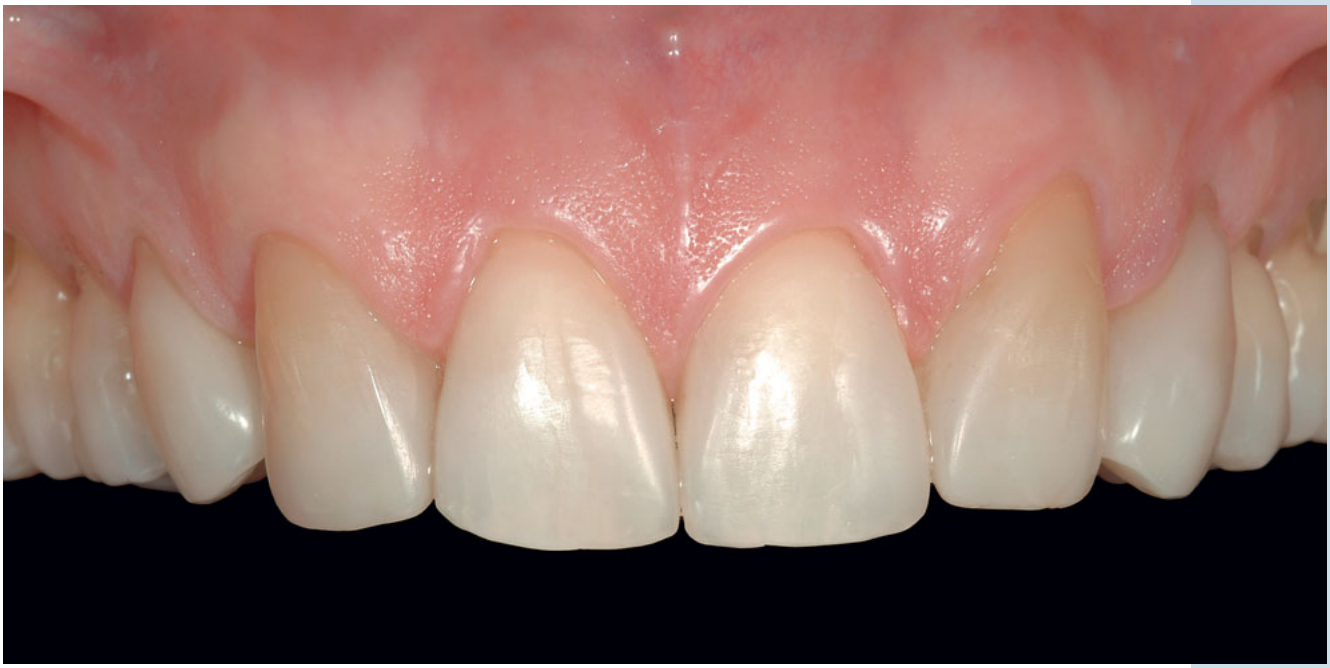

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Abstract

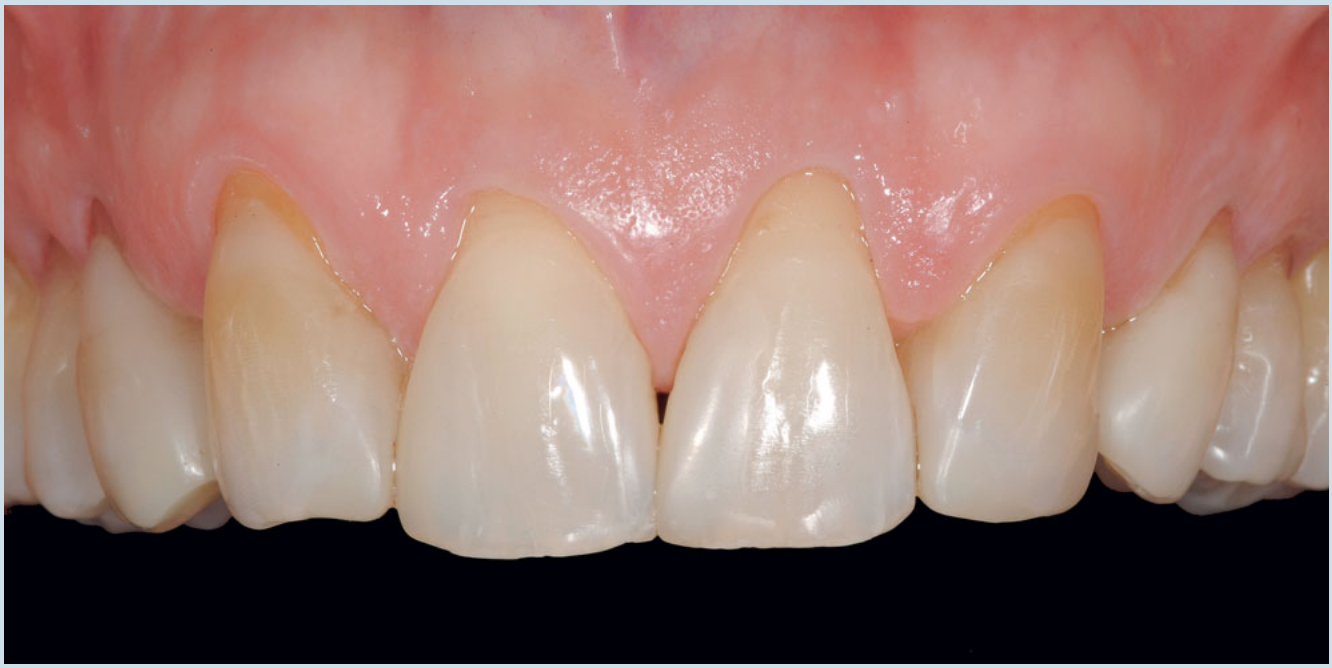
Objectives: The aim of this study was to systematically review the literature on the clinical behavior of direct anterior composite restorations and to identify the factors potentially influencing restoration success and longevity.

Materials and methods: The search included all existing references until September 2016 cited in the PubMed database, the Cochrane central register of controlled trials and Cochrane Library, EMBASE, an internet search using Google internet search engine (possibly including unpublished data), a hand search (University of Geneva library), and the perusal of the references of relevant articles. Studies with appropriate research protocols and that clearly reported data about the performance of anterior composite restorations were included. Yearly failure rates (YFRs) were computed for each study based on survival rates or, when not reported, using United States Public Health Service (USPHS) scores leading to reintervention. The potential impact of the following factors was evaluated: composite filler technology (microfilled, macrofilled, nanofilled or hybrid), polymerization mode (chemical or light cured), treatment environment (academic, private or social) and operator (single or multiple). The studies were analyzed according to the observation time (< 2 years, 2 to 5 years, and > 5 years).

Results: 39 potential studies were identified, from which 24 met the review inclusion criteria: nine randomized controlled trials (CTs), two prospective CTs, one retrospective CT, six prospective case series (CSs), and four retrospective CSs.

Conclusion: This review followed a standard approach and explored an alternative review process that limited the significant data loss that occurs when the meta-analysis method is used. Overall, anterior composite restorations have shown a large heterogeneity in performance, as is typically observed in reviews of clinical studies, but the present appraisal identified influential factors such as treatment environment and the number of operators.

