Longevity of Resin Composite and Amalgam Posterior Restorations: A Systematic Review

Keywords

Composite Resins
Dental Amalgam
Longevity

Authors

Carolina M. Maciel *
(DDS, MSc, PhD)

Kusai Baroudi ‡
(DDS, MSc, PhD)

Leonardo D. S. Barroso ‡
(DDS, MSc)

Larissa D. C. Costa *
(DDS, MSc, PhD)

Tatiane C. V. Souto *
(DDS, MSc, PhD)

Rafael Pino Vitti §
(DDS, MSc, PhD)

Address for Correspondence

Kusai Baroudi ‡

Email: d_kusai@yahoo.co.uk

* *School of Dentistry, University of Tiradentes, Aracaju, Sergipe, Brazil*

‡ *Associate Professor in the Postgraduate Program, School of Dentistry, University of Taubate, Taubate, Brazil*

§ *School of Dentistry, Herminio Ometto University Center, Araras, Sao Paulo, Brazil*

Received: 19.10.2021
Accepted: 10.02.2022

doi: 10.1922/EJPRD_2371Maciel09

ABSTRACT

Objectives: The objective of this systematic review was to compare the longevity of direct amalgam and composite resin restorations, in posterior teeth, through clinical, prospective or retrospective studies, with at least 5 years of follow-up. Materials and Methods: Studies published in the last 15 years (from 2006 to 2021) were collected using the PubMed and Medline databases. Results: The search strategy associated with the established inclusion and exclusion criteria resulted in a total of 17 articles. Factors related to failures in the performance of restorations were analyzed together with the clinical performance results of each material over the years of study, according to the methodology of each article. Conclusions: Regardless of the restorative material, the successful results over more than 5 years are due much more to the correct application of the technique, the operator's skill/knowledge and factors related to the patient, such as the type of tooth, number of faces involved in the restoration and oral hygiene.

INTRODUCTION

Dental amalgam (AM) was, for some time, the material of choice for restorations of posterior teeth.Some authors mention the reduction of secondary caries through time due to oxidation formation of cavity margins.[1] Still, despite obtaining good long-term and cost-effective clinical results, this material does not meet the requirements for esthetic restorations.[2,3] The need to search for alternatives to AM was one of the reasons for the increase in the utilization of resin composites (RC) in restorations of posterior teeth.[4]

For many years, the resin composites have been able to promote restoration and adequate esthetic conditions to teeth; however, they have not presented satisfactory mechanical properties to be used in posterior teeth.[1] The lower wear resistance when compared to AM,[5] besides the higher technique sensitivity, the shrinkage during polymerization and the possibility of marginal gap formation are among the reasons, which may cause postoperative sensitivity and consequent increase in the probability of secondary caries (marginal gaps of at least 100 μm).[6] The limitations for the use of non-resin composite material in posterior teeth found in literature would be the critical factors related to composites durability.[7] With the emergence of "universal" composites, the good esthetics they promoted after correct polishing, and the wear resistance (<10 μm/year) lead to the use of such esthetic material in anterior and posterior teeth with more confidence.[1] An important advantage of the use of RC is the adhesive technique, which needs minimum dental tissue removal for restoration,[8] in addition to its strengthening of weak dental structures.[9]

Nevertheless, despite the replacement of AM by the resin composites, there are still some controversies in the studies regarding longevity of these materials when applied to posterior restorations.[2] Also, the survival rate of RC restorations that are performed in clinics are low and only a few are based on random controlled clinical trials.[10] With the increase in the use of composites in posterior teeth, it is important that clinicians are aware of the probable longevity and of the possible failure modes in posterior teeth.[1,11]

In the last few years, short-term studies have been emphasized as an attempt to promote long-term clinical performance forecast of posterior composites.[12,13] Yet, short-term studies do not provide scientific evidence and the loss of anatomical shape observed in these studies do not have clinical relevance in terms of long-term survival.[14] Long-term studies are still necessary to identify failure modes and their possible causes.[11,14]

This systematic review originates in the fact that there are still controversies regarding longevity and clinical performance of direct posterior restorations. Thus, the aim of this systematic review was to compare the longevity of direct AM and RC restorations in posterior teeth through clinical, prospective or retrospective studies, with at least 5 years of follow-up to demystify the factors that could be associated to the clinical performance of RC and AM posterior restorations.

