

**Recurrent caries activity in composite resin and amalgam posterior restorations: An evidence-based study of the literature**

Albertina Chan (BMus, MMus), Lillian Chan (HBSc), Mark Jesin, Dan Chau (HBSc), Persis Cho, Leena Chohan (BSc), Brett Cerqua (HBSc), Meagan Bennett (HBSc), Priti Chakerwari

All authors are Doctor of Dental Surgery candidates at:

Faculty of Dentistry  
University of Toronto  
124 Edward Street  
Toronto, Ontario  
M5G 1G6

All correspondence regarding the manuscript may be directed to Albertina Chan at the address above or (416) 979-4900, ext. 3413 or [albertinachan@sympatico.ca](mailto:albertinachan@sympatico.ca).

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## **Abstract**

This evidence-based review of the literature investigated the incidence of recurrent caries pertaining to composite resin and amalgam use in the posterior permanent dentition. Three approaches were used to identify relevant articles: a search through 2 electronic databases (MedLine and PubMed), a review of references from articles obtained through MedLine and PubMed, and a review of references from dental textbooks obtained from the University of Toronto library catalogue. Ninety-two articles were retrieved and reviewed, and 4 of these were determined to be relevant based on their ability to meet 5 inclusion criteria. Validity was measured according to an “efficacy of therapy” checklist assessing 17 items. Of the 4 studies examined, 2 were properly randomized controlled trials with split-mouth design in all patients. The remaining 2 were randomized but without split-mouth design in all patients. In all 4 studies, recurrent caries was not the primary outcome evaluated, and with the exception of 1, the studies were not calculated for power. However, all 4 studies stated findings of no significant difference in the development of secondary caries between composite resin and amalgam posterior restorations. At this point, no firm recommendation can be made to support either composite resin or amalgam posterior restorations with regard to minimizing recurrent caries incidence; the choice of restorative material should be based on the financial or esthetic needs of the patient.

MeSH Key Words: recurrent caries/prevention, posterior composites, controlled trials

Recurrent or secondary caries, defined as a “positively diagnosed carious lesion which occurs at the margins of an existing restoration” by the Federation Dentaire Internationale, remains the principal cause for replacement of restorations.<sup>1,2,3,4,5,6</sup> Thus, it is important that dentists aim to minimize the occurrence of recurrent decay. The risk factors for recurrent caries development are numerous and can be grouped under the following categories: caries experience, saliva factors, dental plaque factors, dietary factors, medical conditions, and restricted access to dental care or low dental knowledge.<sup>6</sup> To help patients reduce the risk of recurrent decay, dentists should also consider the implications of various restorative materials on potential recurrent caries development.

Much of the literature available regarding recurrent caries indicates that although it may occur with all restorative materials, there are differences in prevalence and times of onset associated with different materials.<sup>7,8,9</sup> Since resin-based restorative materials are becoming more popular among patients desiring better aesthetics, dentists should be aware of the potential outcomes associated with use of these materials. Published surveys indicate that dentists diagnose secondary caries around composite resin restorations at a higher prevalence compared to amalgam, and it is a commonly accepted dogma among practitioners that composite resin is inferior to amalgam in terms of longevity, recurrent caries, and wear rate.<sup>2,9,10,11,12</sup>

A comprehensive review of the literature was performed to determine if the aforementioned claims and beliefs were based on sound evidence and to answer the following question: Can the incidence of recurrent caries be minimized when composite resin is used instead of amalgam for restorations in the posterior permanent dentition? The null hypothesis was that no difference in secondary caries incidence was found between composite resin and amalgam. The strongest evidential studies comparing composite resin with amalgam restorations are examined in this paper.

## **Methods**

A systematic method was applied to identify, select and critically appraise relevant studies.

### *Search Strategy*

Three approaches were used to obtain potentially relevant articles pertaining to our area of interest. First, a literature search of relevant publications dating from January 1986 to January 2005 was performed in two databases, PubMed and MedLine. To identify the maximal papers possible, the following keywords, and combinations of keywords, were used in the PubMed search: recurrent caries, prevention and recurrent caries, prospective study and recurrent caries, and randomized control trial and recurrent caries. From these search terms, 455, 119, 12, and 1 articles were retrieved from the database respectively. At this stage, the relevance of articles was determined by title, abstract, and restriction to the English language, resulting in a yield of 52 potential articles. The same keywords were applied to the MedLine search, and from these search terms, 200, 8, 5, and 0 articles were retrieved from the database respectively. Relevance of these articles based on title, abstract, English language restriction, and exclusivity from PubMed yielded an additional 2 articles. Second, the references of the relevant articles were thoroughly reviewed to obtain additional relevant articles. These articles were selected on the basis of title relevance. This resulted in an additional 33 articles. Third, the references from dental textbooks were reviewed to identify additional articles. After accounting for duplicates from the previous searches, 5 more articles were collected.