(Int J Esthet Dent 2019;14:252–270)



Introduction

Since their introduction to the market in 1962, composite resins have undergone considerable development and have achieved much success. They can be considered the standard of care for partial esthetic restorations of the anterior teeth. A large part of the confidence that dental professionals have in direct composite restorations actually relies on individual experience, industry advertising, and clinical reports detailing their application and esthetic 'success.'[1-4] Apart from the most relevant success criterion from the patient's point of view, which is an immediate and successful esthetic outcome, the longevity of composite restorations is also important, not only to patients and dentists, but also to funding agencies, social and health agencies, and dental manufacturers.[5] Thus, systematic reviews can help all the partners involved in dental care and restorative materials development and production to optimize composite technology and application techniques in the best interests of patients.

Thus far, only two literature reviews have been published: one systematic review,[6] and one meta-analysis.[7] The results and conclusions of these recent publications mainly relate to failure rates and reasons for failure. Only the review by Heintze et al[7] tried to identify a few influential technical factors such as bonding procedures (bonding agent applied or not after enamel etching), and margin design (beveling as opposed to non-beveling). The analysis, however, resulted from an extremely small number of studies. As stipulated in a recent review on the use of meta-analysis in medical science,[8] this type of analysis is designed to systematically assess previous research studies in order to achieve a more precise estimate of the effect of treatment or risk factors for disease or other outcomes than any individual study contributing to the pooled analysis. The benefits of meta-analysis include a consolidated and quantitative review of the literature that is large, often complex, and sometimes apparently conflicting. While the rationale and interest of this statistical method is obvious; namely, to approach as closely as possible the unknown common truth hidden behind individual study results,[9] the use of meta-analysis in dentistry might be problematic when only a very small proportion of studies share a common clinical protocol and treatment outcome evaluation and analysis. This is especially true for restorative dentistry, which involves numerous confounding factors (often unidentified or uncontrollable) such as: the clinician's skill and experience; the treatment environment (academic center, private practice or social clinic); patient selection and compliance, together with the control of individual risk factors; the difficulty in standardizing the treatment outcome ranking; and, above all, the unlimited local dental variations of the biomechanical tooth condition (ie, extent of cavity or decay, tooth age, hard tissue quality, functional and occlusal environment, etc). Frequently, in an attempt to avoid heterogeneity in pooled data, the authors apply strict data selection criteria and therefore eliminate the core of available information in order to run a meta-analysis. The need to withdraw a large proportion of identified studies is arguably a questionable approach, as what often remains is a very limited amount of data (possibly insufficient) from which to extract the expected information, which in the end will not reflect the true performance of a given material or clinical protocol. In other words, the strength of the method becomes a weakness when the computed average success or failure rate ignores the bulk of published data. Moreover, the search for an average success or failure rate is moderately relevant for the clinician, as opposed to the

'natural' variability in the treatment outcome related to identified and non-identified variables. Then, in the absence of a meaningful data mass with which to run a meta-analysis, the effective alternative for evaluating the impact of different techniques and the selection of materials or products on the quality outcome and/or restoration longevity is based on the calculation of annual failure rate ranges, as derived from the survival rates and observation periods of individual studies.[10,11] Study selection criteria, although less restrictive, do of course also apply to such an analysis. The authors of the present study can conclude from this that the derived information can be more powerful, as it provides an estimate of success as well as the failure risk for the same type of treatment in various environments, and for different types of patients using a broader if less homogenous data mass.

The aims of this review were, firstly, to systematically analyze the available clinical literature reporting the survival rate and/or quality of anterior composite restorations, and secondly, to attempt to identify all the available studies that would present enough homogeneity to run a meta-analysis. In addition, with or without meta-analysis capability, the available data were organized and analyzed using grouping factors that have not been used thus far in the literature on direct anterior composite restorations, in an attempt to identify new factors that account for variations in the longevity and performance of anterior composite restorations.

Materials and methods

No funding was received for the present work. Regarding ethical approval and compliance with ethical standards, this article does not contain any studies with human participants or animals performed by any of the authors. All procedures performed in the studies in this review involving human participants were in accordance with the ethical standards of the institutional and/or national research committee, and with the 1964 Helsinki Declaration and its later amendments or comparable ethical standards, valid at the time the selected studies were performed. No formal informed consent is required for this type of study.

Review method

Review method and article selection

All relevant randomized and quasi-randomized controlled trials (CTs) and case series (CSs) on Class II and IV restorations published between 1975 and September 2016 were considered for this review, following a search within the databases or using the methods listed below:

- PubMed/Medline database
- Cochrane central register of controlled trials, and Cochrane Library
- EMBASE
- Internet search using Google internet search engine (possibly including unpublished data)
- Hand search (University of Geneva library)
- Perusal of the references of relevant articles (references of the references)

The search key words used were "anterior" or "Class III" or "Class IV" composite restoration or reconstruction or filling. When appropriate, the search was filtered using the option "clinical trial, survival or longevity;" for the electronic word search "MeSH" and/or "text word, abstract, title" were applied (Boolean logic). All relevant studies were selected, irrespective of their original language, providing they contained at least an English abstract and readable data and statistics. The potentially relevant studies were primarily selected according to their abstracts, then the full texts of the articles were read. Studies were included or excluded

Table 1 Inclusion and exclusion criteria for selecting studies

Inclusion criteria	Exclusion criteria
Clinical studies (randomized CTs or CSs) for anterior composite restorations Studies assessing or reporting survival or restoration quality Material type and restoration intervention clearly described Adequate sample size	Case reports Clinical evaluations without reliable statistical approach Non-scientific, peer-reviewed publications *In vitro* trials Studies related to the treatment of tooth wear

based on the inclusion and exclusion criteria listed in Table 1. For the purpose of this review, all randomized controlled clinical trials and non-randomized controlled clinical trials were grouped as controlled trials (CTs), and the other trials as case studies (CSs); they were then subclassified according to a longitudinal (prospective, retrospective) or transversal time approach.

Review objectives and data analysis

The longevity of partial anterior composite restorations is the main subject of this systematic review. 'Longevity' here relates to the period during which a restoration is considered functionally, biologically, and esthetically satisfactory; conversely, a 'failure' relates to restorations no longer considered biologically, functionally, and esthetically acceptable and which justify an intervention such as a repair or replacement (Figs 1 and 2).[12] Then, depending on the study evaluation method, 'major' or 'minor' failures are reported.[13] For instance, the restoration loss (debonded restoration), fractures, periodontal complications relating to the restoration, recurrent decays or related pulpal complications are termed 'major' or 'definite' failures as they lead to restoration replacement (Fig 1). A 'minor' or 'relative' failure occurs when, for instance, the restoration maintains its biological and functional properties despite small partial fractures or reduced esthetic qualities; restoration repair is the likely action applied to such cases (Fig 2). In short-term studies, a quality assessment such as one using United States Public Health Service (USPHS) criteria[12,14,15] is frequently used due to the low number of failures reported; it can, however, serve to indirectly calculate the real success or failure rate of these studies by computing the percentage of unacceptable restorations according to selected criteria (ie, a Charlie or Delta score within the USPHS or modified USPHS ranking system). In addition to the 'definite' failure rates, some additional review questions were addressed such as