METHODOLOGY

This systematic review was carried out in accordance with the criteria established by Cochrane. The methods applied included a search strategy for articles in the literature, related to the longevity of direct restorations with amalgam and/or resin composite. Using the PubMed and Medline databases, searches were carried out by combining the descriptors: “posterior restorations” and “resin composite” or “amalgam” and “longevity”. The survey was carried out in two moments, in January 2017 and in March 2021. Both surveys used the same descriptors and inclusion and exclusion criteria.

INCLUSION CRITERIA

For the first stage of the research, the inclusion criteria were: articles in English published in full in the last 10 years (2006-2017), and for the second stage of the research, articles published in full in the last 15 years (2006-2021) were collected.

Only clinical studies, performed in humans, with segments of longitudinal studies, with prospective or retrospective directions (with at least 5 years of analysis and/or follow-up) were selected; and to analyze the longevity of amalgam and/or resin composite restorations. Only data referring to restorations in posterior dental units, in class I and/or II cavities, were observed. The clinical survival time between placement and the need to repair or replace the restorations was also analyzed, as well as the factors that influenced the failures.

EXCLUSION CRITERIA

Review articles, case studies, cohort studies, longevity assessment of restorations that have already been replaced and/or repaired, and studies that assessed the professional’s knowledge through questionnaires were excluded. It is noteworthy that some articles evaluated various restorative materials, applied to deciduous and permanent teeth, and in different types of cavities. Data from these articles that were related to the longevity of restorative materials other than amalgam and resin composite, or that had been applied to primary teeth, were excluded from the analysis of this review.

ARTICLE SELECTION

The research based on the descriptors mentioned was carried out in two moments: January 1, 2017, and March 12, 2021. The selection of texts, application of the inclusion/exclusion criteria and extraction of information were performed by two independent reviewers at different times of the research, and confirmation of all data collected was performed by a third reviewer (kappa = 0.87) . Any disagreements between reviewers were discussed and resolved by consensus.

RESULTS

At the first search, 78 articles were collected. In the second search, a total of 96 papers were collected. After applying the inclusion and exclusion criteria, 14 and 10 studies were obtained, respectively. By excluding the repeated articles, 17 complete and eligible articles for this systematic review were obtained, as described in the flowchart *(Figure 1)*.

Eleven retrospective studies were found (Opdam *et al.*, 2007; Opdam *et al.*, 2007; Sunnegårdh-Grönberg *et al.*, 2009; Käkilehto *et al.*, 2009; Opdam *et al.*, 2010; Baldissera *et al.*, 2013; Kim *et al.*, 2013; Rho *et al.*, 2013; Lempel *et al.*, 2015; Laske *et al.*, 2016; Palotie *et al.*, 2017)[1,2,9,11,14-20] in addition to 6 prospective studies (Bernardo *et al.*, 2007; Soncini *et al.*, 2007; Pallesen *et al.*, 2013; Pallesen *et al.*, 2014; Dietz *et al.*, 2014; Jardim *et al.*, 2020).[21-26]

It was observed that the longevity of restorations can be influenced by clinical variables, such as: restoration size,[22,23] location of restored tooth (maxillary or mandibular),[1,11,23] restored cavity classification,[15,11,18,19,23,24] number of surfaces involved,[1,11,14,20,21,23,24] dental unit involved,[11,14,19,20,23] number of restorations per patient,[22] age,[15,16,23,19,20] patient’s gender,[19,24] behavioral aspects such as caries risk,[9,15,16,21] and the quality and the technical experience of operator.[15,16,19] Regarding failures, caries and fracture of the tooth and/or restoration were the most cited among the articles evaluated.

All analyzed studies applied standardized methodologies to assess the longevity of restorations. The USPHS system was cited in six of these studies. Lempel *et al.* (2015)[14] used the conventional USPHS method. Opdam *et al.* (2010)[17] used