### **Determination of Relevance**

After elimination of 748 articles based on title, abstract, and overlap between the electronic journal database, 92 articles were read and reviewed to determine relevance. Articles were deemed relevant if they met all of the following 5 criteria: 1) The article was based on

primary research in human clinical studies. Articles that were reviews, surveys, commentaries or case studies were rejected and used only for supplemental information. A list of these excluded articles and their reasons for exclusion is found in **Appendix 1** (see appendix at the end of the article). 2) The study restricted placement of restorations and evaluation of secondary caries incidence to restorations of posterior permanent teeth only. 3) The study used amalgam as a control for comparison to composite resin. 4) The subjects of the study were healthy patients with no serious oral complications or underlying medical condition, e.g., xerostomia and cancer. 5) The study design was either a prospective study or a randomized controlled trial.

### **Validity Instrument**

Four articles met all 5 inclusion criteria,<sup>13, 14, 15, 16</sup> and these were then scored according to a checklist to assess evidence of efficacy of therapy or prevention adapted by Leake<sup>17</sup> (**Table 1**). The highest attainable score was 17.

### **Results**

The four scored articles present evidence obtained through randomized trials from various parts of the world. In each of the studies, cavity preparations were performed according to standards for amalgam restorations, and all restorations were inserted, carved, finished, and polished according to standard techniques.<sup>13, 14, 15, 16</sup> The final assessment of secondary caries was qualified in accordance with U.S. Public Health Service criteria.<sup>13, 14, 15, 16</sup> However, recurrent caries was not the primary outcome investigated in any of the four studies. While investigating the effect of composite resin on recurrent caries development, only the studies conducted by Collins and others<sup>13</sup> and Johnson and others<sup>14</sup> utilized a split-mouth design using amalgam as proper controls in all patients. In the studies conducted by Letzel<sup>15</sup> and Norman and others,<sup>16</sup> only a portion of the patients received amalgam restorations as controls. **Table 2** summarizes the main findings from the studies.

Between the two properly controlled and randomized studies, Collins and others<sup>13</sup> presented stronger evidence than Johnson and others.<sup>14</sup> Although follow up of patients was markedly lower in the study by Collins and others,<sup>13</sup> the evidence presented should be considered stronger since a higher number of composite resin and amalgam restorations were placed and the duration of the study was longer (see **Table 2**).

While the multicentre study by Letzel<sup>15</sup> had the most participants, there was no calibration between the examiners from different centres in the trial. The evidence from this study is considered weak since amalgam controls were not used in 5 of the 10 evaluated centres. Furthermore, in 3 of the original 11 centres, participants were primarily dental students instead of a random sample from the general population; no mention was made in the article as to whether these 3 centres were among the controlled centres or not.<sup>18</sup> As previously mentioned earlier, the study by Norman and others<sup>16</sup> also failed to place amalgam controls in certain patients. Therefore, this study design is ranked lower than that of Johnson and others<sup>14</sup> even though the latter was two years shorter in duration (see **Table 2**).

Despite three studies detecting secondary caries at a higher rate among posterior composite resin restorations, all the articles presented findings of no significant difference pertaining to the development of secondary caries when comparing composite resin and amalgam restorations.

## **Discussion**

Based on the evidence from this literature review, no recommendation for the use of composite resin over amalgam for posterior restorations based on caries incidence can be made at this point for the following reasons. Firstly, the incidence of recurrent caries was too low in all four studies to be able to substantiate any claims as to whether composite resin is better than amalgam. Secondly, none of the studies provided a statistical analysis strictly examining the

relationship between recurrent caries and type of restorative material. In all the cases, recurrent caries was only one of many criteria used to identify the deterioration properties of composite resin and amalgam. Thirdly, restorations that were identified as having failed in other areas, e.g., bulk fracture, were not included for observation of recurrent caries; thus, the results were based on a biased sample. Fourthly, it has been suggested by Lambrechts and others<sup>19</sup> and McComb and others<sup>5</sup> that studies should be longer than four years in order to allow sufficient time for unfavorable properties, e.g., recurrent caries, to manifest. In this review, only two of the scored studies were more than four years long. Fifthly, there was too much variation, e.g., duration and examiner calibration, between the four studies; in Letzel's case, there was even variability within the study.<sup>15</sup> Sixthly, outside patient care was not controlled in any of the studies. Lastly, too few studies met our inclusion criteria, and of the four that did, three may be considered underpowered.

To determine whether the occurrence of secondary caries is affected by material type, more research in the area is required. Further investigations may include meta-analysis reviews, but better still would be human clinical randomized trials. The following recommendations serve to minimize the weaknesses identified in the reviewed articles: 1) Focus the study on observation of secondary caries only. 2) Recruit a large sample size and utilize a split mouth design for proper control. 3) Ensure that the study is of sufficient length that the recurrent caries has time to develop. 4) Calibrate the examiners to a known standard or require all examiners to evaluate every patient. 5) Perform multivariate analyses to control for confounding variables from outside care, e.g., oral hygiene and fluoride treatments. 6) Ensure that the study has been reviewed by an ethics board.