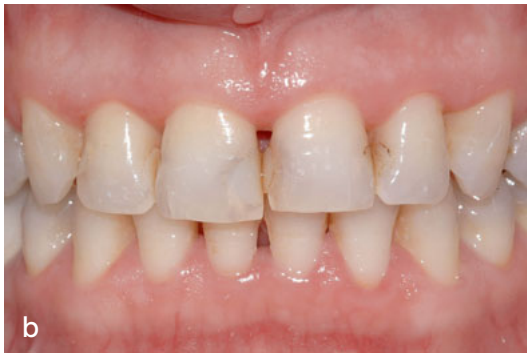
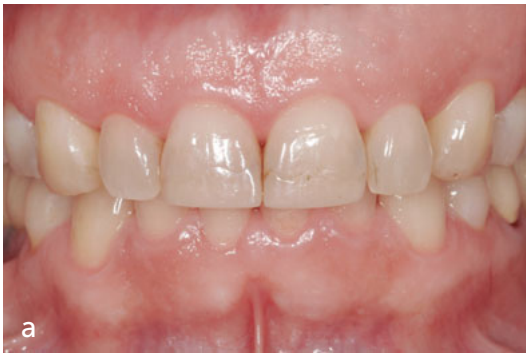


Fig 1 (a and b) These presented cases illustrate major failures of anterior composite restorations for margins, form, and color match, respectively. As opposed to minor failures, major failures require restoration replacement.

the potential impact on the longevity of the restoration of the environment, the operator, the type of composite, and the curing mode.

For each study, the participant 'population,' the type of 'intervention' applied to the participants, the possibility of a 'comparison' with a control group (intervention or participant), and the treatment 'outcome' according to different follow-up time periods were tentatively identified. The main variables related to these four study elements (PICO) are as follows (Table 2):

- **Population:** The target population may have several characteristics that identifies it from other populations (ie, gender, age, carious risk, socioeconomic background, occlusal factors, etc). Such variables are identified (potential grouping factor) or not (confounding factors).



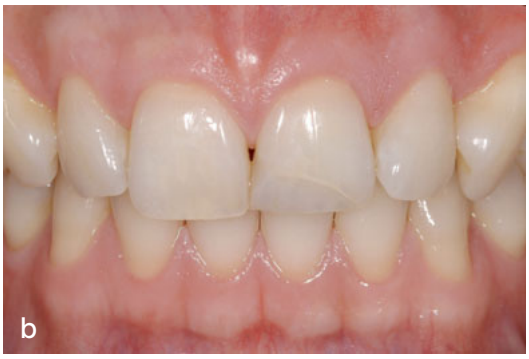


Fig 2 (a and b) These presented cases illustrate minor failures of anterior composite restorations for margins (a), and form and color match (b). Such failures require restoration repair as opposed to replacement.

Population	Intervention	Comparison	Outcome
Age Gender Socioeconomic background and status Oral hygiene Nutritional risks Carious risk Occlusal and functional factors	**Restoration*** Material type* Material composition Curing mode* Placement technique Polishing and finishing Shading concept Shade accuracy	Active comparison group/s	Survival USPHS criteria or modified USPHS criteria Color match Marginal adaptation
	Preparation Form and configuration Volume Margin design Proximal extension		
	Operator Experience Skills and handling		
	Environment** Public academic centers Private practice Public social centers Multi- or single-center Multi- or single-operator		

Table 2 Study elements impacting the outcome of anterior composite restorations

* Primary grouping factors; ** secondary grouping factors.

- **Intervention:** Interventions in restorative dentistry depend on multiple factors related to the restorative protocol and material, the operator, and the treatment environment; intervention parameters serve as potential grouping factors.
- **Comparison:** In controlled studies, whether a comparison group is an active control group (no placebo group for a restorative treatment) depends on the main objective of each study, based on the intervention or the population.
- **Outcome:** The outcome of every study relates to restoration performance, measured as survival/complication rate (usually in medium- to long-term studies) or restoration quality (usually in short-term studies), mainly using USPHS criteria or any modification thereof;[12,14,15] outcome data serve to run a meta-analysis or to compare results non-statistically.

On the basis of the aforementioned approach and definitions, the review was performed using primary and secondary grouping factors, with an attempt to assess their impact on the quality and failure rate of anterior composite restorations. The primary grouping factors and review questions concerned the impact of the material properties, including both material composition (macrofilled, microfilled, hybrid, or nanofilled) and polymerization type (chemical or light curing). The secondary grouping factors concerned the environment (academic, private or social), the operator (single or multiple) and the timeframe (short, medium or long term). Short term was < 2 years, medium term was 2 to 5 years, and long term was > 5 years. Other intervention features such as product brand and cavity configuration (Class III and IV) were not retained as study variables in this review. The aforementioned factors, combined with composite brand information, served to generate the overall data collection and results presentation (Tables 3a to c).

Data management and analysis

The available data, expressed as survival rate, failure rate, percentage of unacceptable restoration quality (based on USPHS criteria – Charlie score), replacement rate, and major complication rate, served to calculate the yearly failure rate (YFR) of the restorations under evaluation in each selected study, using either of the following formulas:

- YFR (%) = (n reported failed samples/ n total samples) x 100/obervation period (year)
- YFR (%) = (100 - % reported survival rate)/ observation period (year)

All available study data were also screened to identify the homogeneity of their study designs and parameters, and to assess the possibility of running a meta-analysis and answering one or more of the review questions. When appropriate, the processing of data was performed using the web-based meta-analysis software application MetaLight, provided by the Evidence for Policy and Practice Information and Coordinating Centre (EPPI-Centre), University of London.

To provide some meaningful clinical interpretation of the review data, an overall performance judgment was made on reported failure rates. The performance of any restorative system under review was then described as 'satisfactory' for YFR ranging from 0% to 2%, 'average' for YFR from 2% to 4%, and 'insufficient' for YFR above 4%. Thus, the 10-year survival of restorations using a 'satisfactory' technique or product would show at least an 80% restoration survival, while those with a restoration survival below 60% would be considered 'insufficient' or unacceptable.

Table 3a Extracted data of selected randomized controlled trials (CTs)