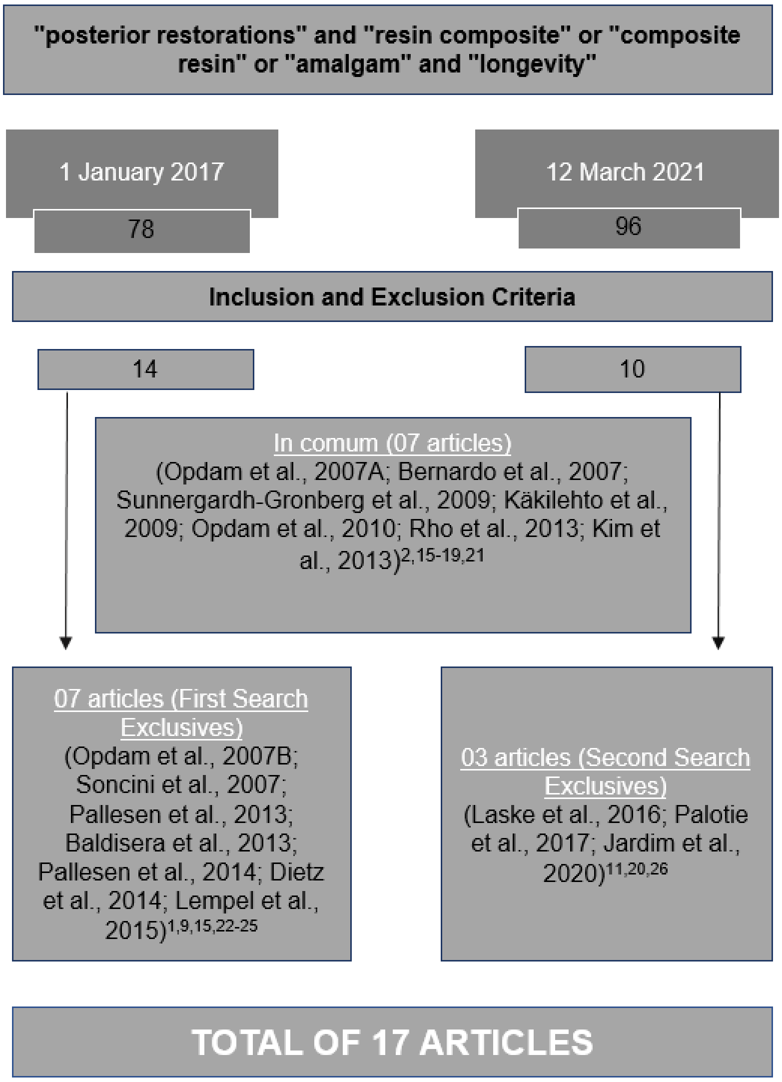

Figure 1: Flowchart of search strategy and results.

Ryge's USPHS method, while Rho *et al.* (2013),[19] Kim *et al.* (2013)[18] and Jardim *et al.* (2020)[26] modified the USPHS method for its use. The research by Dietz *et al.* (2014)[25] used, in addition to the modified USPHS system, evaluation of models reproduced from restorations made in scanning electron microscopy (SEM), immediately after placement, after 6 months, after 1 year and followed by annual evaluations. Other studies used database analysis,[2,9,15,16,24] annual analysis interproximal radiographs,[21,24] clinical evaluation every 6 months for 5 years,[22] and analysis through electronic files referring to medical records.[11,20] One study used data from reports from dental surgeons.[23] Only one study was based on the criteria of the FDI (Federal Drug Administration, USA).[1]

Table 1 shows the studies selected for this review with the following descriptions: authors and respective year of publication; research evaluation time associated with the type of study, retrospective or prospective; the annual failure rate and/or survival rate of evaluated restorative materials; the main failures and associated factors; and time with the methods that were applied by the authors to evaluate the clinical performance of restorations. It is noteworthy that some articles cited factors related to the patient, presence of base material, operator experience, restorative technique, dental unit involved, number of restorations and surfaces involved, location of restoration, cavity size and classification, use of absolute isolation and characteristics of definitive restorative materials (AM or RC) as potentially relevant to restoration failures.

DISCUSSION

Regarding the analysis of longevity between RC and AM in posterior teeth, the studies by Soncini *et al.* (2007),[22] Opdam *et al* (2007),[2] Palotie *et al.* (2017)[11] and Jardim *et al.* (2020)[26] found no statistically significant differences between restorative materials. However, other studies[15-17,19-21] found some relevant differences. In the study by Opdam *et al.*(2010)[17] and Laske *et al.* (2016)[20] RC had greater longevity than AM, with lower failure rates over the years of study. For Opdam *et al.* (2010),[17] both materials (RC and AM) had comparable performances at 5 years, but after 12 years of follow-up, RC showed longer survival rate than AM. In other studies,[15,16,18,19,21] the

