European Journal of Prosthodontics and Restorative Dentistry (2024) **32**, 403–414

Success and Survival of Composite Resin Restorations for the Management of Localized Anterior Tooth Wear: A Systematic Review and Meta-Analysis

Keywords

Tooth Wear
Composite Resins
Survival Rate
Tooth Surface Loss
Success Rate
Dahl

Authors

Ibrahim M. Aziz *
(BDS, MClinDent (Pros), M Pros RCSEd)

Matthew Locke §
(BDS, MFDS, PhD, FDSRCS Eng (Rest Dent), FHEA)

Address for Correspondence

Ibrahim M. Aziz *

Email: iaziz@sharjah.ac.ae

* *Department of Restorative Dentistry, College of Dental Medicine, University of Sharjah, Sharjah, United Arab Emirates*

§ *Swansea Bay University Health Board, Department of Restorative Dentistry, Morriston Hospital, Swansea, UK*

Received: 23.05.2023
Accepted: 28.10.2024
doi: 10.1922/EJPRD_2576Aziz12

ABSTRACT

Purpose: To systematically review the literature and assess the success and survival rates of anterior composite restorations used in the management of anterior tooth surface loss, and to estimate complete posterior occlusion re-establishment when a Dahl approach is utilized. Materials and Methods: An electronic search was performed in the following databases: MEDLINE via Ovid and Scopus, for articles published from 1970 to November 2020. The systematic review was performed according to the PRISMA and Meta-analyses guidelines. Only randomized and non-randomized clinical trials, and Cohort studies that involved the exclusive use of direct/indirect anterior composite restorations for the management of localized anterior tooth wear were included. Results: From the 724 studies identified through the initial search, six studies fulfilled the inclusion criteria and were included in the review; three prospective and three retrospective. In total, 141 patients received 1068 direct and indirect composite restorations. Follow-up periods ranged between 5 months and 10 years. The survival rate for anterior composite resin restorations reported in this review was 88% (95% CI: 70% to 98%) over a period of 2 and 10 years; however, high heterogeneity was observed amongst included studies; (I^2 = 97%). Sensitivity analysis reported survival rates of these restorations of 93% (95% CI: 85% to 98%) over a period of 2 and 7 years, (I^2 = 83%). Success rates were reported for these restorations of 68% (95% CI: 44% to 87%) over a period of 2 and 10 years, high heterogeneity; (I^2 = 98%). The success of composite Dahl in re-establishing posterior occlusion was 85% (CI: 73% to 94%). Conclusions: The result of this systematic review and meta-analysis support the use of anterior composite restorations as a short-medium term option for the management of tooth wear. In the long-term, patients should be informed that these restorations will require monitoring, repairs, or replacements.

INTRODUCTION

Tooth wear (TW) also known as tooth surface loss (TSL) is defined as the pathologic non-carious loss of dental hard tissues.[1] Tooth wear is a well-recognized condition affecting the general population of many developed countries.[2] It can be regarded as a normal physiologic process that takes place throughout an individual's life, however, it is considered to be pathologic when it affects the younger patient or when it adversely affects an individual's dental health.[3]

TW is a generic term that describes the process of dental hard tissue loss. It includes individually recognised processes of attrition, erosion, abrasion, and abfraction, these factors can act solely or, more often as an interplay resulting in multifactorial tooth surface loss. Patients initial realisation of tooth wear often relate to aesthetic issues firstly and then functional difficulties if the wear process progresses.[4]

Management of tooth wear necessitates knowledge of these differing aetiologies, presentations, and of preventive measures in order to select the most appropriate treatment modality for each case. This ranges from non-invasive preventive regimens, through direct composite resin restorations to significant indirect extracoronal restorations and/or removable prostheses. A recent European consensus highlights the importance of advocating an "additive" rather than a "subtractive" approach for managing tooth wear to minimize tooth structure loss and to preserve tooth vitality.[5]

The Dahl approach is often described in the literature as the process of axial tooth movement that is seen when an appliance or a restoration is placed at an increased occlusal vertical dimension (OVD) in an attempt to gain space for managing localized tooth surface loss.[6,7] Darbar and Hemmings (1997) describe the use of composite placed at an increased OVD used in the management of localized anterior tooth surface loss.

Composite resin in the management of localized anterior tooth wear has been well documented.[8–12] Many studies have shown favourable short to medium-term survival rates.[11] These restorations offer the advantage of being conservative, cost-effective and easy to apply with excellent aesthetic results. Several studies have examined the survival of anterior composite Dahl restorations; reporting a broad range of survival rates from less than 50%[13] to a 100%.[9]

Whenever TW necessitates an active restorative intervention, a conservative minimally invasive approach should be adopted.[5] By doing so, biological complications that would arise when adopting an invasive approach would be avoided together with the fabrication of durable aesthetic restorations with favourable pulpal health and patient satisfaction levels.[13] Additionally, worn teeth usually present with structurally compromised tooth structure, thus, the preservation of remaining tooth structure is of paramount importance. This will ensure that future restorative options are feasible, a 'dynamic restorative concept' as described by Creugers; in which "dynamic" means maintaining several options for new or repeated options when the previous treatment fails.[14]

Direct and indirect materials and techniques can be used for the management of severely worn teeth.[15] Traditionally, worn teeth were restored using conventional prosthodontic techniques by means of full and partial coverage extra-coronal restorations.[5] Such restorations are invasive and require the removal of dental hard tissues for teeth that are already structurally compromised, which may further compromise the prognosis of these teeth. These restorations may also be more likely to elicit a negative peri-radicular tissue reaction; in a radiographic study, it was found that almost one-fifth of crowned teeth were associated with radiographic signs of peri-radicular pathoses.[16] However, such techniques may still be used to restore severely worn teeth, particularly where more conservative options were used and repeatedly failed.

AIMS AND OBJECTIVES

The aims of this systematic review and meta-analysis are to systematically review the literature from 1970 to November 2020, with the intention to assess the success and survival rates of anterior composite restorations used in the management of anterior tooth surface loss and to estimate the percentage of complete posterior occlusion re-establishment when a Dahl approach is utilized.

OBJECTIVES

A) Determine the longevity (expressed by the number of years the restoration survived) and/or the survival/failure rates (expressed by percentage survival) of anterior composite restorations used in the management of localized anterior tooth wear at two different levels:

- Major failure
- Combined major and minor types of failure

B) Estimate the percentage of complete occlusal re-establishment of posterior teeth when anterior composite restorations are placed at increased occlusal vertical dimension (OVD).

MATERIALS AND METHODS

The present systematic review was conducted following the Preferred Reporting Items for Systematic reviews and Meta-analysis (PRISMA).[17–19] The PRISMA checklist was followed. The systematic review was registered at the NIH International Prospective Register of Systematic Reviews (PROSPERO) (CRD42020212492).[20] The Population, Intervention, and Outcome (PIO) framework was used in formulating the research question and is as follows: "What are the success and survival rates (O) of anterior composite restorations (I) used in the management of anterior tooth surface loss (P)?" where Survival is defined as any restoration that had remained in service and had not been categorized as category C on the modified USPHS criteria or had not been replaced and Success is defined as any restoration that had remained in service and and had not been categorized as category B or C on the modified USPHS criteria and had not been repaired or replaced.

SEARCH STRATEGY

A comprehensive literature search was conducted by one reviewer (I.A.) through an electronic search in two databases; MEDLINE via Ovid and Scopus. The electronic search was performed on the 6th of November 2020. Nineteen seventy was selected as the starting point for the search as it was the period

where the use of composite increased significantly.[21] Search terms and a detailed search strategy for each database is illustrated in Table 1 and in Figure 1 and 2. Only studies published in the English language were included. The asterisk (*) wildcard was used to identify alternate word endings. Grey literature was also explored in OpenGrey (http://www.opengrey.eu/). Moreover, citation mining via cross-reference inspection of the selected studies was also performed to look for any potentially eligible studies. The PRISMA flowchart of the systematic review search is included in the result section Figure 3. All the articles were added to Mendeley Reference Manager Program, and duplicates were removed using the same program.

Table 1. Search terms used in Ovid and Scopus databases (November 2020).