Study	Polymerization	Composition	Material brand	Cavity configuration	Environment	Center	Operator	Major complication	Minor complication	Reported survival rates	Observation period (years)
Joelson et al (1981)[16]	Chemical cure	Macrofilled	Adaptic	III, IV, V	Academic	Single	Single	-	Color mismatch Surface roughness	100%	1
	Chemical cure	Macrofilled	Concise		Academic	Single	Single	-	-	100%	
	Chemical cure	Macrofilled	Cosmic		Academic	Single	Single	-	-	100%	
	Chemical cure	Microfilled	Isopast		Academic	Single	Single	-	-	100%	
Christensen and Christensen (1982)[17]	Chemical cure	Macrofilled	Adaptic	III	Private	Multi	Multi	-	Marginal discoloration Surface roughness	100%	3
	Chemical cure	Microfilled	Isocap		Private	Multi	Multi	-	-	100%	
Schalpbach et al (1982)[18]	Chemical cure	Microfilled	Silar	III	Academic	Single	Multi	Marginal degradation	-	96%	2
	Chemical cure	Microfilled	Isopast		Academic	Single	Multi	Marginal degradation	-	23%	
	Chemical cure	Macrofilled	Concise		Academic	Single	Multi	Marginal degradation	-	94%	
Weber-Gaud et al (1982)[19]	Chemical cure	Microfilled	DRS Coltène	III, IV, V	Academic	Single	Single	-	Surface roughness	100%	1
	Chemical cure	Microfilled	Silar		Academic	Single	Single	-	-	100%	
	Chemical cure	Hybrid	Finesse		Academic	Single	Single	-	-	100%	
	Chemical cure	Hybrid	Miradapt		Academic	Single	Single	-	Surface roughness	100%	
van der Veen et al (1989)[20]	Light cure	Hybrid	Silux	III, IV	Academic	Single	Multi	-	-	100%	1
	Light cure	Hybrid	Valux		Academic	Single	Multi	-	-	100%	
	Light cure	Microfilled	Clearfil Lustre		Academic	Single	Multi	-	Color match	100%	
Smales and Gerke (1992)[21]	Light cure	Hybrid	Aurafill	III, IV, V	Academic	Single	Single	Marginal degradation	Surface staining	92%	4
	Light cure	Microfilled	Silux		Academic	Single	Single	Marginal degradation	Gingivitis	90%	
	Light cure	Hybrid	Valux		Academic	Single	Single	Marginal degradation	Gingivitis	94 %	
Reusens et al (1999)[22]	Light cure	Microfilled	Silux plus	III	Academic	Single	Single	-	Marginal discoloration	100%	2
	Light cure	Hybrid	Herculite XRV		Academic	Single	Single	-	-	100%	
Närhi et al (2003)[23]	Light cure	Hybrid	Z 250	III, IV, V	Private	Multi	Multi	-	Color mismatch Marginal discoloration	100%	1
	Light cure	Hybrid	Z 100		Private	Multi	Multi	-	Color mismatch Marginal discoloration	100%	
Loguerico et al (2007)[24]	Light cure	Microfilled	Durafill VS	III	Academic	Single	Multi	-	Marginal discoloration	100%	1
	Light cure	Hybrid	Filtek Z250		Academic	Single	Multi	-	Marginal discoloration	100%	
	Light cure	Nanofilled	Filtek Supreme		Academic	Single	Multi	-	Marginal discoloration	100%	

Table 3b Extracted data of selected prospective and retrospective controlled trials (CTs)

Study	Polymerization	Composition	Material brand	Cavity configuration	Time approach	Environment	Center	Operator	Major complication	Minor complication	Reported survival rates	Observation period (years)
van Dijken (1986)[25]	Chemical cure	Hybrid	Adaptic	III ,IV	Prospective	Academic	-	N/A	-	Marginal discoloration Marginal degradation Surface roughness	100%	6
	Chemical cure	Hybrid	Profile		Prospective	Academic	-	N/A	-			
	Chemical cure	Microfilled	Silar		Prospective	Academic	-	N/A	-			
	Chemical cure	Microfilled	Isopast		Prospective	Academic	-	N/A	-			
	Light cure	Microfilled	Durafill		Prospective	Academic	-	N/A	-			
	Chemical cure	Hybrid	Miradapt		Prospective	Academic	-	N/A	-			
	Chemical cure	Hybrid	DRS		Prospective	Academic	-	N/A	-			
Van Noort and Davis (1993)[26]	Chemical cure	Hybrid	Adaptic	III	Prospective	Social	Multi	Multi	Secondary caries Marginal degradation Surface discoloration Restoration fracture Form loss	Color mismatch Marginal discoloration	70%	5
	Chemical cure	Hybrid	Miradapt			Social	Multi	Multi			65%	
	Chemical cure	Hybrid	CRM			Social	Multi	Multi			64%	
	Chemical cure	Hybrid	Healthco			Social	Multi	Multi			63%	
	Chemical cure	Microfilled	Silar			Social	Multi	Multi			60%	
	Chemical cure	Microfilled	Brilliant			Social	Multi	Multi			56%	
Jokstad et al (1994)[27]	Chemical cure	Microfilled	Silar	III, IV, V	Retrospective	Academic	Single	Single	Secondary caries	Anatomic form loss	80%	10
	Chemical cure	Macrofilled	Concise		Retrospective	Academic	Single	Single	Restoration loss	Marginal adaptation	95%	

Table 3c Extracted data of selected prospective and retrospective case series (CSs)

Study	Polymerization	Composition	Material brand	Cavity configuration	Time approach	Environment	Center	Operator	Major complication	Minor complication	Reported survival rates	Observation period (years)
De Trey et al (1977)[28]	Chemical cure	Macrofilled	Adaptic	III, IV, V	Prospective	Academic	Single	Single	-	Marginal degradation	100%	1.5
Lutz et al (1977)[29]	Light cure	Macrofilled	Nuva system	III, IV	Prospective	Academic	Single	Multi	Marginal degradation	Marginal degradation Color mismatch Improper anatomy	99%	1.5
Ferrari et al (1990)[30]	Light cure	Microfilled	D 588	III, IV, V	Prospective	Academic	Single	Multi	Fracture	Color mismatch Marginal discoloration	97%	1
Komatsu et al (1990)[31]	Light cure	Hybrid	Lumifor	N/A	Prospective	Academic	Single	Multi	Restoration loss Marginal degradation	Marginal discoloration	92%	2
Qvist and Strøm (1993)[32]	Chemical cure	Microfilled	Silar	III	Prospective	Academic	Single	Single	Secondary caries	Marginal discoloration Chipping	84%	11
Millar et al (1997)[33]	Light cure	Hybrid	Opalux	III, IV, V	Prospective	Academic	Single	Multi	Secondary caries	-	73%	8
Peumans et al (1997a,b)[34,35]	Light cure	Hybrid	Herculite XR	Buildup	Prospective	Academic	Single	Single	-	Marginal discoloration Color mismatch	100%	5
Bachelard et al (1997)[36]	Light cure	Hybrid	Herculite XRV	III, IV, V	Prospective	Academic	Single	Multi	-	Color mismatch Marginal discoloration	100%	1
Rule and Elliot (1975)[37]	Chemical cure	Macrofilled	Adaptic	IV	Retrospective	Academic	Single	Multi		Discoloration	90%	1.5
Smales (1975)[38]	Chemical cure	Macrofilled	Adaptic Addent 12 Concise	III, IV, V	Retrospective	Academic	Single	Multi	Marginal decay	Marginal discoloration Surface roughness	95%	3
*Lucarotti et al (2005a-d)[39-42]	N/A	N/A	N/A	III, IV	Retrospective	Social	Multi	Multi	Caries Fracture Restoration loss Marginal degradation	N/A	60–80%	5
Moura et al (2011)[43]	Light cure	Hybrid	TPH	III IV	Retrospective	Academic	Single	Multi	Restoration loss Fracture	Surface roughness Marginal staining Color mismatch	92% 80%	3

Table 4 Time period considered to subclassify studies under review together with number of studies entering into each time category and study design

	Controlled trials (CTs)	Case series (CSs)
Short-term studies (≤ 2 years)	14	8
Mid-term studies (> 2 and ≤ 5 years)	8	5
Long-term studies (> 5 years)	3	4

Note: some studies appear in more than one time category.