Since the evidence from the studies reviewed indicate findings of no significant difference between the use of composite resin and amalgam for posterior restorations with

regards to recurrent caries incidence, the choice of restorative material used should depend on the financial or esthetic needs of the patient. From an economic standpoint, it is favorable to use amalgam for posterior restorations as it is a less expensive material and has less wear-associated deterioration (see **Table 3** for technology assessment).<sup>20</sup> The placement of amalgam is less technique sensitive than that of composite resin, and hence reduces treatment time for the practitioner and patient. However, because of an ever increasing demand for esthetic restorations, the proper techniques for posterior composite resin placement should be mastered.

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## References

1. Fontana M, Cabezas C. Secondary caries and restoration replacement: An unresolved problem. *Compend Compan Educ Dent* 2000; 21(1):15-24.
2. Kelsey W, Franco S, Blankenau R, Cavel W, Barkmeier W. Caries as a Cause of Restoration Replacement: A Clinical Survey. *Quintessence Int* 1981; 971-4.
3. Kidd EAM. Diagnosis of secondary caries. *J Dent Educ* 2001; 65(10):997-1000.
4. Kidd EAM, Toffenetti, Mjör IA. Secondary caries. *Int Dent J* 1992; 42:127-38.
5. McComb D, Erickson RL, Maxymiw WG, Wood RE. A clinical comparison of glass-ionomer, resin-modified glass ionomer and resin composite restorations in the treatment of cervical caries in xerostomic head and neck radiation patient. *Oper Dent* 2002; 27:430-7.
6. Hicks J, Garcia-Godoy F, Donly K, Flaitz C. Fluoride-releasing restorative materials and secondary caries. *Dent Clin N AM* 46 2002; 247-76.
7. Forss H, Widstrom E. Reasons for restorative therapy and the longevity of restorations in adults. *Acta Odontol Scand* 2004; 62(2):82-6.
8. Mjör IA. The reasons for replacement and the age of failed restorations in general dental practice. *Acta Odontol Scand* 1997; 55(1):58-63.
9. Mjör IA. Glass-ionomer cement restorations and secondary caries: A preliminary report. *Quintessence Int* 1996; 27:171-4.
10. Mjör IA, Jokstad A. Five-year study of class II restorations in permanent teeth using amalgam, glass polyalkenoate (ionomer) cement and resin-based composite materials. *J Dent* 1993; 21(6):338-43.
11. Qvist V, Qvist J, Mjör IA. Placement and longevity of tooth-coloured restorations in Denmark. *Acta Odontol Scand* 1990; 48:305-11.

12. Rosenstiel SF, Land MF, Rashid RG. Dentists' molar restoration choices and longevity: a web-based survey. *Prosthet Dent* 2004;91(4):363-7.
13. Collins CJ, Bryant RW, Hodge K-LV. A clinical evaluation of posterior composite resin restorations: 8-year finding. *J Dent* 1998; 26(4):311-7.
14. Johnson GH, Bales DJ, Gordon GE, Powell LV. Clinical performance of posterior composite resin restorations. *Quintessence Int* 1992; 23(10):705-11.
15. Letzel H. Survival rates and reasons for failure of posterior composite restorations in multicentre clinical trial. *J Dent* 1989; 17:S10-7.
16. Norman RD, Rydberg RJ, Felkner LL. A 5-year study comparing a posterior composite resin and an amalgam. *J Prosthet Dent* 1990; 64(5):523-9.
17. Leake JL, Head of Community Dentistry, Faculty of Dentistry, University of Toronto. Unpublished document. Course notes Den 300Y1. The checklist was adapted from Fletcher RH, Fletcher SW, Wagner EH. *Clinical epidemiology. The essentials*. 3<sup>rd</sup> ed. Baltimore:Williams and Wilkins, 1996; and Sackett DL, Richardson WS, Rosenberg W, Haynes RB. *Evidence-based medicine: how to practice and teach EBM*. 2<sup>nd</sup> ed. New York: Churchill Livingstone, 1997.
18. Norman RD, Wilson NHF. Three-year findings of a multiclinical trial for a posterior composite. *J Prosthet Dent* 1988; 59(5):577-83.
19. Lambrechts P, Vanherle G. Structural evidences of the microfilled composites. *J Biomed Mater Res* 1983; 17(2):249-60.
20. Tobi H, Kreulen CM, Vonderling H, Van Amerogen WE. Cost-effectiveness of composite resin and amalgam in the replacement of amalgam class 2 restorations. *Community Dent Oral Epidemiol* 1999; 27(2):137-43.

**Table 1. Checklist to Assess Evidence of Efficacy of Therapy or Prevention for each relevant article<sup>17</sup>**

- 1) Was the study ethical?
- 2) Was a strong design used to assess efficacy?
- 3) Were outcomes (benefits and harms) validly and reliably measured?
- 4) Were interventions validly and reliably measured?
- 5) What were the results?
  - Was the treatment effect large enough to be clinically important?
  - Was the estimate of the treatment effect beyond chance and relatively precise?
  - If the findings were “no difference” was the power of the study 80% or better
- 6) Are the results of the study valid?
  - Was the assignment of patients to treatments randomized?
  - Were all patients who entered the trial properly accounted for and attributed at its conclusion?
  - I) was loss to follow-up less than 20% and balance between test and controls?
  - Ii) Were patients analyzed in the groups to which they were randomized?
  - Was the study of sufficient duration?
  - Were patients, health workers, and study personnel “blind” to treatment?
  - Were the groups similar at the start of the trial?
  - Aside from the experimental intervention, were the groups treated equally?
  - Was care received outside the study identified and controlled for
- 7) Will the results help in caring for your patients?
  - Were all clinically important outcomes considered?
  - Are the likely benefits of treatment worth the potential harms and costs?