Database	Search terms
MEDLINE via Ovid	A) Composite resins OR composite OR composite build up*. B) Tooth wear OR tooth abrasion OR tooth attrition OR tooth erosion OR tooth surface loss. C) A AND B. Filters: Publication date from 01/01/1970 to 06/11/2020).
Scopus	(TITLE-ABS-KEY (composite* OR {Composite resin*} OR {Composite build up*})) AND (TITLE-ABS-KEY ({Tooth wear} OR {Tooth surface loss} OR {Tooth abrasion} OR {Tooth attrition} OR {Tooth erosion})) AND (LIMIT-TO (PUBYEAR , 1970-2020) AND (LIMIT-TO (LANGUAGE , "English"))

1. Composite Resins/
2. composite.ti,ab.
3. composite build up*.ti,ab.
4. 1 or 2 or 3
5. exp tooth wear/ or tooth abrasion/ or tooth attrition/ or tooth erosion/
6. tooth wear.ti,ab.
7. tooth abrasion.ti,ab.
8. tooth attrition.ti,ab.
9. tooth erosion.ti,ab.
10. tooth surface loss.ti,ab.
11. 5 or 6 or 7 or 8 or 9 or 10
12. 4 and 11
13. limit 12 to english language
14. limit 13 to humans

Figure 1: Search strategy used in MEDLINE via Ovid (November 2020).

(TITLE-ABS-KEY (composite* OR {Composite resin*} OR {Composite build up*}) AND (TITLE-ABS-KEY ({Tooth wear} OR {Tooth surface loss} OR {Tooth abrasion} OR {Tooth attrition} OR {Tooth erosion})) AND (LIMIT-TO (PUBYEAR , 2020) OR LIMIT-TO (PUBYEAR , 2019) OR LIMIT-TO (PUBYEAR , 2018) OR LIMIT-TO (PUBYEAR , 2017) OR LIMIT-TO (PUBYEAR , 2016) OR LIMIT-TO (PUBYEAR , 2015) OR LIMIT-TO (PUBYEAR , 2014) OR LIMIT-TO (PUBYEAR , 2013) OR LIMIT-TO (PUBYEAR , 2012) OR LIMIT-TO (PUBYEAR , 2011) OR LIMIT-TO (PUBYEAR , 2010) OR LIMIT-TO (PUBYEAR , 2009) OR LIMIT-TO (PUBYEAR , 2008) OR LIMIT-TO (PUBYEAR , 2007) OR LIMIT-TO (PUBYEAR , 2006) OR LIMIT-TO (PUBYEAR , 2005) OR LIMIT-TO (PUBYEAR , 2004) OR LIMIT-TO (PUBYEAR , 2003) OR LIMIT-TO (PUBYEAR , 2002) OR LIMIT-TO (PUBYEAR , 2001) OR LIMIT-TO (PUBYEAR , 2000) OR LIMIT-TO (PUBYEAR , 1999) OR LIMIT-TO (PUBYEAR , 1998) OR LIMIT-TO (PUBYEAR , 1997) OR LIMIT-TO (PUBYEAR , 1996) OR LIMIT-TO (PUBYEAR , 1995) OR LIMIT-TO (PUBYEAR , 1994) OR LIMIT-TO (PUBYEAR , 1993) OR LIMIT-TO (PUBYEAR , 1992) OR LIMIT-TO (PUBYEAR , 1991) OR LIMIT-TO (PUBYEAR , 1990) OR LIMIT-TO (PUBYEAR , 1989) OR LIMIT-TO (PUBYEAR , 1988) OR LIMIT-TO (PUBYEAR , 1987) OR LIMIT-TO (PUBYEAR , 1986) OR LIMIT-TO (PUBYEAR , 1985) OR LIMIT-TO (PUBYEAR , 1984) OR LIMIT-TO (PUBYEAR , 1983) OR LIMIT-TO (PUBYEAR , 1981) OR LIMIT-TO (PUBYEAR , 1980) OR LIMIT-TO (PUBYEAR , 1979) OR LIMIT-TO (PUBYEAR , 1978) OR LIMIT-TO (PUBYEAR , 1977) OR LIMIT-TO (PUBYEAR , 1976) OR LIMIT-TO (PUBYEAR , 1975) OR LIMIT-TO (PUBYEAR , 1974) OR LIMIT-TO (PUBYEAR , 1973) OR LIMIT-TO (PUBYEAR , 1972) OR LIMIT-TO (PUBYEAR , 1971) OR LIMIT-TO (PUBYEAR , 1970)) AND (LIMIT-TO (LANGUAGE , "English")) View less ^

Figure 2: Search strategy used in Scopus (November 2020).

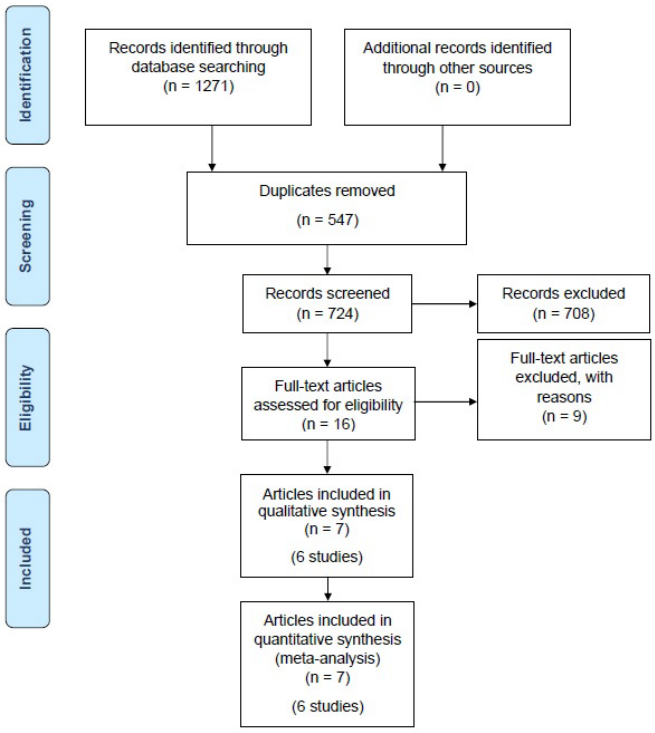

Figure 3: PRISMA flowchart diagram for the followed search strategy.

SELECTION OF STUDIES

Publications were screened by (I.A.) following the inclusion/exclusion criteria, given in Table 2, based on titles initially, then based on the abstracts of the studies, and finally, full-text evaluation of the remaining studies was performed. Only studies that met the inclusion criteria were included in the systematic review. In contrast, studies that did not meet the inclusion criteria were excluded, and the reason for excluding each study following full-text evaluation is given in Table 3.

DATA EXTRACTION AND METHOD OF ANALYSIS

Data tables were created to extract the relative information from the selected studies. Extracted data included: Study author(s) and year, Study type, Number and age of participants, Number of restorations, Location for intervention (maxillary vs. mandibular), Type of intervention (direct vs. indirect composite), Type of composite, Increase in the occlusal vertical dimension (OVD) (amount of increase and period to re-establish posterior occlusion), Follow-up period, Definition of failure, Number of failed restorations, Assessment of intervention, and longevity/survival rate (expressed in years/percentage, respectively). Where relevant data were missing, or there are any uncertainties, study authors were contacted via email and/or telephone and requested to respond. A single reminder email was sent when a response was not received.

Meta-analysis allows finding a pooled estimate across a group of studies (subgroup analysis) or overall the studies (overall analysis) for the point estimate and confidence interval of a single proportion. Subgroup analysis was performed for a subset of different groups of studies according to some criteria. Pooled estimates from meta-analysis were found for these subgroups in addition to any overall analysis.

Table 2. Inclusion and Exclusion Criteria.

Inclusion Criteria	Exclusion Criteria
1) Clinical studies involving the exclusive use of direct/ indirect anterior composite restorations for managing localized anterior tooth wear.	1) Studies using other restorative interventions (e.g., gold, ceramic restorations, RPDs) alongside anterior composite restorations to manage tooth wear.
2) Adults of any age or gender with tooth wear, including attrition, erosion, and abrasion.	2) Studies focused on the survival of composites used for non-carious cervical lesions (NCCL).
3) Restorations with a follow-up period of at least 5 months.	3) Excluded study types: • Meta-analyses. • Systematic reviews. • Narrative reviews. • Case series/case reports. • Animal/laboratory-based studies.
4) Included study types: Randomized and non-randomized controlled trials. Prospective studies. Retrospective studies.	4) Studies not published in the English language.
5) Publications limited to the English language.	

Table 3. Excluded studies based on full-text assessment with reason(s) for exclusion.