Table 1. Results description

Authors	Time	Results	Major Failures	Factors Associated With Failure	Evaluation Method
Opdam *et al.* (2007A)[2]	5 and 10 (RL)	SR 5 years CR: 91,7%; AM: 89,6% SR 10 years CR: 82,2%; AM: 79,2%	Caries, tooth fracture, endodontic treatment.	Authors do not cite	Own method (database analysis)
Bernardo *et al.* (2007)[21]	7 (PL)	SR 7 years CR: 85,5% AM: 94,4%	Recurrent caries, fracture or loss of restoration.	Caries risk, number of surfaces involved.	Own method (annual evaluation plus interproximal radiography)
Opdam *et al.* (2007B)[9]	9 (RL)	SR CR: 88,1% IC+CR: 70,5%		Risk of caries, presence of CIV.	Own method (database analysis)
Soncini *et al.*(2007)[22]	5 (PL)	Replacement CR: 14,9%; AM: 10,8% Repair CR: 2,8%; AM: 0,4%	Caries, fracture of the tooth and/or restoration.	Number of restorations, cavity size.	Own method (clinical evaluation 6/6 months)
Sunnegardh-Gronberg *et al.* (2009)[15]	16 years (RL)	SR AM: 16 years; CR: 6 years	New or recurrent caries, fracture or loss of restoration.	Caries risk, cavity classification, operator experience.	Own method (database analysis - prevalence study)
Kakilehto *et al.* (2009)[16]	>10 years (RL)	SR AM: 13,6 years (1970) 7,9 years (1980) SR CR: 4,9 to 7,3 years (1970 to 1980)		Patient age, use of new materials, restorative technique.	Own method (database analysis)
Opdam *et al.* (2010)[17]	5 and 12 (RL)	Failure rate: 5 years CR: 1,78%; AM: 1,25% Failure rate: 12 years CR: 1,68%; AM: 2,41%	Secondary caries, fracture or loss of restoration.	Caries risk	USPHS (Ryge 1980)

Table 1 continued over leaf...

Table 1. Results description continued...

Authors	Time	Results	Major Failures	Factors Associated With Failure	Evaluation Method
Pallesen *et al.* (2013)[23]	8 (PL)	SRCR: 84,3% Failure rate per age: 5-11: 17% a 37% 12-19: 9% a 15%		Patient age, material used, tooth location, cavity size and classification, presence of base material, postoperative sensitivity, number of surfaces, dental unit involved.	Own method (report evaluation)
Baldissera *et al.* (2013)[1]	20 (RL)	Failure rate– posterior CR 12%	---	Number of surfaces, restoration location, restorative material.	FDI criteria
Rho *et al.* (2013)[19]	>8 years (RL)	Failure rate AM: 55,7%; CR: 42,1% SR AM: 8,7 years; CR: 5years	Caries, fracture of the restoration and cracked tooth syndrome.	Operator experience, restorative material, involved dental unit, patient age and gender, cavity classification.	Modified USPHS
Kim *et al.* (2013)[18]	5 and 10 (RL)	SR AM: 8,9 years; CR: 9,7 years	Primary or secondary caries, tooth or restoration fracture.	Caries, marginal loss of fit, marginal discoloration and hypersensitivity.	Modified USPHS
Pallesen *et al.* (2014)[24]	8 (PL)	SR CR: 84,3% (8years)	Fracture, marginal degradation, endodontic treatment, contouring.	Patient gender, number of surfaces, cavity classification, presence of base material.	Own method (Assessment through data collection and radiographs)
Dietz *et al.* (2014)[25]	15 (PL)	Annual failure rate 1,92% SR - CR: 91,4% (6 years) 81,3% (9 years) 73,6% (13 years until the end of evaluation)	Caries, fracture or loss of restoration, loss of retention.	Marginal integrity failure, marginal fracture, loss of material, surface roughness and texture, excess material.	Modified USPHS Morphology evaluation -SEM (Evaluation after placement, 6 months, 1st year and annually)
Lempel *et al.* (2015)[14]	10 (RL)	Failure rate–CR Filtek: 0,9% Herculite: 1,36% Renew: 7,81% Gradia: 8,57%	Cavity Type, Operator Experience, Patient Age and Gender.	Restorative material, number of surfaces, marginal discoloration, dental unit involved.	USPHS

Table 1 continued over leaf...

Table 1. Results description continued...

