Clin Oral Invest (2014) 18:819–827
DOI 10.1007/s00784-013-1052-x

ORIGINAL ARTICLE

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

Ulla Pallesen · Jan W. V. van Dijken · Jette Halken · Anna-Lena Hallonsten · Ruth Höigaard

Received: 7 May 2013 / Accepted: 5 July 2013 / Published online: 20 July 2013

Abstract
Objectives The aim of the study was to investigate reasons for replacement and repair of posterior resin composite (RC) restorations placed in permanent teeth of children and adolescents attending Public Dental Health Service in Denmark.
Material and method All posterior RC placed consecutively by 115 dentists over a period of 4 years were evaluated at baseline and up to 8 years later. The endpoint of each restoration was defined when repair or replacement was performed. The influence of patient, dentist and material factors on reasons for repair or replacement was investigated.
Results A total of 4,355 restorations were placed. Replacements comprised 406 and repairs 125 restorations. The cumulative survival rate at 8 years was 84 %. Failed restorations were most frequently seen due to secondary caries (57 %), post-operative sensitivity (POS) (10 %) and RC fracture (6 %). POS was observed in 1.5 % of the evaluations and reported more often in girls and from teeth restored with a base material. Older dentists showed lower proportion of replaced restorations due to secondary caries than younger dentists.
Conclusion Posterior RC restorations in children and adolescents performed in general practice showed a good durability with annual failure rates of 2 %. The main reason for failure was secondary caries followed by post-operative sensitivity and resin composite fracture. A high proportion of replaced/repaired RC restorations were caused by primary caries in a non-filled surface.
Clinical relevance Secondary caries was the main reason for failure of RC in children and young adults. More teeth with post-operative sensitivity and a shorter longevity of restorations were observed when a base material was used.

Keywords Children · Clinical · Longevity · Posterior · Resin composite · Restorations

Introduction

Replacement of failed restorations is still the most common procedure in general dentistry, accounting for a larger proportion of restorative treatments in adults than primary caries, and represents enormous economic expenses each year [1–3]. Due to the environmental concern of mercury, claimed toxicity of amalgam and the increased demand for aesthetic restorations, resin composite (RC) has replaced amalgam increasingly in many countries [1, 4, 5]. As the share of amalgam was continuously decreasing and many dentists had not received basic education in posterior RC therapy during their dental education, it is necessary to know what impact this may have on placement and reasons for replacement of posterior RC restorations. Restorations diagnosed as failed will in most cases be replaced. Some diagnoses of failures are easy and objective, while other, more subjectively estimated reasons, such as bulk or marginal discoloration and secondary caries, have been disputed [6, 7].

The evidence of recording reasons for replacement and longevity depends on the accuracy of the operator in keeping the records after treatment [8]. Unfortunately, recording the reasons for failure is not mandatory in many countries, and

Jette Halken is deceased.

U. Pallesen (✉)
Section of Cariology & Endodontics and Paediatric Dentistry & Clinical Genetcs, Department of Odontology, Faculty of Health and Medical Sciences, University of Copenhagen, Nörre Alle 20, 2200 Copenhagen N, Denmark
e-mail: ul@sund.ku.dk

J. W. V. van Dijken
Department of Odontology, Umea University, Umea, Sweden

J. Halken · A.-L. Hallonsten · R. Höigaard
Public Dental Health Service, Copenhagen, Denmark

therefore information has mainly been based on reports of selected practitioners in cross-sectional studies and from longitudinal well-controlled randomised studies. In most of these studies, selected groups of general practitioners have been involved [9–11]. Only a few studies involved a randomised selection or the involvement of all practitioners in a decided population [1, 12]. Controlled prospective long-term clinical trials are therefore the preferred evaluation method with a high level of evidence. However, these evaluations are time consuming and many studies have difficulties keeping low dropout rates. Therefore, methods that are more easy to perform such as retrospective and cross-sectional studies have often been chosen.

In cross-sectional, prospective and retrospective long-term evaluations, secondary caries, material and/or tooth fracture have been the predominant reasons for failures of posterior RC in adults [1, 8, 13–17]. In the young permanent dentition, a few studies also observed secondary caries as the main reason for failure [13, 18–21].

The increased use of RC and the wider indication area makes its necessary to regularly study its longevity and reasons for replacement. Only one 4-year follow-up study from Norway recently reported why RC were replaced or repaired in Public Dental Health Service (PDHS) clinics [22]. Recently, we reported the 8-year durability of posterior RC restorations placed in permanent teeth of children and adolescents during a 4-year period by PDHS practitioners in the municipalities of Copenhagen and Frederiksberg [23].

The aim of this study was to evaluate the reasons for failure of posterior resin composite restorations placed in these children and adolescents and to determine whether patient, dentist or material factors influence the proportions of failure reasons. The first hypothesis tested was that the proportional distribution of the reasons for failure of the RC restorations was independent of age and gender of the children. The second hypothesis was that dentist factors had no influence on the reasons for failure.

Materials and methods

The study design was a prospective, longitudinal, structured data collection study applied to all children and adolescent patients consecutively treated in the municipalities of Copenhagen and Frederiksberg, Denmark [23]. All children and adolescents up to 18 years treated between November 1998 and December 2002 in all PDHS clinics, in need of one or more class I and class II RC restorations in permanent teeth, were included in the follow-up. Dentists in Frederiksberg continued for another 3 years (December 2002–December 2005) placing posterior RC restorations. The reasons for placement were primary caries or replacement of restorations due to secondary caries, fracture of restoration, fracture of tooth or request by the participants. Excluded were participants with known allergic symptoms for dental resins and teeth with cavity margins deep below the gingival margins or cavities with difficult access, where moisture could not be controlled during the restorative procedure. The study was performed during ordinary public dental service and therefore no approval by the ethical committee was needed. Acceptance from the Danish Data Protection Agency was obtained.