Study	Reason for exclusion
1. (Loomans et al. 2018)[25]	Involved restoration of posterior teeth with composite
2. (Brignardello-Petersen 2018)[26]	A review of [25] study
3. (Bartlett and Varma 2017)[27]	Involved restoration of posterior teeth with composite
4. (Milosevic and Burnside 2016)[11]	Involved restoration of posterior teeth with composite
5. (Clark 2012)[28]	Case report
6. (Hamburger et al. 2011)[29]	Involved restoration of posterior teeth with composite
7. (Smales and Berekally 2007)[30]	Involved restoration of posterior teeth with composite/crowns
8, (Yip et al. 2003)[31]	A review article
9. (Darbar and Hemmings 1997)[32]	A review article

Due to the small number of studies, no exploration of bias via funnel plots could be carried out. However, statistical heterogeneity was measured by using I^2.

Fixed-effects meta-analysis assumes that variation was limited to what was within the studies included in the analysis, and not between the studies. It weighed the contribution of each study in inverse proportion to the standard error (squared) and was used when heterogeneity is low. By contrast, random-effect meta-analysis assumes that variation can occur both within and between the studies included in the analysis. This method is used when heterogeneity is of moderate to large strength. The R Foundation version 3.6.1 (R Foundation for Statistical Computing, Vienna, Austria) was used for data analysis.

In some cases, obvious outliers occur for data from specific studies. A sensitivity analysis repeats the meta-analysis with outliers removed to see how they affect results.

Meta-analysis of a single proportion gives a result in terms of the proportion directly and associated 95% confidence intervals for all studies, pooled (average) estimates for subgroups (as appropriate), and a pooled (average) overall estimate for all studies (as appropriate). It uses a transformation of data to ensure that pooled point estimates and associated 95% confidence intervals always lie in the range 0 to 1; in plain terms, this ensures that one cannot have a proportion of something" that is greater than 1 (or 100%) or less than 0 (or 0%), as required. As is standard in such cases, the "Arcsine" transformation via the "metaprop" in R V3.6.1. was used here to carry out meta-analyses. Other transformations (double arcsine, logit, etc.) were also tested, although this did not lead to a large change in the results of meta-analysis.

QUALITY ASSESSMENT OF INCLUDED STUDIES

Articles were critically appraised based on the design of each study. The 2nd version of the Cochrane risk-of-bias tool for randomized trials (RoB 2) was chosen as the quality assessment tool for randomized clinical trials if included.[22] For cohort studies (prospective and retrospective studies), the Newcastle-Ottawa scale (NOS) was used for risk assessment.[23]

RESULTS

STUDY SELECTION

Figure 3 demonstrates the PRISMA diagram flowchart for the search process. In total, 1271 studies were retrieved through an electronic search of two databases (568 from MEDLINE via Ovid and 703 from Scopus), no additional records were identified using other sources (hand search and grey literature). Of these 1271 studies, 547 were duplicates and were removed. Of the remaining 724 studies, 708 were excluded after screening the titles and abstracts (645 by titles and 63 by abstracts). Sixteen articles were eligible for full-text assessment. Nine of these articles were excluded, with reasons given in Table 2.

A total of seven articles have met the inclusion criteria that were set for the review. One article[24] was not included in the analysis because it was later reported as a follow-up study by Al-Khayatt and colleagues.[10]

DATA COLLECTION AND ANALYSIS

Six studies were included in the qualitative and quantitative analysis of this systematic review.[8–10,13,33,34] Data extraction tables for the six included studies were completed and are illustrated in Appendix 1. The extracted data include author(s), year, study design, number of patients and restorations, location and type of intervention, type of composite, amount of OVD increase, follow-up period, the definition of failure, number of failed restorations, assessment of intervention, longevity/survival rate.

The included studies were cohort studies (three prospective and three retrospective studies). One study involved the restoration of maxillary teeth only,[9] two articles (same study) involved the restoration of mandibular teeth only,[10,24] and four studies involved the placement of anterior restorations in both arches.[8,13,33,34] In total, 141 patients received 1068 composite restorations. The number of patients and restorations in each study ranged between 12 patients, 75 restorations[9] and 41 patients, 296 restorations.[33] Most of these restorations were direct composite restorations (809 out of 1068), followed by indirect composite restoration (229 out of 1068), and a combination of direct and indirect composite (30 out of 1068). The follow-up periods ranged between 5 months and ten years.

TYPE OF COMPOSITE MATERIAL

The types of composite material used were as follows:

- Microfilled Durafill composite (Heraeus Kulzer, Hanau, Germany)[8,13,34]
- Microhybrid Herculite XRV composite (Kerr, Orange, CA, USA)[8,10,34]
- Enamel plus HFO Microhybrid composite (Micerium)[13]
- Gradia Microhybrid composite (GC, Japan)[13]
- CeramX Duo Nanofilled composite (Dentsply UK Ltd., Surrey, UK)[33]
- Ceromer Artglass® (Heraeus Kulzer, Hanau, Germany)[8,9,13]

AETIOLOGY OF TOOTH WEAR

The aetiology of tooth wear was identified in 5 out of 6 studies and is shown in Table 4. One study did not mention the aetiology of presented TSL.[34] The study by Poyser and Al-Khayatt had originally 18 patients, but only 14 and 15 patients could have been reassessed at 2.5 and 7 years, respectively:

NATURE OF TOOTH PREPARATION PRIOR TO PLACEMENT OF COMPOSITE RESTORATIONS

Prior to placement of the restorations, some form of tooth preparation was performed in some studies, where only sharp enamel margins or undermined enamel was reduced.[33,34] The study by Poyser *et al.* (2007) was a split-mouth design in which some teeth on one side of the arch were prepared with a 1 mm deep circumferential enamel chamfer margin of 0.5mm in thickness, whereas no tooth preparation was undertaken in the contralateral side. Details of the nature of tooth preparation were not mentioned in three studies.[8,9,13]

Table 4. Aetiology of tooth wear in 4 out of 6 studies included in the review.

Aetiology of tooth wear	Number of patients
Primarily erosion	62
Primarily attrition	15
Primarily abrasion	2
Multifactorial	49

AMOUNT OF OVD INCREASE AND RE-ESTABLISHMENT OF POSTERIOR OCCLUSION

The occlusal vertical dimension (OVD) was increased in all studies. However, the amount of OVD increase was only mentioned in some studies with a range between 0.5-5.0 mm.[9,10,24,34] Complete re-establishment of posterior occlusion was reported in 117 out of 141 patients. The time required to re-achieve posterior occlusion ranged from 1.5 months for up to 25.4 months. However, the study by Aljawad and Rees was retrospective; therefore, it was not possible to determine the exact time needed to re-establish posterior occlusion.

ASSESSMENT OF INTERVENTION AND DEFINITION OF FAILURE

All studies used the modified United States Public Health Service (USPHS) system for clinical performance of composite restorations.[35] Most studies described the failure of the restoration as restorations with a USPHS score of 3 or category C.[8,9,13] Hemmings and colleagues defined failure as events in which restorations have been lost, fractured, marginally stained, lost marginal integrity, suffered from noticeable wear, pain or sensitivity, or with endodontic/aesthetic failure.[34]

Poyser, and successively, Al-Khayatt study defined failure of restoration as complete bulk failure with no remaining composite on the tooth surfaces (no loss, replacement, or repair of the restoration).[10,24] Aljawad and Rees described failure as any restorations that required replacement due to total restoration loss or bulk fracture.[33]

QUALITY ASSESSMENT

The risk of bias of the studies included in the meta-analysis was assessed. Six cohort studies[8–10,13,33,34] were assessed by (I.A.) and (M.L.) separately using the Newcastle-Ottawa quality assessment scale for cohort studies. An agreement was

reached between both reviewers Table 5; the included studies were given scores of between 7 and 8 stars, which indicates that the studies are of good quality with low risk of bias.[36] The Cochrane risk-of-bias tool (RoB2) for randomized trials was not used as the search result did not involve any randomized controlled trials.

QUANTITATIVE ANALYSIS

SURVIVAL WHEN CONSIDERING MAJOR FAILURE ONLY

The result of this meta-analysis is presented in the forest plot shown in Figure 4. In the vertical axis of the forest plot, the studies are arranged according to the type of composite material used in the study (direct vs. indirect). The number of events indicates the number of restorations that had a major type of failure, that means any restoration that had been categorized as category C using the modified USPHS criteria; in different terms, any restoration that had been lost, replaced, or had evident inadequacies and were clinically unacceptable. There was too much heterogeneity indicated by I^2 of 98% to find a reliable overall estimate for all studies. The heterogeneity of these studies could be related to the different types of composite used with different mechanical and wear characteristics that can affect the survival of those restorations in each study. Additionally, from the forest plot, it can be noted that the study by Gulamali *et al*. is an outlier compared to the other studies; this might be a reflection of the long follow-up period of this study (10 years) in which the longevity of these restorations is compromised for such a long period.