Authors	Time	Results	Major Failures	Factors Associated With Failure	Evaluation Method
Laske *et al.* (2016)[20]	15 (RL)	Failure rate CR: 4,5% AM: 5,3% Trained dentists ≤ 1980: 4,5% – 1990: 4,7% ≥ 1990: 5,3% Dental unit involved Premolar: 4% Molar: 5,2% Number of surfaces 1 to 3 sides: 4,3% a 5,2% 4 sides: 5,9% Endodontic treatment With: 10,9% Without: 4,5% Age ≥ 65 years: 6,8% < 65 years: 4,3 a 5% Presence of prothesis With: 6,4% a 7,8% Without: 4,5%	Secondary caries, post-operative tenderness, tooth or restoration fracture.	Dental unit involved, number of surfaces, patient age, teeth with endodontic treatment, presence of removable prosthesis.	Own method (Electronic files referring to medical records).
Palotie *et al.* (2017)[11]	13 (RL)	SR – CR MO/DO: 12,3 years Premolar 9,2 years Molar MOD: 9,6 years Premolar 6,3 years Molar CR e AM Top tooth - 10,4 years Bottom tooth - 9,2 years Failure rate - CR MO/DO: 2,9 % Premolar 5 % Molar MOD: 4,3 % Premolar 7,1 % Molar	Secondary caries, fracture of the restoration, total or partial loss of the restoration.	Dental unit involved, cavity classification, number of surfaces, tooth location.	Own method (Electronic files referring to medical records).
Jardim *et al.* (2020)	5 years (PL)	SR statistically similar AM (83%) = CR (75%)	Secondary caries, fracture of the restoration, endodontic treatment.	No influence on longevity was observed between type of tooth, location in the arch and extension of the cavity.	Modified USPHS (evaluation after five years)

* CR (composite resin); AM (amalgam); PL (prospective longitudinal study); RL (retrospective longitudinal study); SR (survival rate).
Authors who do not report the annual failure rate, cite only the average longevity of restorations or the survival rate.

highest survival rates were for the AM. This can be explained that the longevity of RC restorations depends, among other factors, on the patient's risk of caries, as this material has a greater capacity to accumulate biofilm,[27] which can stimulate the development of secondary caries. According to Bernardo *et al.* (2007),[21] poor oral hygiene, the most common feature in young patients, is responsible for high number of recurrent caries in RCs. The higher the caries risk index, the greater the probability of failures in clinical performance, which is aggravated when associated with extensive restorations and cariogenic diet.[15,16] For Opdam *et al.* (2010),[17] among the failure factors in the high-risk group (55.9%), more caries were found, whereas in the low-risk group (21.1%), fractures and "cracked tooth syndrome" were more observed, and mainly in AM restorations.

Some studies[21,22,26] cited the use of rubber dam in AM and RC restorations. Soncini *et al.* (2007)[22] and Jardim *et al.* (2020),[26] when comparing the longevity of AM and RC restorations performed with rubber dam, found no significant difference between the materials. Bernardo *et al.* (2007)[21] used rubber dam, and, even with the use of this practice, considered AM as a material with greater longevity than RC. The authors justified that these findings may come from the age group of subjects included in this study. And, once again, inadequate oral hygiene and characteristic of adolescents were cited as responsible for the highest failure rates in RC restorations placed, even with rubber dam. Studies[14,23,24] that cited the use of relative isolation technique, with cotton rolls and suction devices, obtained high resin survival rates composite, but these studies did not compare the survival of AM and RC restorations. Therefore, the survival rates of these studies cannot be compared with those that evaluated comparisons between the two restorative materials.

Some studies[2,9,15-17,19,20,25] did not mention which isolation technique was applied. Thus, the comparison of these data is hampered, since the resin composite is the material that can be most affected if there is saliva contamination. Among the studies[2,15-17,19,20] that did not mention the use of isolation and compared both materials, AM and RC, only Opdam *et al.* (2010)[17] and Laske *et al.* (2016)[20] found RC as a material with longer life span than AM, and lower failure rates.

The main reasons cited for the failure of posterior restorations with resin composite were caries and fractures. Importantly, the articles did not mention factors related to temporomandibular dysfunction (TMD) and bruxism. Probably, secondary caries, being a relapse of primary caries, highlights the failure of operators and patients to act effectively in the etiology and prevention of the disease, as well as the quality of the material used and its proper use. While the fracture of restoration or tooth may be related to the presence of a base material/liner under the restoration, restorations with intermediate material failed more compared to those without base material.[2,23,24] It has been suggested that the base material decreases the strength and durability of restoration,[28] but this does not justify a direct relationship with the failure of restoration as it also depends on other factors such as, for example, the operator experience.[20]

With the advancement of adhesive systems and good esthetic properties, composites have become the preferred material for direct restorations in posterior teeth. When hybrid composites, so-called universal or 'gold standard' are used for subsequent restorations, a reduced annual failure rate is expected. However, some authors[1,20,21,22] observed that the clinical longevity ofresin composite restorations mainly depends on factors that are not related to the properties of materials.