**Table 2. Evidence Table**<sup>13, 14, 15, 16</sup>

<b>Author, date</b>	<b>Population Description</b>	<b>Intervention</b>	<b>Control</b>	<b>Outcome</b>	<b>Critical Appraisal comments</b>	<b>Conclusion, Strength of evidence and classification</b>
Collins and others, 1998	- adults and children 13-32.4 years old (average age = 16.8) - 85% female, 15% male - routine patients of a large teaching hospital serving a socio-economically less advantaged part of a metropolitan area (n = 46)	- 161 composite resin restorations -three types of composite resins: i) Heliomolar Radiopaque (Vivadent) ii) Herculite XR (Kerr) iii) P-30 APC (3M) - each patient received at least one restoration of each of the three composite resins	- 52 amalgam restorations -one type of amalgam: Dispersalloy (Johnson and Johnson) - each patient received at least one amalgam control - allocation of restorations was randomized	- composite restorations in posterior teeth failed at a rate two to three times that of amalgam restorations - most common reason for failure was i) bulk fracture ii) secondary caries - 8 failures due to secondary caries: 7 composite and 1 amalgam	- follow-up was poor at 64% (46 of 72 patients) - examiners were not blind to treatment since they could identify the restorative material by visual inspection - no calculation of power; study may be underpowered - no control for outside care - no statistical results were calculated/noted with respect to recurrent caries	Grade I, Level I

**Table 2. Evidence Table (cont'd)**

<b>Author, date</b>	<b>Population Description</b>	<b>Intervention</b>	<b>Control</b>	<b>Outcome</b>	<b>Critical Appraisal comments</b>	<b>Conclusion, Strength of evidence and classification</b>
Johnson and others, 1992	- each participant had at least three posterior teeth with carious lesions (n =27) - no other demographic data was reported	- 88 composite resin restorations -two types of composite resin: i) P-30 (3M) ii) Bisfill-P (Bisco Dental) - each participant received at least one restoration of each composite resin	- 40 amalgam restorations -one type of amalgam: Dispersalloy (Johnson & Johnson) - each participant received at least one amalgam restoration placed by 2 dentists following standard procedures	- no recurrent caries found for either amalgam or composite restorations	- no review board cited - sample size was very small (only 27 participants); the study may have been underpowered - duration of study may not have been long enough (only 3 years) - no demographic data on the participants – results may not be generalized - lacked proper accounting of participants	Grade I, Level I

**Table 2. Evidence Table (cont'd)**

<b>Author, date</b>	<b>Population Description</b>	<b>Intervention</b>	<b>Control</b>	<b>Outcome</b>	<b>Critical Appraisal comments</b>	<b>Conclusion, Strength of evidence and classification</b>
Johnson and others, 1992 (cont'd)		- 48 Bisfil-P and 40 P-30 composite resin restorations were placed by 2 dentists following standard procedures - allocation of restorations was randomized			- examiners were not blind to the treatment - no control for outside care	
Letzel H, 1989	- multicentre clinical trial - 12 centres world-wide (6 countries), 33 investigators - adult patients (n=447)	- 932 composite resin Class I and Class II restorations were placed - one type of composite: Occlusin (ICI Dental)	- 232 amalgam Class I and Class II restorations were placed - 5 of the centers had amalgam controls	- composite restorations failed more than amalgam restorations (relative risk larger than 1 with p<0.05)	- study was not ideally controlled – only 5 of the centers had amalgam controls	Grade II-3, Level I

**Table 2. Evidence Table (cont'd)**

<b>Author, date</b>	<b>Population Description</b>	<b>Intervention</b>	<b>Control</b>	<b>Outcome</b>	<b>Critical Appraisal comments</b>	<b>Conclusion, Strength of evidence and classification</b>
Letzel H, 1989 (cont'd)	- most of the patients at 3 of the 11 centres were dental students - data for this study was taken from 11 of the 12 centres	- placement of restorations was standardized - all restorations were evaluated independently by at least 2 standardized investigators		- 15 failures due to secondary caries: 2 amalgam and 13 composite (controlled and uncontrolled data was combined) - no statistical results were calculated/noted with respect to recurrent caries	- data from the 5 centres that used amalgam controls was combined with the uncontrolled centers - lacked proper accounting of participants - some centers had very low recall rates and other centers had a very small number of participants - evaluators were not blind to the treatment - no control for outside care - since participants at 3 of the 11 centres were mostly dental students, results cannot be generalized	