Regardless, an overall pooled estimate is given in the forest plot shown in Figure 5. From the meta-analysis, the failure rate of these restorations when considering major failure only is 12%

Table 5. Summary of quality assessment for the studies included in the meta-analysis using the Newcastle-Ottawa scale (NOS) for cohort studies.

Study	Selection (a maximum of 4 stars)	Comparability (a maximum of 2 stars)	Outcome (a maximum of 3 stars)	Total
(Hemmings et al. 2000)[34]	✱ ✱ ✱	✱ ✱	✱ ✱ ✱	8
(Gow and Hemmings 2002)[9]	✱ ✱ ✱	✱	✱ ✱ ✱	7
(Redman et al. 2003)[8]	✱ ✱ ✱	✱ ✱	✱ ✱ ✱	8
(Gulamali et al. 2011)[13]	✱ ✱ ✱	✱ ✱	✱ ✱ ✱	8
(Al-Khayatt et al. 2013)[10]	✱ ✱ ✱	✱	✱ ✱ ✱	7
(Aljawad and Rees 2016)[33]	✱ ✱ ✱	✱ ✱	✱ ✱ ✱	8

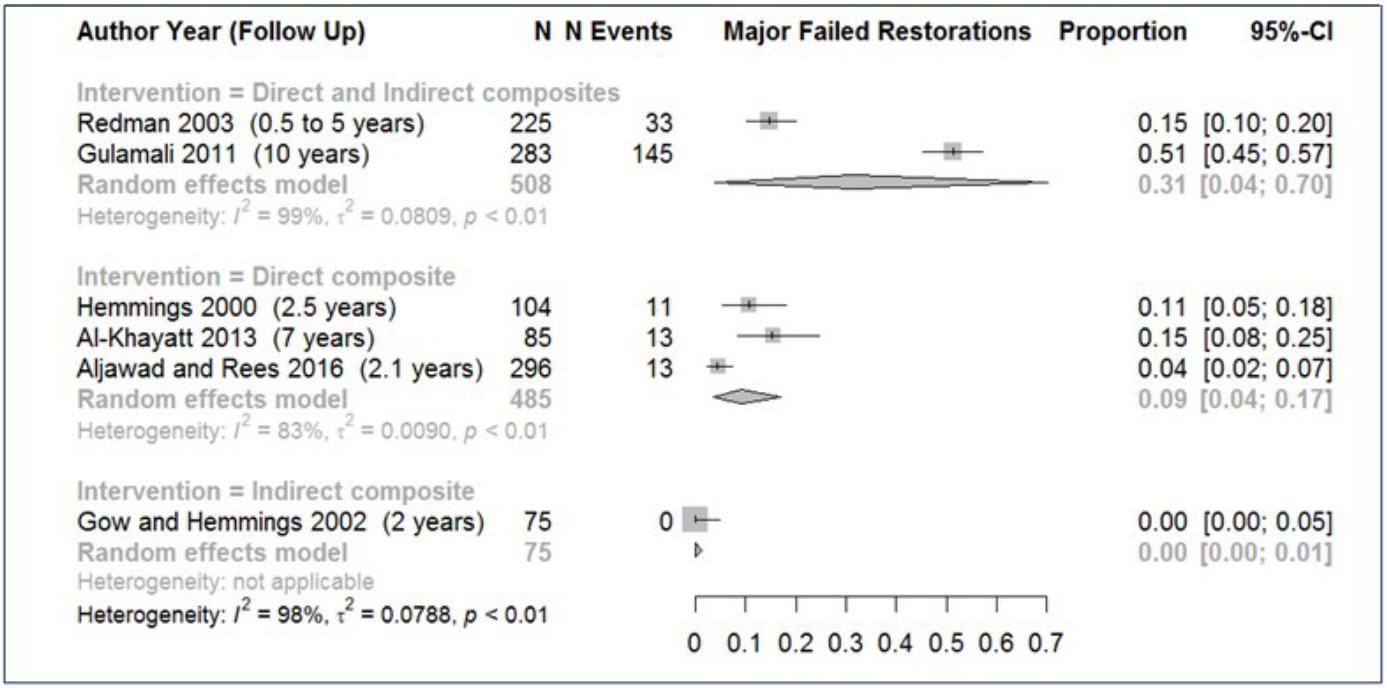

Figure 4: Meta-analysis for major type of failure with no overall pooled estimate.

(95% CI: 2% to 30%), which reflect to a survival rate of anterior composite restorations when used for the management of localized anterior tooth surface loss of 88% (95% CI: 70% to 98%).

A sensitivity analysis was carried out which repeats the meta-analysis with the outlier removed to see how it affects the results *(Figure 6)*. Therefore, it was possible to give an overall pooled result for all studies as overall heterogeneity is a little less (I^2 is 83%). From this meta-analysis, the failure rate of these restorations when considering major failure only is 7% (95% CI: 2% to 15%), which reflect to a survival rate of anterior composite restorations when used for the management of localized anterior tooth surface loss of 93% (95% CI: 85% to 98%).

SURVIVAL WHEN CONSIDERING COMBINED MAJOR AND MINOR TYPES OF FAILURE

The result of this meta-analysis is presented in the forest plot shown in Figure 7 The number of events here indicates the number of restorations that had combined major and minor

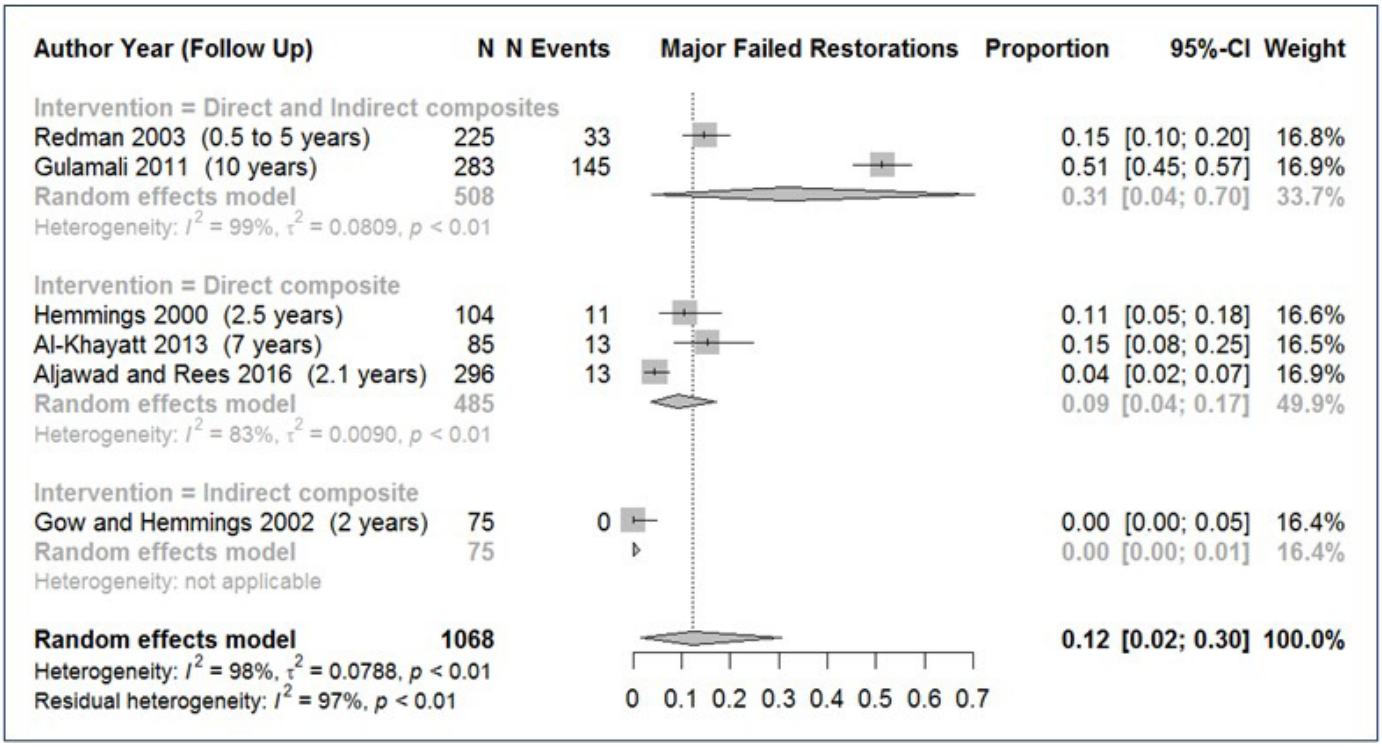

Figure 5: Meta-analysis for major type of failure with an overall pooled estimate.