Opdam *et al.* (2007A)[2] and Kim *et al.* (2013)[18] reported that cavity size, operator experience, patient age, gender and number of restorations can influence the survival rate of RC and AM restorations. For Kim *et al.* (2013)[18] and Rho *et al.* (2013),[19] the greatest risk of failure in AM restorations occurred in class II cavities. This may be related to the fact that Class II amalgam preparations require a cavity conformation that does not advocate maximum preservation of the structure, as the preparation needs to mechanically retain the restorative material in the cavity. This factor may be the explanation for the greatest AM failures in class II cavity, since the tooth structure is more fragile. For the same authors,[18,19] RC restorations did not obtain significant differences between the cavity types, classes I and II. Some authors[1,11,14,18,20,21,23,24] demonstrated that posterior restorations involving more than one surface showed higher failure rates. However, it is worth emphasizing what Pallesen *et al.* (2014)[24] observed that for RC restorations, due to the polymerization shrinkage factor, the highest failure rates are associated with RC restorations in class I. These authors also highlighted a higher frequency of replacement due to secondary caries in class I restorations of RC, when compared to restorations with two, three or more surfaces; with restoration and/or tooth fractures being the biggest failures in restorations involving more than one surface.

Regarding the position of tooth in the dental arch, only Pallesen *et al.* (2013)[23] and Palotie *et al.* (2017)[11] cited that restorations in mandibular teeth are a contributing factor to failure rates. This shorter survival can be explained by an operative field of greater saliva accumulation and possible biofilm accumulation.

Regarding the type of tooth, some authors (Rho *et al.*, 2013; Pallesen *et al.*, 2013; Lempel *et al.*, 2015; Laske *et al.*, 2016; Palotie *et al.*, 2017)[11,14,19,20,23] mentioned that restorations placed in molars was a contributing factor to failure rates, being more likely to be replaced or repaired than premolars. Furthermore, Rho *et al.* (2013)[19] demonstrated that molars with RC had shorter longevity when compared to molars restored with AM. This can be explained by a less accessible field both for performing the restorative technique and for cleaning.

Kakilehto *et al.* (2009)[16] demonstrated that the survival rate of RC on occlusal surfaces varied according to the age of patients. Rho *et al.* (2013)[18] obtained lower longevity values for restorations in adolescent patients and those aged over 70 years. Pallesen *et al*. (2013)[23] showed a lower relative frequency of failure of restorations in 12-19 aged patients group compared to the 5-11 aged group. Laske *et al*. (2016)[20] cited higher failure rates for restorations in patients older than 65 years. The high failure rate in younger patients or patients over 70 years old can be explained by higher risk of caries, the difficult cooperation in daily oral hygiene and the difficulty in cooperating when performing a quality restorative technique. Furthemore, regarding the patient's gender, according to Rho *et al*. (2013),[19] female patients had RC restorations with shorter longevity than AM. In contrast, Pallesen *et al*. (2014)[24] observed a higher frequency of secondary caries for men than for women. Lawrence *et al*. (2008)[29] suggest that women have a better perception of oral health than men, in addition to being more adept at preventive appointment.

It is well accepted today, but with little evidence that the operator is one of the most important variables in determining the diagnosis, technique and quality of the restoration, material selection and hygiene instructions for patients. Sunnergardh-Gronberg *et al*. (2009),[15] Rho *et al*. (2013)[19] and Laske *et al*. (2016)[20] showed the influence of operator experience on the service life of restorations. In the study by Laske *et al*. (2016),[20] the number of replaced restorations was lower for more experienced dentists. In the last 50 years, changes in the practice of restorative dentistry have focused on the development of new restorative materials, thus, the skill in the restorative technique can influence the clinical longevity of restorations, and this is directly related to the experience of the technical and clinical profession.[16] The work of Rho *et al*. (2013)[18] evaluated operators with varied clinical experiences, from students to professors, more faithfully representing the clinical reality than if only restorations performed by more experienced professionals had been chosen.