Results

From the abstracts and references identified though the aforementioned search approach, 39 articles were selected for a full reading, out of which nine were excluded based on the exclusion/inclusion criteria shown in Table 1. From the remaining 30 studies, a further six were excluded due to unusual patient selection, incomplete data and improper observation period, insufficient number of restorations or excessive dropout. The present review finally included 24 studies,[16-43] consisting of nine randomized CTs, two prospective CTs, one retrospective CT, eight prospective CSs, and four retrospective CSs; one study in the latter group consisted of a publication/data analysis in four parts[39-42] (the four reports are considered as one single study in Table 3c). The reviewed articles with relevant extracted data are listed in Tables 3a to c. The distribution of selected CTs and CSs according to the primary and secondary grouping factors are shown in Table 4 (distribution of studies by time period) and Tables 5a to d, respectively. Data analysis according to primary and secondary group-

Table 5a Subclassification of the overall performance of reported restorations presented as yearly failure rates (YFRs) according to timeframe and composite filler technology factors

	Short term (≤ 2 years)		Mid term (2 to 5 years)		Long term (> 5 years)	
	CT	CS	CT	CS	CT	CS
Macrofilled	0–3.4%	-	2–2.5%	-	2.3–2.8%	-
Hybrid	0–5%	0–6.6%	0–8.8%	2.2–7.4%	2.5–8.5%	3.3%
Microfilled	0–2.5 (33.5%)*	0–3.4%	0–9.2%	1.7%	0.2–9.1%	1.40–1.45%
Nanofilled	0%	-	-	-	-	-

CT = controlled trial; CS = case series; * atypical (highest YFR reported in a single study).[18]

Table 5b Subclassification of the overall performance of reported restorations presented as yearly failure rates (YFRs) according to the timeframe and polymerization mode factors

	Short term (≤ 2 years)		Mid term (2 to 5 years)		Long term (> 5 years)	
	CT	CS	CT	CS	CT	CS
Self cure	0–3.4 (33.5%)*	0–6.6%	0–9.2%	1.6–1.75%	0.2–9.1%	1.40–1.45%
Light cure	0–5.0%	0–3.4%	2.3–5.3%	2.2–7.4%	2.8%	3.3%

CT = controlled trial; CS = case series; * atypical (highest YFR reported in a single study).[18]

ing factors are shown in Tables 5a to d, respectively.

According to the main review questions, only two pairs of studies (Smales and Gerke[21] and Reusens et al,[22] and van der Veen et al[20] and Loguercio et al[24]) appeared feasible for a meta-analysis to investigate the performance of microfilled and hybrid composites after a 2-year follow-up in a single-center and operator environment, or a 1-year follow-up in a single-center and multi-operator environment, respectively. However, the calculations proved inconclusive due to the high survival rates of Class III or IV restorations, varying only between 99% for the study by Smales and Gerke,[21] and 100% for the other three studies.[20,22,24]

Reasons for failures

This review confirmed that fracture and marginal degradation leading to secondary caries were the most frequently reported major complications, accounting for definite restoration failures, while color mismatch and marginal discoloration were the most prevalent reasons for relative failures or minor complications,[13] although such conditions were not considered in the calculation of YFR.

Discussion

Review approach and data management

Considering the material collected for this review and the restoration failure or survival rates of the treatments, the meta-analysis methodology proved inappropriate due to the excessive heterogeneity of research protocols; restorative approaches; and quality and quantity of operators, products, and environments. Only two pairs of studies were identified that had adequate homogeneity in their protocol, but due to nearly

	Short term (≤ 2 years)		Mid term (2 to 5 years)		Long term (> 5 years)	
	CT	CS	CT	CS	CT	CS
Academic	0–3.4% (33.5%)*	0–6.6%	1.0–8.8%	1.6–2.7% (7.4%)	0.2–9.1%	1.4–3.3%
Private	0%	-	0%	-	-	
Social	-	-	5.9–9.2%	4.0–8.0%	-	5.7%

CT = controlled trial; CS = case series; * atypical (highest YFR reported in a single study).[18]

Table 5c Subclassification of the overall performance of reported restorations presented as yearly failure rates (YFRs) according to the timeframe and treatment environment factors

	Short term (≤ 2 years)		Mid term (2 to 5 years)		Long term (> 5 years)	
	CT	CS	CT	CS	CT	CS
Single	0–5%	0–2%	1.0–5.3%	1.7–2.2%	0.2–2.8%	1.40–1.45%
Multiple	0–3.4% (33.5%)*	0–6.6%	5.9–9.2%	1.6–8.0%	-	3.3–5.7%

CT = controlled trial; CS = case series; * atypical (highest YFR reported in a single study).[18]

Table 5d Subclassification of the overall performance of reported restorations presented as yearly failure rates (YFRs) according to the timeframe and operator factors

identical study outcomes, no meaningful calculation could be performed. Moreover, another basic obstacle to conducting a meta-analysis successfully and meaningfully was the number of inherent variables characterizing dental restorative procedures, combined with the rather short observation periods of prospective studies and the very low failure rates represented. Studies reporting restoration quality and performance based on marginal adaptation (using a replica technique and observation under a scanning electron microscope [SEM])[44] or the widely used USPHS ranking system or any of its modifications[14,15] were also not considered suitable enough for a meta-analysis, even though calibration among evaluators for scoring the study outcome is possible and statistically defendable using Cohen's kappa coefficient.[45] Thus, failure or survival rates remained the most concrete data for undergoing the statistical or non-statistical review process.

Selected studies were subclassified according to the study design into two main subgroups: CTs and CSs. The former included randomized, prospective, and retrospective CTs; the latter included prospective and retrospective CSs. However, only a low number of prospective, randomized CTs were available, with nearly a total absence of mid- and long-term reports in this category. The particularly rapid development cycle of new composite systems and brands may have discouraged scientists to further evaluate the performance of products already withdrawn from the market.

Influence of composite type

Due to their extensive presence on the market, hybrid and microfilled composites were the materials on which performance was reported in the majority of studies (hybrids: nine CTs and six CSs; microfilled: 11 CTs and two CSs); there were fewer studies evaluating macrofilled composite longevity as these were replaced some time ago with hybrid formulations (macrofilled: three CTs) (Table 5a).

Macrofilled materials presented an overall YFR ranging from 0% to 3.4%, microfilled composites from 0% to 33.5%, and hybrids from 0% to 8.8%. The YFR upper limit in the three observation time intervals proved lower for macrofilled than for microfilled and hybrid systems, and lower for hybrid than for microfilled systems. The extended range of failure rate observed for microfilled composites was due to the poor performance of one product (Isopast; Ivoclar Vivadent), as reported in two studies after either 2 years[18] or 6 years,[25] while with the same product other authors[16] reported a 100% survival at 1 year. Interestingly too, the performance of Silar (3M ESPE) in single-operator studies reported a YFR below 1%.[27,32] The performance of this product was therefore considered fully satisfactory in these two studies, while in a third multi-operator study,[25] the YFR increased to above 5%, which indicated insufficient behavior of this material. This confirms the potential impact of the operator on restoration performance. The performance of so-called nanofilled composites in anterior teeth was only evaluated in one short-term study and could therefore not be meaningfully compared with other technologies.