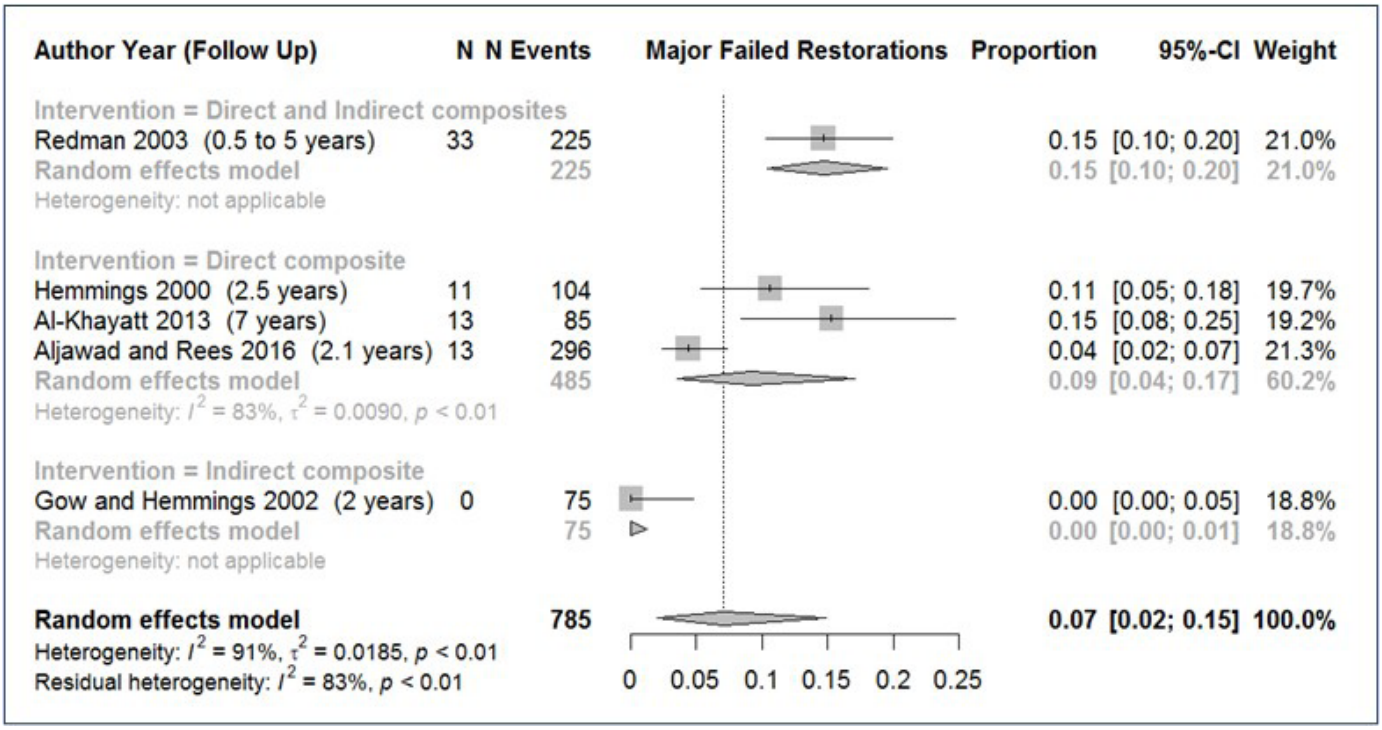

Figure 6: Sensitivity analysis for major type of failure excluding the Gulamali study with an overall pooled estimate.

types of failure, which means any restoration that had a major failure as described above in addition to any restoration that had been categorized as category B using the modified USPHS criteria; in different terms, any restoration with some shortcomings that required monitoring, refinishing or repair but still within clinically acceptable limits. Again, there was a large heterogeneity indicated by I^2 of 98% to find a reliable overall estimate for all studies.

Sensitivity analysis was carried out *(Figure 8)*. No significant change in the heterogeneity was evident even when excluding the Gulamali study; I^2 value continued to be remarkably high (97%). Nonetheless, from this meta-analysis, the failure rate of these restorations when considering combined major and minor types of failure is 32% (95% CI: 13% to 56%), which reflect to a success rate of anterior composite restorations when used for the management of localized anterior tooth surface loss of 68% (95% CI: 44% to 87%).

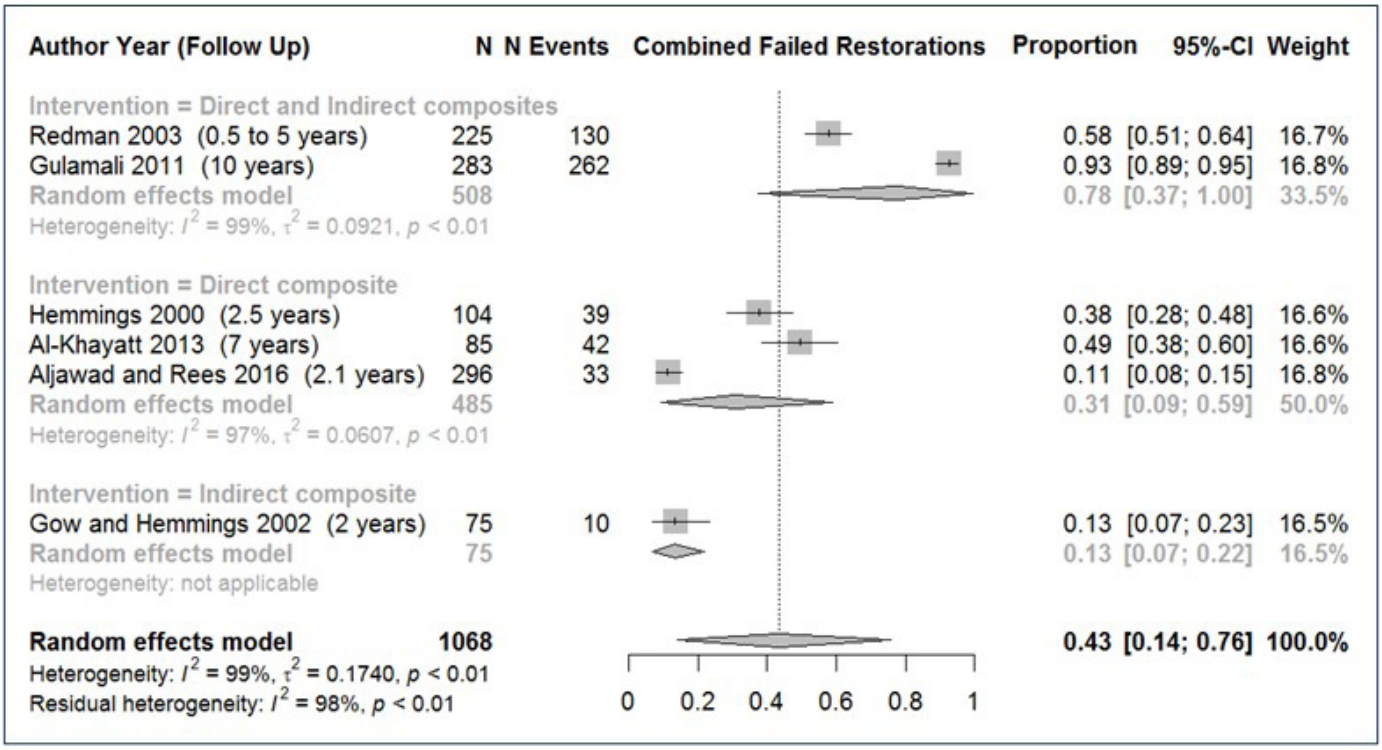

Figure 7: Meta-analysis for combined major and minor types of failure with an overall pooled estimate.