**Table 2. Evidence Table (cont'd)**

<b>Author, date</b>	<b>Population Description</b>	<b>Intervention</b>	<b>Control</b>	<b>Outcome</b>	<b>Critical Appraisal comments</b>	<b>Conclusion, Strength of evidence and classification</b>
Norman and others, 1990	- adults; mean age approx. 29 +/- 10 years (n=62) - patients generally had good oral hygiene	- 80 composite resin restorations - one type of composite: Occlusin (Imperial Chemical Industries) - each patient received at least one composite restoration - maximum of four restorations per patient - allocation of restorations was randomized	- 43 amalgam restorations - ¾ of the patients had both amalgam and composite resin while the remaining ¼ had only composite resin restorations	- no statistical differences between amalgam and composite resin restorations with respect to marginal adaptation, anatomic form and interproximal contacts - 4 failures due to secondary caries: 3 composite and 1 amalgam - no statistical results were calculated/noted with respect to recurrent caries	- no review board cited - study was not ideally controlled; ¼ of participants had only composite restorations - two standardized evaluators were used to inspect the teeth but no kappa scores were given - evaluators were not blind to the treatment - no control for outside care - no calculation of power; study may have been underpowered	Grade II-3, Level I

**Table 3. Technology Assessment Table<sup>20</sup>**

Relative costs of composite	Comparison of outcomes with composite		
	Better	Same	Worse
Less			
Same			
More		<b>X</b>	

**Appendix 1. List of articles excluded and reasons for exclusion**

Articles	Reason for exclusion
Cehreli and Altay 2000; Donly and others 2002; Ho and others 1999; Luo and others 2000; McComb and others 2002; Mjör 1996; Mjör and Jokstad 1993; Sachdeo and others 2004; Svanberg and others 1990; Tyas and others 1991	Study included glass-ionomer restorations
Dionysopoulos and others 1996; Donly 1994; Fitzgerald and others 1994; Hicks and others 2002; Nair and others 1998; Skartveit and others 1991; Tam and others 1997	<i>In vitro</i> study
Akerboom and others 1993; Donly and others 1999; Duggal and others 2002; Eriksen and others 1986; Haveman and others 2003; Jepson and others 2001; Mjör and Toffenetti 1992; Soderholm and others 1989	Study did not include composite resin.
Barr-Agholme and others 1991; Judd and others 1990; Kilmartin 1993; Kohler and others 2000; Morinushi and others 2002; Oldenburg and others 1987; Papathanasiou and others 1994	Study is on primary teeth

<p>Fontana and others 2000; Garcia-Godoy 2000; Goldberg 1990; Hicks and others 2002; Hicks and others 2003; Kidd 2001; Kidd and others 1992; Lambrechts and others 1987; Mjör and others 1990; Mjör and Qvist 1997; Mjör and Toffenetti 2000; Owens 1996; Qvist and others 2000; Randall and others 1999; Roulet 1988; Swift 1989; York and Arthur 1993</p>	<p>Not a study but a review</p>
<p>Barnes and others 1990; Barnes and others 1991; Blinkhorn and Davies 1996; Boksman and others 1986; Friedl and others 1995; Heymann and others 1986; Kidd and Beighton 1996; Kinomoto and others 2004; Lutz and others 1992; Norman and others 1988; Otto and Rule 1988; Raskin and others 1999; Shimizu and others 1988; Shimizu and others 1995; Wendt and Leinfelder 1994; Wilson and others 1986</p>	<p>Did not present results for both amalgam and composite resin.</p>
<p>Cloyd and others 1997; Mertz-Fairhurst and others 1987; Walls and others 1988</p>	<p>Study includes sealants</p>

Brantley and others 1995; Chiappelli and others 2002; Kidd 1989; Lutz and others 1992; Mair 1995	Did not look at recurrent caries
Mair 1998	Sample size unknown
Burke and others 1999; Qvist and others 1990; Wilson and others 1997	Not a study but a survey
Sakrana and others 2004, van Dijken 1986	Study is on anterior teeth
Berry and others 1989; Oulis and others 1990; Wan and others 1999	Article not in English
Bryant and Hodge 1994; Dutta and others 2001; Going 1989; Hendriks and others 1986; Rowe 1989; Welbury and others 1990	Unable to locate

Akerboom HB, Advokaat JG, Van Amerongen WE, Borgmeijer PJ. Long-term evaluation and re-restoration of amalgam restorations. *Community Dent Oral Epidemiol* 1993; 21(1):45-8.

Barnes DM, Blank LW, Thompson VP, Ginell JC. A 5- and 8- year clinical evaluation of a posterior composite resin. *Quintessence Int* 1991; 22: 143-51.

Barnes DM, Holston AM, Strassler HE, Shires PJ. Evaluation of clinical performance of twelve posterior composite resins with a standardized placement technique. *J Esthet Dent* 1990; 2: 36-43.

Barr-Agholme M, Oden A, Dahllof G, Modeer T. A two-year clinical study of light-cured composite and amalgam restorations in primary molars. *Dent Mater* 1991; 7(4):230-3.