RC has undergone many technological advances in recent years, in addition to having a lower fracture rate, reinforcing the hypothesis that adhesive restorations strengthen the tooth structure. In this review, only one study shows a statistically higher survival rate for RC restorations compared to AM,[17] a difference especially evident after a longer observation period (12 years). This emphasizes the need for more long-term randomized clinical trials to assess the clinical longevity of RC restorations compared to AM restorations.

It is important to highlight that amalgam has been questioned in recent years, mainly because of the presence of mercury in its composition. In addition, amalgam does not provide procedures with aesthetic characteristics, nor with more conservative cavity preparation parameters.[7,30] Thus, as the restorative technique with amalgam has such disadvantages, resin composite is increasingly being the material of choice for direct restoration procedures.

CONCLUSIONS

Regardless of the restorative material, the clinical performance of restorations over more than 5 years, depends on the correct application of the technique, skill/knowledge of the operator and factors related to the patient, such as oral hygiene, risk of caries and so forth. Therefore, due to the several disadvantages of amalgam in relation to marginal sealing and risks of fracture, the tendency is for the composite resin to replace it definitively. Advances in adhesive materials and mechanical strengths of composite resins have proven that amalgam restorations do not have superior long-term clinical performance to resins, since the restorative technique be performed correctly.

REFERENCES

1. Baldissera, R.A., Corrêa, M.B., Schuch, H.S., Collares, K., Nascimento, G.G., Jardim, P.S., Moraes, R.R., Opdam, N.J.M. and Demarco, F.F. Are there universal restorative composites for anterior and posterior teeth? *J Dent*. 2013; **41**:1027-1035
2. Opdam, N.J., Bronkhorst, E.M., Roeters, J.M. and Loomans, B.A.C. A retrospective clinicalstudy on longevity of posterior composite and amalgam restorations. *Dent Mater*. 2007; **23**:2-8
3. Moncada, G., Vildósola, P., Fernández, E., Estay, J., de Oliveira Júnior, O.B., de Andrade, M.F., Martin, J., Mjör, I.A. and Gordan, V.V. Longitudinal results of a 10-year clinical trial of repair of amalgam restorations. *Oper Dent*. 2015; **40**:34-43.
4. Knobloch, L.A., Kerby, R.E., Seghi, R., Berlin, J.S. and Clelland, N. Fracture toughness of packable and conventional composite materials. *J Prosthet Dent*. 2002; **88**:307-313.
5. Ferracane, J.L. Dental composites: Present status and reseats CRH directions. In: Transactions of the Second International Congress on Dental Materials. Honolulu: Academy of Dental Materials. 1993: 43-53.
6. Busato, A.L., Loguecrio, A.D., Reis, A. and Carrilho, M.R. Clinical evaluation of posterior composite restorations: 6-year results. *Am J Dent*. 2001; **14**:304-308.
7. Moraschini, V., Fai, C.K., Alto, R.M. and Dos Santos, G.O. Amalgam and resin composite longevity of posterior restorations: A systematic review and meta-analysis. *J Dent*. 2015; **43**:1043-1050.
8. Cenci, M., Demarco, F. and de Carvalho, R. Class II resin composite restorations with two polymerization techniques: relationship between microtensile bond strengthand marginal leakage. *J Dent*. 2005; **33**:603-610.
9. Opdam, N.J., Bronkhorst, E.M., Roeters, J.M. and Loomans, B.A. Longevity and reasons for failure of sandwich and total-etch posterior resin composite restorations. *J Adhes Dent*. 2007; **9**:469-75.
10. Opdam, N.J., Loomans, B.A., Roeters, F.J. and Bronkhorst, E.M. Five years Clinical Performace of posterior resin composite restorations placed by dental students. *J Dent*. 2002; **87**:642–649
11. Palotie, U., Eronen, A.K., Vehkalahti, K. and Vehkalahti, M.M. Longevity of 2- and 3-surface restorations in posterior teeth of 25- to 30-year-olds attending Public Dental Service – a 13-year observation. *J Dent*. 2017; **62**:13
12. Mazer, R.B., Leinfelder, K.F., Teixeira, L.C. and Cury, C.G. Short term clinical studies for predicting posterior composite performance. *J Dent Res*, 1992: 71-112.