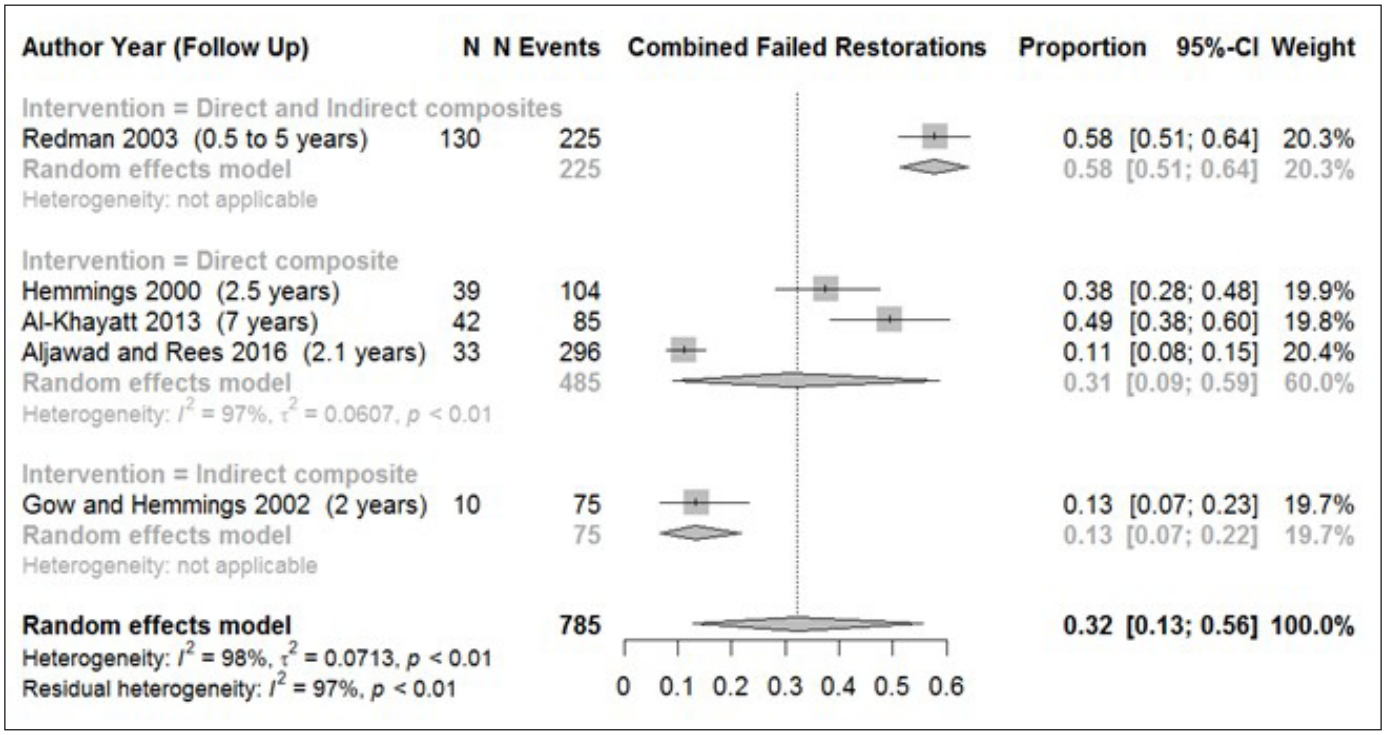

Figure 8: Sensitivity analysis for combined major and minor types of failure excluding the Gulamali study with an overall pooled estimate.

POSTERIOR OCCLUSION RE-ESTABLISHMENT

The result of this meta-analysis is presented in the forest plot shown in Figure 9. In the vertical axis of the forest plot, the studies are arranged according to the year of publication, from the oldest to the most recent. The number of events indicates the number of subjects in which posterior occlusion failed has failed to re-establish.

From the meta-analysis, the point estimates indicate that the proportion of people who will fail to achieve complete posterior occlusal re-establishment is 15% (95% CI: 6% to 27%), which reflect to a success rate of anterior Dahl approach to re-establish posterior occlusion of 85% (CI: 73% to 94%). There were no obvious trends with follow-up time.

DISCUSSION

This systematic review and meta-analyses were aimed to assess the evidence that relates to the success and survival rates of composite restorations for the management of localized anterior tooth surface loss, and to give an estimate of the success of anterior composite Dahl approach to re-establish posterior occlusion after an increase in the OVD. Three prospective and three retrospective studies were included that involved 1068 direct and indirect composite restorations placed in 141 patients. The follow-up period for these restorations ranged from 0.5-10 years.

A previous systematic review was conducted by Ahmed and Murbay (2016) to investigate the survival rates of those restorations used for the same purpose, the study demonstrated that there were inconsistencies in reporting the restoration survival rates between studies.[37] Some of the included studies reported the survival rates of composites, while other reported a Median Survival Time (MST). Additionally, some of the numbers reported in the review were incorrect, which might have affected the results; the review reported that in the study by Gulamali *et al.*, the number of restorations that had major failure was 202, whereas only 145 has been confirmed by the original author in this study.[13] Thus, the current systematic review was able to pool out the exact number of restorations that had a major failure, and combined major and minor types of failure by contacting the relevant authors where missing information was evident.

SURVIVAL RATE

Composite restorations were shown to have favourable survival rates when used anteriorly to manage localized tooth wear cases. The survival rate reported with this study is 88% (95% CI: 70% to 98%) over a period of 2 and 10 years; however, due to large variations in study design, sample size, type of intervention, and follow-up period, there was considerable heterogeneity indicated by I^2 value of 97%. Therefore, pooled results should be interpreted with caution.

Heterogeneity observed in the first analysis was largely due to the presence of an outlier study,[13] which can conflict with the remaining studies, increasing the degree of heterogeneity. In meta-analyses, heterogeneity is an inevitable observation, and there is no acceptable degree of heterogeneity to make reliable assumptions of the validity of the pooled results.[38] However, one method to address large clinical heterogeneity is to perform a sensitivity analysis (Higgins and Green 2008). A sensitivity analysis is a repetition of the primary analysis (meta-analysis) with the outlier removed to see how it might affect the result.

As a result, a more reliable outcome was generated with a survival rate of composite resin restorations when used to manage localized anterior tooth wear of 93% (95% CI: 85% to 98%) over a period of 2 and 7 years (*Figure 6*). This is slightly more favorable to the results reported by Ahmed and Murbay, who reported a survival rate of composites used for the same manner of nearly 90% and 50% at 2.5 and 6 years, respectively. The current systematic review supports the use of anterior composites in restoring worn teeth at increased OVD with good short-medium term performance.

SUCCESS RATE

The success rate of these restorations was assessed by pooling the number of restorations that had combined major and minor types of failure. Hence, it can be stated that the success rate of these restorations is 68% (95% CI: 44% to 87%) over a period of 2 and 10 years. However, even larger heterogeneity was detected here, which once again suggests that these findings should be quoted cautiously. This can be further explained by the large variation in defining failure and what is and is not

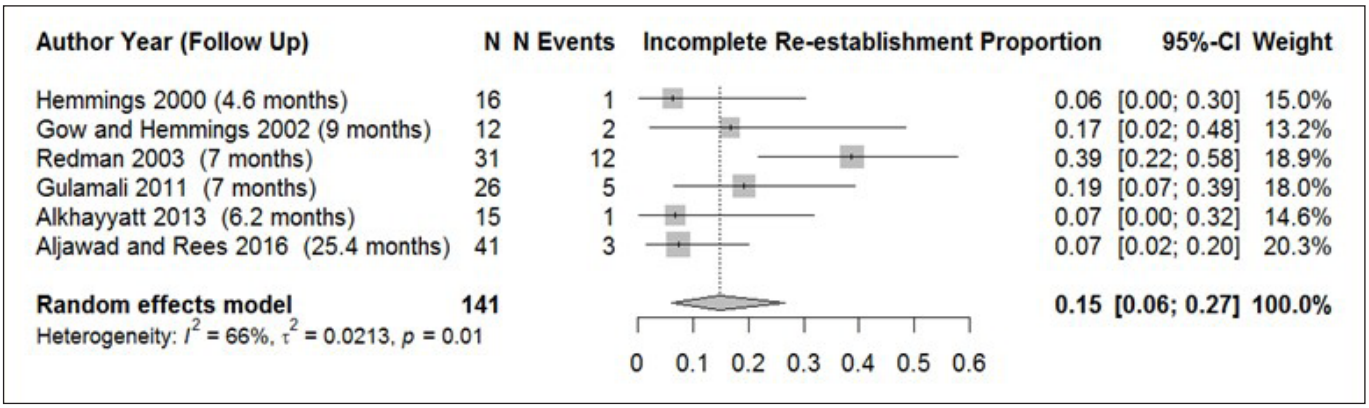

Figure 9: Forest plot for incomplete posterior occlusion re-establishment.

clinically acceptable with the lack of an objective restoration assessment tool between a large number of operators. The results of this review suggest that these restorations should not be considered as a long-term treatment option.