- Berry C, Vachey E, Rouge J. Caries recurrence: descriptive, analytic and prospective clinimetric study. *J Odontol Conserv* 1989; 10:17-26.
- Blinkhorn AS, Davies RM. Caries prevention: a continued need worldwide. *Int Dent J* 1996; 46(3):119-25.
- Boksman L, Suzuki M, Jordan R, Charles DH. A visible light cured posterior composite resin results of a 3-year clinical evaluation. *J Am Dent Assoc* 1986; 112(5):627-31.
- Brantley CF, Bader JD, Shugars DA, Nesbit SP. Does the cycle of restoration lead to larger restorations? *J Am Dent Assoc* 1995; 126(10):1407-13.
- Bryant RW, Hodge KLV. A clinical evaluation of posterior composite resin restorations. *Aust Dent J* 1994; 39: 77-81.
- Burke FJT, Cheung SW, Mjör IA, Wilson NHF. Restoration longevity and analysis of reasons for the placement and replacement of restorations provided by vocational dental practitioners and their trainees in the United Kingdom. *Quintessence Int* 1999; 30: 234-42.
- Cehreli ZC, Altay N. Three-year clinical evaluation of a polyacid-modified resin composite in minimally invasive occlusal cavities. *J Dent* 2000; 28(2):117-22.
- Chiappelli F, Dickmeyer J, Harper S. Dental needs of the elderly in the 21st century. *Gen Dent* 2002; 50(4):358-63.
- Cloyd S, Gilpatrick RO, Moore D. Preventive resin restorations vs. amalgam restorations: a three-year clinical study. *J Tenn Dent Assoc* 1997; 77(4):36-40.
- Dionysopoulos P, Kotsanos N, Papadogianis Y. Secondary caries formation in vitro around glass ionomer-lined amalgam and composite restorations. *J Oral Rehabil* 1996; 23(8):511-9.
- Donly KJ. Enamel and dentin demineralization inhibition of fluoride-releasing materials. *Am J Dent* 1994; 7(5):275-8.

- Donly KJ, Segura A. Fluoride release and caries inhibition associated with the resin-modified glass-ionomer cement at varying fluoride loading doses. *Am J Dent* 2002; 15(1):8-10.
- Donly KJ, Segura A, Kanellis M, Erickson RL. Clinical performance and caries inhibition of resin-modified glass ionomer cement and amalgam restorations. *J Am Dent Assoc* 1999; 130(10): 1459-66.
- Duggal MS, Toumba KJ, Sharma NK. Clinical performance of a compomer and amalgam for the interproximal restoration of primary molars: a 24-month evaluation. *Br Dent J* 2002; 193(6):339-42.
- Dutta BN, Gauba K, Tewari A, Chawla HS. Silver amalgam versus resin modified GIC class-II restorations in primary molars: twelve month clinical evaluation. *J Indian Soc Pedod Prev Dent* 2001; 19(3):118-22.
- Eriksen HM, Bjertness E, Hansen BF. Cross-sectional clinical study of quality of amalgam restorations, oral health and prevalence of recurrent caries. *Community Dent Oral Epidemiol* 1986; 14(1):15-8.
- Fitzgerald RJ, Adams BO, Davis ME. A microbiological study of recurrent dentinal caries. *Caries Res* 1994; 28(6): 409-15.
- Fontana M, Gonzalez-Cabezas C. Secondary caries and restorations replacement: an unresolved problem. *Compend Contin Educ Dent* 2000; 21(1):15-24.
- Friedl KH, Hiller KA, Schwartz G. Placement and replacement of composite restorations in Germany. *Oper Dent* 1995; 20(1):34-8.
- Garcia-Godoy F. Resin-based composites and compomers in primary molars. *Dent Clin North Am* 2000; 44(3):541-70.
- Going RE. Better restorative, greater prevention. *Singapore Dent J* 1989; 14(1):46-7.

- Goldberg AJ. Deterioration of restorative materials and the risk for secondary caries. *Adv Dent Res* 1990; 4:14-8.
- Haveman CW, Summitt JB. Three restorative materials and topical fluoride gel used in xerostomic patients: a clinical comparison. *J Am Dent Assoc* 2003; 134(2):177-84.
- Hendriks FHJ, Letzel, H. and Vrijhoef MMA. Composite versus Amalgam restoration: a three year clinical evaluation. *J Oral Rehab* 1986; 13:401-11.
- Heymann, HO, Wilder AD Jr., May KN, Leinfelder KF. Two year clinical study of composite resins in posterior teeth. *Dent Mater* 1986; 2:37-41.
- Hicks J, Garcia-Godoy F, Donly K, Flaitz C. Fluoride-releasing restorative materials and secondary caries. *Dent Clin North Am* 2002; 46(2):247-76.
- Hicks J, Garcia-Godoy F, Donly K, Flaitz C. Fluoride-releasing restorative materials and secondary caries. *J Calif Dent Assoc* 2003; 31(3):229-45.
- Hicks J, Milano M, Seybold S, Garcia-Godoy F, Flaitz C. Fluoride-releasing resin bonding of amalgam restorations in primary teeth: in vitro secondary caries effect. *Am J Dent* 2002; 15(6):361-4.
- Ho TF, Smales RJ, Fang DT. A 2-year clinical study of two glass ionomer cements used in the atraumatic restorative treatment (ART) technique. *Community Dent Oral Epidemiol* 1999; 27(3):195-201.
- Jepson NJ, Moynihan PJ, Kelly PJ, Watson GW, Thomason JM. Caries incidence following restoration of shortened lower dental arches in a randomized controlled trial. *Br Dent J* 2001; 191(3):140-4.
- Judd PL, Kenny DJ, Johnston DH, Yacobi R. Composite resin short-post technique for primary anterior teeth. *J Am Dent Assoc* 1990; 120(5):553-5.
- Kidd EAM. Caries diagnosis within restored teeth. *Oper Dent* 1989; 14(3):149-58.