Overall, a few microfilled and hybrid brands pushed failure rate ranges to much higher values, either due to the multi-operator environment or conceivably also because this review includes some studies using early formulations of certain materials.[18,25,26] On the contrary, survival rates reached 100% in short- or mid-term studies that took place in a private environment. Otherwise, no specific trend was identified with regard to the overall performance of various composite filler technologies over the three observation periods.

Influence of curing mode

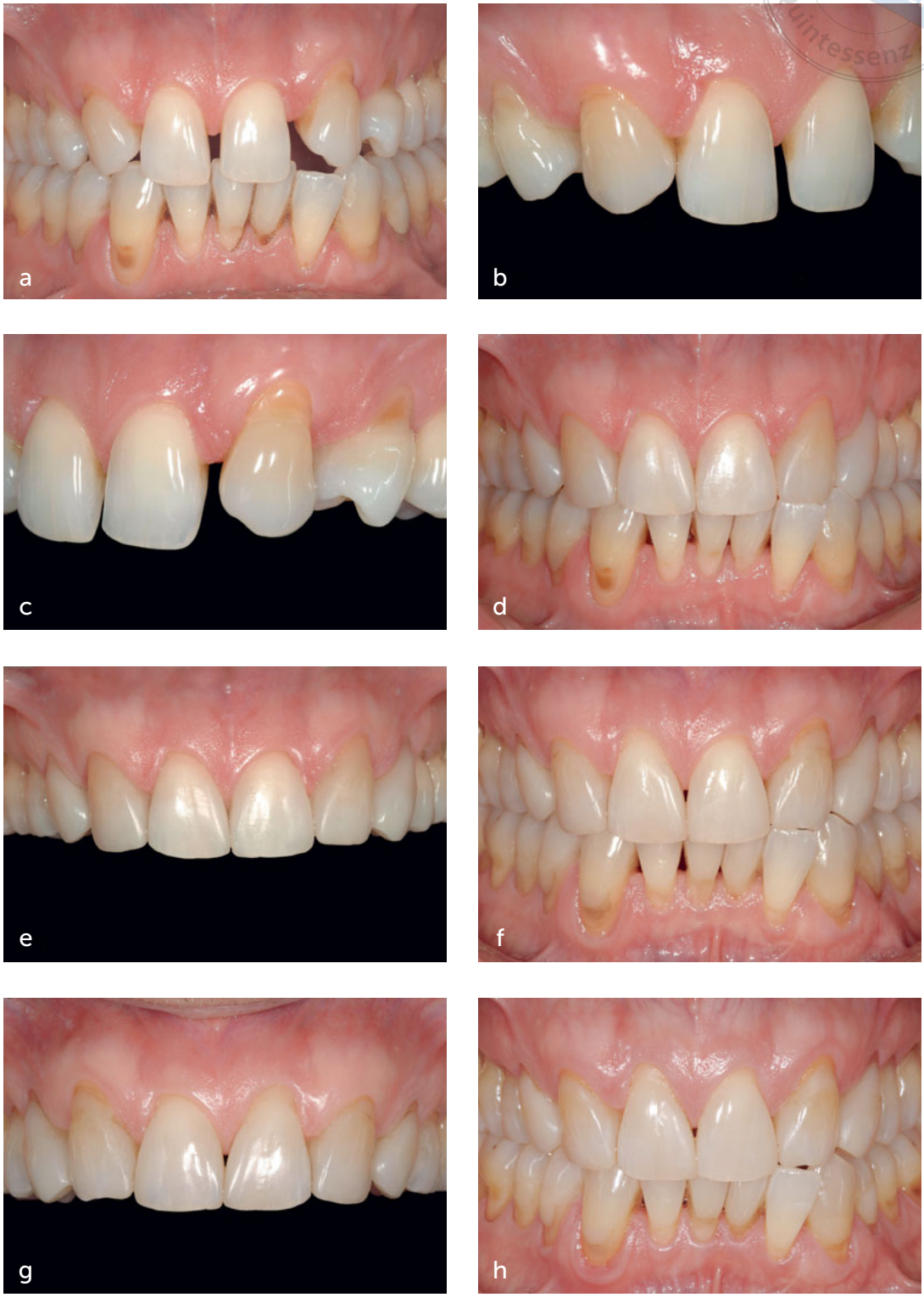
With the exception of one study,[39-42] a clear description was given of the curing mode in all the studies in this review (chemical curing: seven CTs and five CSs; light curing: six CTs and six CSs) (Table 5b). The relative proportion between these curing modes was well balanced, although there was no conclusive advantage of one over the other. This goes to show that, apart from an obvious impact on composite clinical application and esthetic outcome, the advent of light-curing technology did not clearly impact composite longevity and performance, contrary to a widespread belief. Such a comparison has less significance today because chemical curing is no longer applied to direct anterior composite restorations.

Influence of the treatment environment

The majority of studies were conducted in academic centers (20 studies: nine CTs and 11 CSs), whereas only two originated from private practices, and two from social clinics (National Health Service [NHS], UK) (Table 5c). For short-term observations, reports only exist from academic centers and private practices, with the YFR ranging from 0% to 3.4%, with one exception peaking at 33.5% (one self-curing microfilled composite among three products tested in an academic center with no rationale given for this insufficient behavior;[18] this atypical performance is shown in parenthesis in Tables 5a to d). No major failure was reported in the private environment, and survival rates peaked at 100%. For mid-term observation periods, the best performance was also reported from private practices, again with 0% YFRs, while ranges were quite large in both academic (1% to 8.8%) and social (4.0% to 9.2%) centers (Fig 3). For long-term observation periods, the range of failure rates in academic centers (0.2% to 9.1%) was larger, with the restoration longevity being lower, comparable or higher than the average longevity reported in a single study within a social environment (5.7%); there was no long-term report for private practices.

Within the context of multi-center and multi-practitioner studies conducted at social clinics, Lucarotti et al[39-42] performed a retrospective analysis of data issued by the NHS in the UK related to 95,805 restorations. These authors stated that the longevity of anterior composite restorations was 'acceptable' at 5 years, with a survival range of 60% to 80%, which should, in fact, be considered insufficient according to a more realistic clinical judgment. Likewise, the 10-year cumulative results from the same restoration survey provided a global survival rate of 43%, or 5.7% YFR, which is close to the results (5.9% to 8.7% YFR) of a previous report performed in the same NHS environment at 5 years;[26] again, such results must be considered largely insufficient. In contrast, an 11-year CSs performed in a multi-operator but single academic center[32] environment reported a restoration survival rate of 91.60% at 6 years (1.4% YFR) to 84% at 11 years (1.45% YFR).