RE-ESTABLISHMENT OF POSTERIOR OCCLUSION

This review reported a success rate of anterior composite Dahl restorations in ensuring complete posterior occlusion reestablishment of 85% CI: 73% to 94%; however, there were few studies to allow analysis by follow-up time. This is comparable to the outcomes reported by Ahmed and Murbay, who reported a re-establishing success rate of 91% within 18 months. However, these results might be misleading as some studies are retrospective and do not include any reference on the exact time needed for these teeth to re-establish posterior occlusion.

TYPE OF COMPOSITE

The type of composite material has been shown to influence the survival of these restorations. It was not possible to perform statistical analyses based on the type of composite used due to the large variation in the materials used in these studies, which further contributed to the heterogenity. However, several studies have supported the use of some types of composites over others. In the study by Hemmings and colleagues, more failures were incurred in the control group where microfilled composites were used compared to the microhybrid composites.[34]

These findings agree with the results reported in the same systematic review published by Heintze *et al.*, where they found that there were more failures in the form of bulk fractures with microfilled composites than with hybrid and macrofilled composites.[40] Thus, for the restoration of worn teeth, microfilled types of composite should be discouraged, and hybrid composites are usually recommended.[41]

ASSESSMENT OF RESTORATIONS

Assessment of composite restorations was made using the modified Ryge criteria. Researchers have modified these criteria in an attempt to make them more relevant to modern restorative materials, hence the so-called modified Ryge criteria or the modified USPHS criteria. Unfortunately, different modifications reported by authors has resulted in large heterogeneity in the reported results, making it difficult to compare and to perform meta-analyses. Thus, a new, standardized, and improved assessment criteria for the clinical performance of direct and indirect restorations is needed.

INFLUENCE OF TOOTH PREPARATION

The influence of tooth preparation prior to the placement of restorations was only investigated by Al-Khayatt *et al.* where they found that the circumferential preparation of teeth with a 1 mm deep circumferential enamel chamfer margin of 0.5 mm in thickness did not influence the performance of these restorations.[10,24] These findings are consistent with the results reported by Heintze *et al.*, where they concluded that bevelling of enamel did not impact the performance of direct anterior restorations.[40] However, some authors recommend that sharp enamel margins be reduced and that dentine surfaces be roughened prior to composite placement.[41,42]

CONCLUSION

In conclusion and within the limits of the present systematic review and meta-analysis:

The findings of this systematic review and meta-analysis support anterior composite restorations as a viable short-medium term treatment option for managing worn teeth. Reported survival rates for these restorations were 88% (95% CI: 70%–98%) over 2 to 10 years, with sensitivity analysis yielding 93% (95% CI: 85%–98%) over 2 to 7 years, though high heterogeneity was observed (I^2 = 97% and I^2 = 83%, respectively). Success rates were 68% (95% CI: 44%–87%) over the same 2 to 10-year period, with similarly high heterogeneity (I^2 = 98%). The success of the composite Dahl approach in re-establishing posterior occlusion was reported at 85% (95% CI: 73%–94%).

Further well-designed clinical trials are required, using standardized restoration assessment tools to enhance the reliability of future meta-analyses. Comparative studies between composite restorations and other treatment modalities should be conducted through cohort-based prospective investigations to better control factors influencing treatment outcomes. These studies should clearly define success and survival while applying standardized assessment criteria. Additionally, consistent reporting of restoration outcomes is essential, emphasizing survival rates over median survival times (MST) for more meaningful comparisons.

REFERENCES

1. Kelleher, M. and Bishop, K. Tooth surface loss: An overview. *Br Dent J* 1999; **186**:61–66.
2. Schlueter, N. and Luka, B. Erosive tooth wear - A review on global prevalence and on its prevalence in risk groups. *Br Dent J* 2018; **224**:364–370.
3. Berry, D.C. and Poole, D.F.G. Attrition: possible mechanisms of compensation. *J Oral Rehabil* 1976; **3**:201–206.
4. Hemmings, K., Truman, A., Shah, S. and Chauhan, R. Tooth wear guidelines for the BSRD part 1: Aetiology, diagnosis and prevention. *Dent Update* 2018; **45**:483–495.
5. Loomans, B., Opdam, N., Attin, T., Bartlett, D., Edelhoff, D., Frankenberger, R, *et al.* Severe tooth wear: European consensus statement on management guidelines. *J Adhes Dent* 2017; **19**:111–119.
6. Dahl, B.L. and Krogstad, O. The effect of a partial bite raising splint on the occlusal face height:an x-ray cephalometric study in human adults. *Acta Odontol Scand* 1982; **40**:17–24.
7. Dahl, B.L., Krogstad, O. and Karlsen, K. An alternative treatment in cases with advanced localized attrition. *J Oral Rehabil* 1975; **2**:209–214.