- Kidd EAM, Toffenetti F, Mjör IA. Secondary caries. *Int Dent J* 1992; 42:127-38.
- Kidd EAM. Diagnosis of secondary caries. *J Dent Edu* 2001; 65(10):997-1000.
- Kidd EAM, Beighton D. Prediction of secondary caries around tooth-colored restorations: A clinical and microbiological study. *J Dent Res* 1996; 74:1942-6.
- Kilmartin WM. Durability of restorations in primary molars. *J Dent* 1993; 21:67-73.
- Lambrechts P, Braem M, Vanherle G. Evaluation of clinical performance of posterior composite resins and dentin adhesives. *Oper Dent* 1987; 12: 53-78.
- Kinomoto Y, Inoue Y, Ebisu S. A two-year comparison of resin-based composite tunnel and Class II restorations in a randomized controlled trial. *Am J Dent* 2004; 17(4):253-6.
- Kohler B, Rasmusson CG, Odman P. A five-year clinical evaluation of Class II composite resin restorations. *J Dent* 2000; 28(2):111-6.
- Luo Y, Lo EC, Fang DT, Wei SH. Clinical evaluation of polyacid-modified resin composite posterior restorations: one-year results. *Quintessence Int* 2000; 31(9):630-6.
- Lutz F, Krejci I, Barbakow F. Restoration quality in relation to wedge-mediated light channeling. *Quintessence Int* 1992; 23:763-7.
- Lutz F, Krejci I, Barbakow F. The importance of proximal curing in posterior composite resin restorations. *Quintessence Int* 1992; 12:605-7.
- Mair LH. Wear patterns in two amalgams and three posterior composites after five years of clinical service. *J Dent* 1995; 23:107-12.
- Mair LH. Ten-year clinical assessment of three posterior resin composites and two amalgams. *Quintessence Int* 1998; 29(8):483-9.
- McComb D, Erickson RL, Maxymiw WG, Wood RE. A clinical comparison of glass ionomer, resin-modified glass ionomer and resin composite restorations in the treatment of cervical caries in xerostomic head and neck radiation patients. *Oper Dent* 2002; 27(5):430-7.

- Mertz-Fairhurst EJ, Call-Smith KM, Shuster GS, Williams JE, Davis QB, Smith CD, Bell RA, Sherrer JD, Myers DR, Morse PK. Clinical performance of sealed composite restorations placed over caries compared with sealed and unsealed amalgam restorations. *J Am Dent Assoc* 1987; 115(5): 689-94.
- Mjör IA. Glass-ionomer cement restorations and secondary caries: a preliminary report. *Quintessence Int* 1996; 27(3):171-4.
- Mjör IA, Jokstad A. Five-year study of class II restorations in permanent teeth using amalgam, glass polyalkenoate (ionomer) cermet and resin-based composite materials. *J Dent* 1993; 21(6):338-43.
- Mjör IA, Jokstad A, Qvist V. Longevity of posterior restorations. *Int Dent J* 1990; 40(1):11-7.
- Mjör IA, Qvist V. Marginal failures of amalgam and composite restorations. *J Dent* 1997; 7:25-30.
- Mjör I, Toffenetti F. Placement and replacement of amalgam restorations in Italy. *Oper Dent* 1992; 17:70-3.
- Mjör IA, Toffenetti F. Secondary caries: a literature review with case reports. *Quintessence Int* 2000; 31(3):165-79.
- Morinushi T, Inoue K, Toyoshima S, Morinushi M, Araki Y, Kondo K. Preventive effects by intensive restorative treatment against caries in children. *J Clin Pediatr Dent* 2002; 26(4):357-62.
- Nair MK, Tyndall DA, Ludlow JB, May K, Ye F. The effects of restorative material and location on the detection of simulated recurrent caries. A comparison of dental film, direct digital radiography and tuned aperture computed tomography. *Dentomaxillofac Radiol* 1998;27(2):80-4.
- Norman RD, Wilson NHF. Three-year findings of a multiclinical trial for a posterior composite. *J Prosthet Dent* 1988; 59(5):577-82.

Oldenburg TR, Vann WF, Dilley DC. Comparison of composite and amalgam in posterior teeth of children. *Dent Mater* 1987b; 3:182-6.

Otto PF, Rule JT. Relationship between proximal cavity design and recurrent caries.

*J Am Dent Assoc* 1988; 116(7):867-70.