The overall comparison of data on restoration survival/failure rates when subclassified according to the environment showed large variations within the three observation periods. Restoration quality fluctuated from satisfactory to insufficient in the academic environment to only insufficient in the social environment. In the former, where products could be identified, YFR variations appeared to be more product-dependent than influenced by composite type (filler technology or curing mode). No trend or difference emerged with regard to YFRs between CTs or CSs. Although private practices did report excellent short- and mid-term performance (0% YFR), the limited number of available studies (two) precludes



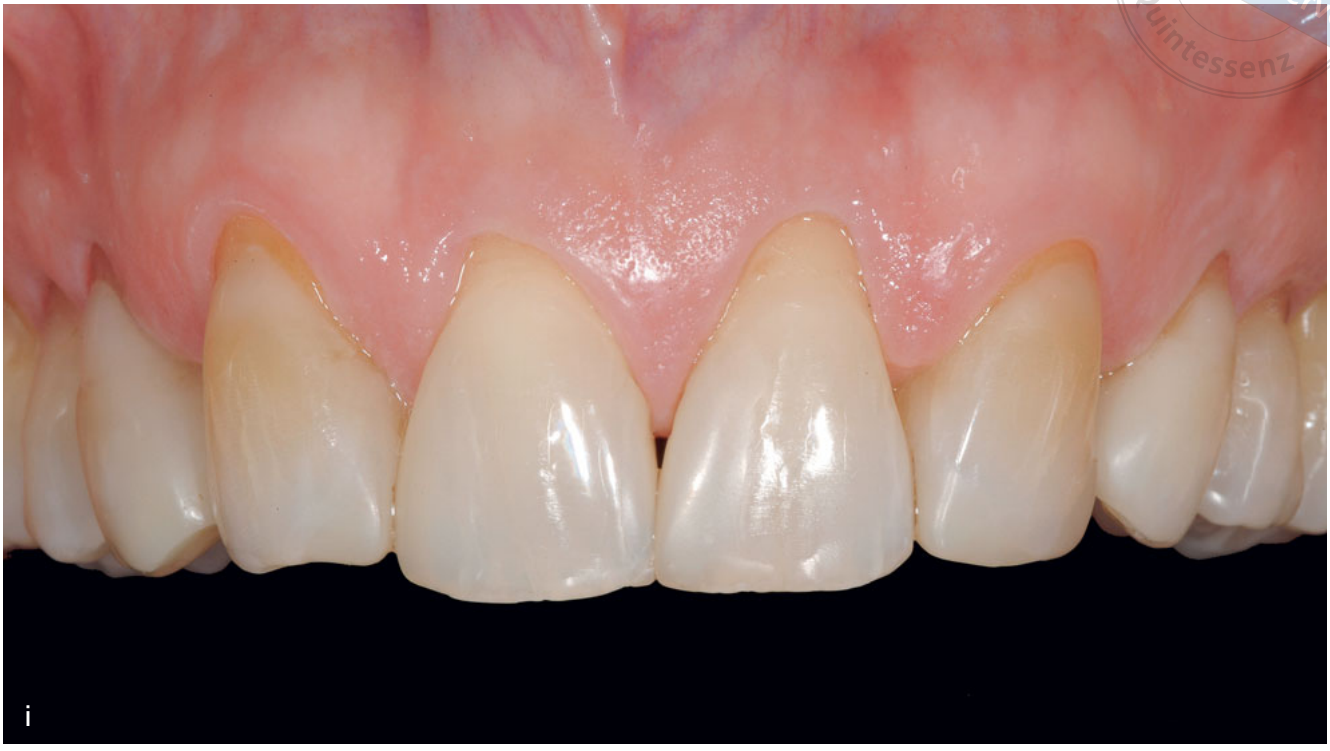


Fig 3 (a to c) Preoperative view showing a 50-year-old patient who sought esthetic improvement. Note the presence of diastemas and the missing lateral incisors, both of which impact smile harmony. Note that the teeth were bleached prior to the restorative procedures. (d and e) Due to financial constraints, a simple and highly conservative approach was selected using only direct bonding to close the diastemas and improve the smile composition. (f and g) Seven-year follow-up showing satisfactory clinical behavior of the direct composite treatment approach. Note that there is, however, some slight marginal degradation of the cervical restorations. Such restorations are considered successful, with minor failures (Bravo margin score, according to the USPHS evaluation system). (h and i) Thirteen-year follow-up showing the same restorations after the repair of the cervical restorations (sandblasting, dentin bonding adhesive [DBA] application, and margin repair with flowable composite resin). The implication of a minor failure is the repair of the restoration, as opposed to a major or definite failure which necessitates full restoration replacement. Such a case also demonstrates the medium- to long-term potential of composite resin when used in an ideal environment such a single-operator, private practice.

any definitive statement. Moreover, one should not ignore a possible interdependence between this specific review factor (treatment environment) and another covariable such as the target population; for instance, a patient at a higher socioeconomic level is more likely to select a private practice over an academic or social clinic, potentially favoring superior restoration longevity through better oral hygiene and reduced carious risk.[17,23]

Influence of operators

There are few multi-center, multi-operator studies compared with single- or multi-operator studies performed in single private or academic centers (Table 5d). In particular, the results of three studies[26,27,39-42] demonstrated insufficient restoration performance, therefore extending the YFR range compared with single-operator studies. Single-operator studies clearly demonstrated lower YFR upper range limits, with 5%, 5.3%, and 2.8% for short-, mid-, and long-term observation periods, respectively.

In single-operator studies, however, the treatment follow-up and performance evaluation are often assumed by the operator. Therefore, one cannot ignore the potential bias and influence on any reintervention decision (in the sense of reduced intervention), which possibly triggers lower failure rates, especially in mid- and long-term studies.[24,32]

Conclusions and prospective implications

The present review analyzed studies evaluating the performance of anterior composite restorations from 1975 to 2016. A meta-analysis approach proved inappropriate due to a structural lack of homogeneity in clinical study protocols, the number of unidentified confounding factors (patient hygiene, carious risk, age, social status, tooth biomechanical status, and function), the inherent structural variability in placing direct composite restorations (operator, treatment environment, observation period, assessment method), and the limited overall number of studies. However, an attempt to mathematically level the results of coherent studies makes sense when a precise estimate of a treatment outcome is possible and meaningful. On the contrary, in this review the variability in the performance of restorative systems or procedures among various operators or environments was considered majorly significant. Ranges of YFRs were used to conduct this review, which preserved the full informative potential of available, relevant data.

Based on the four selected primary and secondary grouping factors (timeframe, composite filler technology and curing mode, environment, and operator), it appears that the composite technology or curing mode have limited or no impact on restoration performance across all timeframes, while treatment environment and number of operators have the potential to impact the longevity or failure rates of anterior direct composite restorations, bearing in mind the potential bias in studies with a single operator/evaluator. Furthermore, the range of failure/survival rates also appears to be product-dependent; this parameter often overruled other investigated grouping factors.

There is an obvious need to improve the significance and relevance of clinical studies in restorative dentistry for all observation intervals. For instance, the use of evaluation criteria and methods that are more discriminative than the USPHS system seems highly desirable for short-term studies. The formerly used methods for observing restoration success through macro photography, replicas, and electron microscopy or even spectrophotometry might limit the bias of operator judgment. For medium- and long-term evaluations, randomized controlled prospective multi-center studies that attempt to analyze known confounding factors and give a clear definition of success and failure are also needed. Until such a demanding research approach can be implemented, the present review strategy has introduced a useful tool and strategy to identify trends and make some conclusive statements about the performance of various direct restorative systems used in anterior teeth.

Disclaimer

The authors declare no conflicts of interest.