8. Redman, C.D.J., Hemmings, K.W. and Good, J.A. The survival and clinical performance of resin-based composite restorations used to treat localised anterior tooth wear. *Br Dent J* 2003; **194**:559–566.
9. Gow, A.M. and Hemmings, K.W. The treatment of localised anterior tooth wear with indirect Artglass restorations at an increased occlusal vertical dimension. Results after two years. *Eur J Prosthodont Restor Dent* 2002; **10**:101–105.
10. Al-Khayatt, A.S., Ray-Chaudhuri, A., Poyser, N.J., Briggs, P.F.A., Porter, R.W.J., Kelleher, M.G.D., *et al.* Direct composite restorations for the worn mandibular anterior dentition: a 7-year follow-up of a prospective randomised controlled split-mouth clinical trial. *J Oral Rehabil* 2013; **40**:389–401.
11. Milosevic, A. and Burnside, G. The survival of direct composite restorations in the management of severe tooth wear including attrition and erosion: A prospective 8-year study. *J Dent* 2016; **44**:13–19.
12. Rees, J.S., Thomas, M. and Naik, P. A prospective study of the prevalence of periapical pathology in severely worn teeth. *Dent Update* 2011; **38**:24-26
13. Gulamali, A.B.B., Hemmings, K.W.W., Tredwin, C.J.J. and Petrie, A. Survival analysis of composite Dahl restorations provided to manage localised anterior tooth wear (ten year follow-up). *Br Dent J* 2011; **211**:E9.
14. Creugers, N.H.J. Minimal invasive dentistry. A revolutionary concept?. *Ned Tijdschr Tandheelkd* 2003; **110**:215–217.
15. Mesko, M.E., Sarkis-Onofre, R., Cenci, M.S., Opdam, N.J,. Loomans, B. and Pereira-Cenci, T. Rehabilitation of severely worn teeth: A systematic review. *J Dent* 2016; **48**:9–15.
16. Saunders, W.P. and Saunders, E.M. Prevalence of periradicular periodontitis associated with crowned teeth in an adult Scottish subpopulation. *Br Dent J* 1998; **185**:137–140.
17. Liberati, A,. Altman, D.G., Tetzlaff, J., Mulrow, C., Gøtzsche, P.C., Ioannidis, J.P.A., *et al.* The PRISMA statement for reporting systematic reviews and meta-analyses of studies that evaluate healthcare interventions: explanation and elaboration. *BMJ* 2009; **339**:b2700.
18. Hutton, B., Salanti, G., Caldwell, D.M., Chaimani, A., Schmid, C.H., Cameron, C., *et al.* The PRISMA Extension Statement for Reporting of Systematic Reviews Incorporating Network Meta-analyses of Health Care Interventions: Checklist and Explanations. *Ann Intern Med* 2015; **162**:777–784.
19. Moher, D., Liberati, A., Tetzlaff, J. and Altman, D.G. Preferred reporting items for systematic reviews and meta-analyses: The PRISMA statement. *BMJ* 2009; **339**:332–336.
20. Sideri, S., Papageorgiou, S.N. and Eliades, T. Registration in the international prospective register of systematic reviews (PROSPERO) of systematic review protocols was associated with increased review quality. *J Clin Epidemiol* 2018; **100**:103–110.
21. Hervás García, A., Angel, M., Lozano, M., Cabanes, Vila J., Escribano, A.B., Galve, P.F., *et al.* Composite resins. A review of the materials and clinical indications. *Med Oral Patol Oral Cir Bucal* 2006; **11**:E215-20.
22. Higgins, J.P., Sterne, J.A., Savovic, J., Page, M.J., Hróbjartsson, A., Boutron, I., *et al.* A revised tool for assessing risk of bias in randomized trials. *Cochrane Database Syst Rev* 2016; **10**:29–31.
23. Wells, G., Shea, B., Robertson, J., Peterson, J., Welch, V. and Losos, M., *et al.* The Newcastle-Ottawa Scale (NOS) for Assessing the Quality of Nonrandomized Studies in Meta-Analysis. 2015.
24. Poyser, N.J., Briggs, P.F.A., Chana, H.S., Kelleher, M.G.D., Porter, R.W.J. and Patel, M.M. The evaluation of direct composite restorations for the worn mandibular anterior dentition - clinical performance and patient satisfaction. *J Oral Rehabil* 2007; **34**:361–376.
25. Loomans, B.A.C., Kreulen, C.M., Huijs-Visser, H.E.C.E., Sterenborg, B.A.M.M., Bronkhorst E.M., Huysmans, M.C.D.N.J.M., *et al.* Clinical performance of full rehabilitations with direct composite in severe tooth wear patients: 3.5 Years results. *J Dent* 2018; **70**:97–103.
26. Brignardello-Petersen, R. Restoring teeth with moderate and severe tooth wear with direct composite resin restorations had a high success and a high survival rate after 3.5 years. *J Am Dent Assoc* 2018; **149**:e126.
27. Bartlett, D. and Varma, S. A retrospective audit of the outcome of composites used to restore worn teeth. *Br Dent J* 2017; **223**:33–36.
28. Clark, D. Composite resins and vertical dimension: treating severely worn lower incisors. *Dent Today* 2012; **31**:91–98.
29. Hamburger, J.T., Opdam, N.J., Bronkhorst, E.M., Kreulen, C.M., Roeters, J.J. and Huysmans, M.-C.D. Clinical performance of direct composite restorations for treatment of severe tooth wear. *J Adhes Dent* 2011; **13**:585–593.
30. Smales, R.J. and Berekally, T.L. Long-term survival of direct and indirect restorations placed for the treatment of advanced tooth wear. *Eur J Prosthodont Restor Dent* 2007; **15**:2–6.
31. Yip, K.H.-K., Smales, R.J. and Kaidonis, J.A. Dahl appliances used for the restorative management of localized anterior tooth erosion. *Gen Dent* 2003; **51**:54–57.
32. Darbar, U.R. and Hemmings, K.W. Treatment of localized anterior toothwear with composite restorations at an increased occlusal vertical dimension. *Dent Update* 1997; **24**:72–75.
33. Aljawad, A. and Rees, J.S. Retrospective study of the survival and patient satisfaction with composite dahl restorations in the management of localised anterior tooth wear. *Eur J Prosthodont Restor Dent* 2016; **24**:222–229.
34. Hemmings, K.W.W., Darbar, U.R.R. and Vaughan, S. Tooth wear treated with direct composite restorations at an increased vertical dimension: results at 30 months. *J Prosthet Dent* 2000; **83**:287–293.
35. Ryge, G. and Snyder, M. Evaluating the clinical quality of restorations. *J Am Dent Assoc* 1973 ;**87**:369–377.
36. Wells, G, Shea, B, O'Connell, D, Peterson, je, Welch, V, Losos, M, *et al.* The Newcastle–Ottawa Scale (NOS) for Assessing the Quality of Non-Randomized Studies in Meta-Analysis. 2000.
37. Ahmed, K.E.E. and Murbay, S. Survival rates of anterior composites in managing tooth wear: systematic review. *J Oral Rehabil* 2016;**43**:145–153.
38. Higgins, J.P.T. Commentary: Heterogeneity in meta-analysis should be expected and appropriately quantified. *Int J Epidemiol* 2008; **37**:1158–1160.
39. Higgins, J. and Green, S. OTE/SPH Cochrane Handbook for Systematic Reviews of Interventions Cochrane Handbook for Systematic Reviews of Interventions: *Cochrane Book Series Edited.* 2008.
40. Heintze, S.D., Rousson, V. and Hickel, R. Clinical effectiveness of direct anterior restorations - A meta-analysis. *Dent Mater* 2015; **31**:481–495.
41. Milosevic, A. Clinical guidance and an evidence-based approach for restoration of worn dentition by direct composite resin. *Br Dent J* 2018; **224**:301–310.
42. Zimmerli, B., De Munck, J., Lussi, A., Lambrechts, P. and Van Meerbeek, B. Long-term bonding to eroded dentin requires superficial bur preparation. *Clin Oral Investig* 2012; **16**:1451–1461.

Appendix 1. Data extraction for all articles that met the structured inclusion criteria. The article by Poyser and colleagues was not included in the qualitative and quantitative analyses of this systematic.

Study author(s) and year	Study type	Number and age of participants	Number of restorations	Location of intervention (Maxillary vs. Mandibular)	Type of intervention	Type of composite	Amount of OVD increase	Period to re-establish occlusion	Follow-up period	Number of restorations that had major, and combined major and minor types of failure, respectively	Major failure definition	Assessment standards	Longevity /Survival
1. Hemmings et al. 2000[34]	Prospective	16 patients Range (19-54 years) Mean (33.8 years)	104	Both	Direct composite	Microfilled and microhybrid	1.5-2 mm	(1-11) months in 15 out of 16 patients	2.5 years	11, 39	Any adverse event affecting the restoration (loss, fracture, marginal discoloration, loss of marginal integrity, noticeable wear, pain or sensitivity, endodontic failure and aesthetic failure)	Modified USPHS criteria [35]	93% Median survival time is 2.9 years
2. Gow and Hemmings 2002[9]	Prospective	12 patients Range (17-61 years)	75	Maxillary	Indirect composite	Ceromer (Artglass)	1-4 mm	(6-12) months in 10 out of 12 patients	2 years	0, 10	USPHS score (3)	Modified USPHS criteria [35]	100%
3. Redman et al. 2003[8]	Retrospective	31 patients Range (15-70 years)	225	Both	134 Direct and 91 indirect composites	Direct (37 microfilled and 97 microhybrid), indirect (18 microhybrid and 73 Ceromer (Artglass))	A range of OVD increases dictated by the severity of wear, incisal relationship, and operator philosophy and technique (especially if using a direct, free-hand technique)	(1.5-18.5) months	0.5-6 years	33, 130	Restoration replaced for any reason and those place in modified USPHS category (C) for bulk fracture, margin fracture, wear, surface roughness, margin colour and surface colour	Modified USPHS criteria [35]	Median survival time is 4.75 years when all types of failure were considered
4. Poyser et al. 2007[24]	Prospective	14 patients Range (31-75 years) Mean (52 years)	77	Mandibular	Direct	Microhybrid	0.5-5 mm	(3-13) months	2.5 years	5	Complete bulk failure with no remaining composite on the tooth surfaces. No loss or repair of the restoration	Modified USPHS criteria [35]	94%
5. Gulamali et al. 2011[13]	Retrospective	26 patients Range (28-80 years)	283	Both	190 Direct, 63 indirect and 30 combined (direct/indirect)	Microfilled and microhybrid and Ceromer (Artglass)	Varied depending on the functional and aesthetic requirement	(1.5-18) months in 21 out of 26 patients	10 years	145, 262	Any restoration that requires complete replacement and included any recall restoration that had a USPHS score of (3)	Modified USPHS criteria [35]	Median survival time is 7 years
6. Al-Khayyatt et al. 2013[10]	Prospective	15 patients Range (38-78 years) Mean (58 years)	85	Mandibular	Direct	Microhybrid	0.5-5 mm	(3-13) months in 14 out of 15 patients	7 years	13, 42	Restoration that had been lost, replaced, or repaired	Modified USPHS criteria [35]	85%
7. Aljawad and Rees 2016[33]	Retrospective	41 patients Range (21-70 years) Mean (39.6 years)	296	Both	Direct	Nano hybrid	Not stated	25.4 months in 38 out of 41 patients	2.1 years	13, 33	Restorations that required replacement due to total restoration loss or bulk fracture	Modified USPHS criteria [35]	95.6% Median survival time is 4.2 years