Oulis C, Berdousis I, Vadiakis G. Secondary caries as a problem. *Hell Stomatol Chron* 1990; 34(2):125-37.

Owens B. Initial placement and replacement of amalgam restorations: a retrospective review. *J Tenn Dent Assoc* 1996; 76(4):37-9.

Papathanasiou AG, Curzon MEJ, Fairpo CG. The influence of restorative material on the survival rate of restorative molars. *Paediatr Dent* 1994; 16:282-8.

Qvist J, Qvist V, Mjör IA. Placement and longevity of amalgam restorations in Denmark. *Acta Odontol Scand* 1990; 48:297-303.

Qvist J, Vibeke Q, Mjör I. Placement and longevity of amalgam restorations in Denmark. *Gen Dent* 2000; 48:288-303.

Randall RC, Wilson NH. Glass-ionomer restoratives: a systematic review of a secondary caries treatment effect. *J Dent Res* 1999; 78(2):628-37.

Raskin A, Michotte-Theall B, Vreven J, Wilson NH. Clinical evaluation of a posterior composite 10-year report. *J Dent* 1999; 27(1):13-9.

Roulet JF. The problems associated with substituting composite resin for amalgam: a status report on posterior composites. *J Dent* 1988; 16(3):101-13.

Rowe AHR. A five-year study of the clinical performance of a posterior composite resin restorative material. *J Dent* 1989; 17: S6-9.

Sachdeo A, Gray GB, Sulieman MA, Jagger DC. Comparison of wear and clinical performance between amalgam, composite and open sandwich restorations: 2-year results. *Eur J Prosthodont Restor Dent* 2004; 12(1):15-20.

Sakrana AA, Tanoue N, Kawasaki K, Matsumura H. One-year clinical evaluation of two composite materials used for anterior class V restorations. *J Oral Rehabil* 2004; 31(10):985-90.

Shimizu T, Inoue M, Kimura S, Tani T, Kagami T, Yamamoto K, Kawahito T, Inoue M, Naikawa K, Fujii B. Four-year clinical evaluation of visible light cured posterior restorative composite resin. "Litefill-P", *Japan J Conserv Dent* 1988; 31(4):1081-8.

Shimizu T, Kitano T, Inoue M, Narikawa K, Fujii B. Ten-year longitudinal clinical evaluation of a visible light cured posterior composite resin. *Dent Mater J* 1995; 14(2):120-34.

Skartveit L, Wefel JS, Ekstrand J. Effect of fluoride amalgams on artificial recurrent enamel and root caries. *Scand J Dent Res* 1991; 99(4):287-94.

Soderholm KJ, Antonson DE, Fischlscweiger W. Correlation between margin discrepancies at the amalgam/tooth interface and recurrent caries. In: Anusavice KJ ed. *Quality evaluation of dental restorations*. London: Quintessence Books; 1989: 95-110.

Svanberg M, Mjör I, Orstavik D. Mutans Streptococci in plaque from margins of amalgam, composite and glass-ionomer restorations. *J Dent Res* 1990; 69(3):861-4.

Swift EJ Jr. Effects of glass ionomers on recurrent caries. *Oper Dent* 1989; 14(1):40-3.

Tam LE, Chan GP, Yim D. In vitro caries inhibition effects by conventional and resin-modified glass-ionomer restorations. *Oper Dent* 1997; 22(1): 4-14.

Tyas MJ. Cariostatic effect of glass ionomer cement: a five-year clinical study. *Aust Dent J* 1991; 36(3):236-9.

Van Dijken JW. A clinical evaluation of anterior conventional, microfilled, and hybrid composite resin fillings. A 6-year follow-up study. *Acta Odontol Scand* 1986; 44(6):357-67.

Walls AWG, Murray JJ, McCabe JF. The management of occlusal caries in permanent molars. A clinical trial comparing a minimal composite restoration with an occlusal amalgam restoration.

*Br Dent J* 1988; 164:288-92.

Wan H, Hu D, Lo E, Holmgren CJ, He D, Liu Y. Atraumatic restorative treatment fillings and fissure sealants in permanent teeth-a 2-year study. *Hua Xi Kou Qiang Yi Xue Za Zhi* 1999;

17(1):42-5.

Welbury RR, Walls AWG, Murray JJ, McCabe JF. The management of occlusal caries in permanent molars. A 5-year clinical trial comparing a minimal composite with an amalgam restoration.

*Br Dent J* 1990; 169:361-6.

Wendt SL Jr, Leinfelder KR. Clinical evaluation of a posterior resin composite: 3-year results.

*Am J Dent* 1994; 7: 207-11.

Wilson NHF, Burke FJT, Mjör IA. Reasons for placement and replacement of restorations of direct restorative materials by a selected group of practitioners in UK. *Quintessence Int* 1997;

28:245-8.

Wilson NHF, Smith GA, Wilson MA. A clinical trial of a visible light cured posterior composite resin restorative material: three year results. *Quintessence Int* 1986; 17(10):643-52.

York AK, Arthur JS. Reasons for placement of dental restorations in the United States navy dental corps. *Oper Dent* 1993; 18: 203-8.