References

1. Dietschi D. Free-hand composite resin restorations: a key to anterior aesthetics. Pract Periodontics Aesthet Dent 1995;7: 15–25.
2. Vanini L, Mangani F. Determination and communication of color using the five color dimensions of teeth. Pract Periodontics Aesthet Dent 2001;13:19–26.
3. Fahl N Jr. Mastering composite artistry to create anterior masterpieces: Part 1. J Cosmetic Dent 2010;26:56–68.
4. Dietschi D, Fahl N Jr. Shading concepts and layering techniques to master direct anterior composite restorations: an update. Br Dent J 2016;221:765–771.
5. Chadwick B, Treasure E, Dummer P, et al. Challenges with studies investigating longevity of dental restorations – a critique of a systematic review. J Dent 2001;29:155–161.
6. 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.
7. Heintze SD, Rousson V, Hickel R. Clinical effectiveness of direct anterior restorations – a meta-analysis. Dent Mater 2015;31: 481–495.
8. Heidich AB. Meta-analysis in medical research. Hippokratia 2010;14(suppl 1):29–37.
9. O'Rourke K. An historical perspective on meta-analysis: dealing quantitatively with varying study results. J R Soc Med 2007;100:579–582.
10. Hickel R, Manhart J. Longevity of restorations in posterior teeth and reasons for failure. J Adhes Dent 2001;3:45–64.
11. 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.
12. 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.
13. Browning WD, Dennison JB. A survey of failure modes in composite resin restorations. Oper Dent 1996;21:160–166.
14. Cvar JF, Ryge C. Criteria for the clinical evaluation of dental restorative materials. Washington DC: US Department of Health, Education, and Welfare, 1971.
15. Ryge G, Snyder M. Evaluating the clinical quality of restorations. J Am Dent Assoc 1973;87:369–377.
16. Joelson K, Herr P, Holz J, Baume LJ. Contrôles clinique, macrophotographique et microphotographique de 4 composites résineux. Rev Mens Suisse Odonto Stomatol 1981;91:877–897.
17. Christensen RP, Christensen GJ. In vivo comparison of a microfilled and a composite resin: a three-year report. J Prosthet Dent 1982;48:657–663.
18. Schalpbach T, Hotz P, Roulet JF. Ein Klinischer Vergleich konventionell und mikrogefüllter komposits für klasse-III-Füllungen – Resultate nach zwei Jahren. Schmeiz Mschr Zahnheilk 1982;92:667–860.
19. Weber-Gaud ML, Herr P, Holz J. Contrôle du comportement clinique de 4 composites après 1 an Rev Mens. Suisse Odonto Stomatol 1982;92:1013–1018.
20. van der Veen HJ, Pilon HF, Henry PP. Clinical performance of one microfilled and two hybrid anterior composite resins. Quintessence Int 1989;20:547–550.
21. Smales RJ, Gerke DC. Clinical evaluation of four anterior composite resins over five years. Dent Mater 1992;8:246–251.
22. Reusens B, D'hoore W, Vreven J. In vivo comparison of a microfilled and a hybrid minifilled composite resin in Class III restorations: 2-year follow-up. Clin Oral Investig 1999;3:62–69.
23. Närhi TO, Tanner J, Ostela I, et al. Anterior Z250 resin composite restorations: one-year evaluation of clinical performance. Clin Oral Investig 2003;7:241–243.
24. Loguercio AD, Lorini E, Weiss RV, et al. A 12-month clinical evaluation of composite resins in class III restorations. J Adhes Dent 2007;9:57–64.
25. van Dijken JW. A clinical evaluation of anterior conventional, microfiller, and hybrid composite resin fillings: a 6-year follow-up study. Acta Odontol Scand 1986;44: 357–367.
26. van Noort R, Davis LG. A prospective study of the survival of chemically activated anterior resin composite restorations in general dental practice: 5-year results. J Dent 1993;21:209–215.
27. Jokstad A, Mjör IA, Nilner K, Kaping S. Clinical performance of three anterior restorative materials over 10 years. Quintessence Int 1994;25:101–108.
28. De Trey E, Lutz F. Beurteilung von 16 Monate alten unterschiedlich aufgebauten, approximalen Frontzahnfüllungen. Schweiz Mschr Zahnheilk 1977;87:694–704.
29. Lutz F, Ochsenbein H, Lüscher B. Nachkontrolle von 1¼ jährigen Adhäsivfüllungen. Schweiz Mschr Zahnheilk 1977;87:126–136.
30. Ferrari M, Mason PN, Bertelli E. A new dentinal bonding agent and microfilled resin system: a 2-year clinical report. Quintessence Int 1990;21:875–881.
31. Komatsu M, Wakui A, Obara M, Kubota M, Okuda R. Two-year clinical observation of light-cured composite resin restorations placed with a dentinal bonding agent. Quintessence Int 1990;21:1001–1006.
32. Qvist V, Strøm C. 11-year assessment of Class-III resin restorations completed with two restorative procedures. Acta Odontol Scand 1993;51:253–262.
33. Millar BJ, Robinson PB, Inglis AT. Clinical evaluation of an anterior hybrid composite resin over 8 years. Br Dent J 1997;182: 26–30.
34. Peumans M, Van Meerbeek B, Lambrechts P, Vanherle G. The 5-year clinical performance of direct composite additions to correct tooth form and position. I. Esthetic qualities. Clin Oral Investig 1997a;1: 12–18.
35. Peumans M, Van Meerbeek B, Lambrechts P, Vanherle G. The 5-year clinical performance of direct composite additions to correct tooth form and position. II. Marginal qualities. Clin Oral Investig 1997b;1: 19–26.
36. Bachelard B, Becke M, Bonte E, et al. Evaluation clinique d'un système adhésif de quatrième génération dans les restaurations composites antérieures. Revue d'Odonto-Stomatologie 1997;26:11–25.

37. Rule DC, Elliott B. Semi-permanent restoration of fractured incisors in young patients. A clinical evaluation of one "acid-etch" technique. Br Dent J 1975;139: 272–275.
38. Smales RJ. Composite resin restorations. A three-year clinical assessment of four materials. Aust Dent J 1975;20: 228–234.
39. Lucarotti PS, Holder RL, Burke FJ. Outcome of direct restorations placed within the general dental services in England and Wales (Part 1): variation by type of restoration and re-intervention. J Dent 2005a;33: 805–815.
40. Burke FJ, Lucarotti PS, Holder RL. Outcome of direct restorations placed within the general dental services in England and Wales (Part 2): variation by patients' characteristics. J Dent 2005b;33:817–826.
41. Lucarotti PS, Holder RL, Burke FJ. Outcome of direct restorations placed within the general dental services in England and Wales (Part 3): variation by dentist factors. J Dent 2005c;33:827–835.
42. Burke FJ, Lucarotti PS, Holder R. Outcome of direct restorations placed within the general dental services in England and Wales (Part 4): influence of time and place. J Dent 2005d;33:837–847.
43. Moura FR, Romano AR, Lund RG, Piva E, Rodrigues Jr SA, Demarco FF. Three-year clinical performance of composite restorations placed by undergraduate dental students. Braz Dent J 2011;22:111–116.
44. Lutz F, Lüscher B, Ochsenbein H. In vitro evaluation of the adaptation and quality of the margins in various composite systems [in French]. Schweiz Monatsschr Zahnheilkd 1977;87:752–763.
45. Cohen J. A coefficient of agreement for nominal scales. Educational and Psychological Measurements 1960;20:37–46.