13. McCracken, M.S., Gordan, V.V., Litaker, M.S., Funkhouser, E., Fellows, J.L., Shamp, D.G., Qvist, V., Meral, J.S. and Gilbert, G.H. A 24-month evaluation of amalgam and resin-based composite restorations: Findings from The National Dental Practice-Based Research Network. *J Am Dent Assoc*. 2013; **144**:583-593.
14. Lempel, E., Tóth, Á., Fábián, T., Krajczár, K. and Szalma, J. Retrospective evaluation of posterior direct composite restorations: 10-year findings. *Dent Mater*. 2015; **31**:115-122.
15. Sunnegårdh-Grönberg, K., van Dijken, J.W., Funegård, U., Lindberg, A. and Nilsson, M. Selection of dental materials and longevity of replaced restorations in Public Dental Health clinics in northern Sweden. *J Dent*. 2009; **37**:673-678.
16. Käkilehto, T., Salo, S. and Larmas, M. Data mining of clinical oral health documents for analysis of the longevity of different restorative materials in Finland. *Int J Med Inform*. 2009; **78**:e68-74.
17. Opdam, N.J., Bronkhorst, E.M., Loomans, B.A. and Huysmans, M.C. 12-year survival of composite vs. amalgam restorations. *J Dent Res*. 2010; 89:1063-1067.
18. Kim, K.L., Namgung, C. and Cho, B.H. The effect of clinical performance on the survival estimates of direct restorations. *Restor Dent Endod*. 2013; **38**:11-20.
19. Rho, Y.J., Namgung, C., Jin, B.H., Lim, B-S. and Cho, B-H. Longevity of direct restorations in stress-bearing posterior cavities: a retrospective study. *Oper Dent*. 2013; **38**:572-582.
20. Laske, M, Opdam, N.J.M., Bronkhorst, E.M., Braspenning, J.C.C. and Huysmans, M.C.D.N.J.M. Longevity of direct restorations in Dutch dental practices. Descriptive study out of a practice based research network. *J Dent*. 2016; **46**:12-7.
21. Bernardo, M., Luis, H., Martin, M.D., Leroux, B.G., Rue, T., Leitão, J. and DeRouen, T.A. Survival and reasons for failure of amalgam versus composite posterior restorations placed in a randomized clinical trial. *J Am Dent Assoc*. 2007; **138**:775-783
22. Soncini, J.A., Maserejian, N.N., Trachtenberg, F., Tavares, M. and Hayes, C. The longevity of amalgam versus compomer/composite restorations in posterior primary and permanent teeth: findings From the New England Children's Amalgam Trial. *J Am Dent Assoc*. 2007; **138**:763-772.
23. Pallesen, U., van Dijken, J.W., Halken, J., Hallonsten, A-L. and Höigaard, R. Longevity of posterior resin composite restorations in permanent teeth in Public Dental Health Service: a prospective 8 years follow up. *J Dent*. 2013; **41**:297-306.
24. Pallesen, U., van Dijken, J.W., Halken, J., Hallonsten, A-L. and Höigaard, R. A prospective 8-year follow-up of posterior resin composite restorations in permanent teeth of children and adolescents in Public Dental Health Service: reasons for replacement. *Clin Oral Investig*. 2014; **18**:819-827.
25. Dietz, W., Montag, R., Kraft, U., Walther, M., Sigusch, B.W. and Gaengler, P. Longitudinal micromorphological 15-year results of posterior composite restorations using three-dimensional scanning electron microscopy. *J Dent*. 2014; **42**:959-969.
26. Jardim, J.J., Mestrinho, H.D., Koppe, B., de Paula, L.M., Alves, L.S., Yamaguti, P.M., Almeida, J.C.F. and Maltz, M. Restorations after selective caries removal: 5-Year randomized trial. *J Dent*. 2020; **99**:103416.
27. Leinfelder, K.F. Do restorations made of amalgam outlast those made of resin-based composite? *JADA*. 2000; **131**:1186-1187.
28. Demarco, F.F., Corrêa, M.B., Cenci, M.S., Moraes, R.R. and Opdam, N.J.M. Longevity of posterior composite restorations: not only matter of materials. *Dent Mater* 2012; **28**:87–101.
29. Lawrence, H.P., Thomson, W.M., Broadbent, J.M. and Poulton, R. Oral health-related quality of life in a birth cohort of 32-year olds. *Community Dent Oral Epidemiol*. 2008; **36**:305–316.
30. Lynch, C.D., Opdam, N.J., Hickel, R., Brunton, P.A., Gurgan, S., Kakaboura, A., Shearer, A.C., Vanherle, G. and Wilson, N.H.F. Guidance on posterior resin composites: Academy of Operative Dentistry European Section. *J Dent*. 2014; **42**:377-383.

ejprd.org - Published by Dennis Barber Journals.