Clinical procedures and evaluation

Before initiation of the study, all dentists in PDHS clinics in Copenhagen and Frederiksberg participated in an educative and introduction course concerning placement of posterior RC restorations to ensure a high uniformity of the technical procedure and a high quality of performance. The detailed clinical recommendations to the treating dentists concerning clinical cavity and restorative procedures have been described earlier [23]. Base materials were placed in medium and deep cavities based on the diagnostic criteria and methods the dentists normally used in their clinic. Cavity base materials used were in 73.4 % (35.7 % Alkaliner, 3M ESPE; 30.0 % Dycal, DeTrey Dentsply; 2.3 %, Calasept covered with Alkaliner or Dycal, Nordiska Dental, Sweden/3M ESPE/DeTrey Dentsply), other materials in 5.4 % and no base material in 26.6 %. Total etch adhesive bonding systems were applied (Prime & Bond, DeTrey Dentsply in 94 %; Scotchbond MP, 3M/ESPE, Germany in 3.9 %) and the RC (most frequent used Spectrum, DeTrey Dentsply in 88.2 %; Herculite, Heraeus Kulzer, Germany in 5.4 %) was applied in 2-mm-thick layers. Directly after polishing, etching of the margins of the restorations with 35 % phosphoric acid during 10 s was performed, followed by water rinse, intensive air drying and application of 99 % ethanol according to Qvist and Strøm [24]. A thin layer of hydrophobic bonding agent (Concise Enamel Bond, chemical cured, 3M ESPE) was then applied with a foam pellet. To isolate the operation field, the dentists used a salivary suction device and cotton rolls.

For each placed restoration a data collection sheet was completed at baseline and clinical registrations were recorded at the recalls by the treating dentists in the PDHS or after leaving PDHS by a private dentist [23]. Baseline registrations concerning patient, operator, cavity and restoration data were performed immediately after finishing of the restorations [23]. Post-operative sensitivity was recorded when the adolescents contacted the PDHS with minor or severe pain. Restorations were evaluated clinically and by use of X-ray. Interventions varied from repairs, when polishing small chip fractures or sealing of small marginal defects with bonding resin, to replacement of the restoration. Date, type and reason for intervention and replacement material were recorded. The participating practitioners diagnosed the need to replace or

repair the existing restorations based on the diagnostic criteria and methods they normally used in their clinic. The reasons were described, and in cases where more than one reason was possible, the principal reason for intervention was recorded. The participating practitioners used every day clinical criteria when assessing the restorations [14]. In the introduction of the study, reasons for replacement were discussed. No calibration of the dentists was performed.

Statistical analysis

The data collected were recorded and analysed using SAS, version 9.1. The endpoint of each restoration was defined when repair or replacement was performed, except for replacements due to caries in a non-filled surface of the same tooth. Descriptive statistics were used to describe data concerning participants and dentists, the type of tooth involved, cavity type, materials used, post-operative systems, repair or replacement. Proportional relative frequencies of reasons for failure were tested versus number of surfaces per cavity, base material, resin composite material and bonding system, and ratio of failed restorations per dentist concerning age and number of placed restorations using Wilcoxon two samples test, Chi^2 test and Fishers Exact test. Before statistical analysis, right-censoring was applied for cases replaced/repaired because of caries at another surface than the restored ones. The dependence between restorations within each individual was taken into account. The null hypothesis was rejected at 5 % level.

Results

In 2,881 children and adolescents (57.2 % girls and 42.8 % boys), 4,355 restorations were placed. The mean age of the participants at baseline was 13.7 years (median 14.1 years; min–max 5–19) and 78 % of the restorations were placed in 12–19 years old children. Forty-nine percent of all restorations were class I, 80.5 % placed in molars (3,507) and 19.5 % in premolars (848). The 115 dentists involved placed a mean of 37.4 (min–max, 2–388) restorations. Ten dentists placed more than 100 restorations each, while 71 dentists placed <25 restorations. The number of dentists involved, all women, in different age groups were as follows: 19 younger than 30 years, 19 between 31 and 39 years, 43 between 40 and 54 years and 14 older than 55 years. Cavity base materials were used in 73.4 % and no base material in 26.6 %, equally distributed over the dentist age groups. The number of placed restorations and evaluated for each of the follow-up years have been given earlier [23]. Placed restorations which were not evaluated at all resulted in a dropout of 16.1 %. Replacements were made in 406 cases and repairs were performed in 125 restorations. Kaplan–Meier survival analysis showed a cumulative survival rate until replacement or repair at 8 years of 84.3 % [23]. The number of restorations placed and relative frequencies of replaced/repaired restorations for the age of the children at the start of the study are shown in Fig. 1. The different reasons for replacement and repair without and including "new" caries are shown in Fig. 2a, b. The absolute frequencies and proportional relative frequencies of reasons for failures for RC restorations evaluated are shown in Table 1. The frequencies are shown both with and without inclusion of replaced/repaired restorations due to caries on a new surface contiguous to the evaluated restoration, assumed as a reason for failure. Secondary caries was registered as the main reason of failure for both replaced and repaired restorations. Post-operative sensitivity (POS) was the second and RC fracture the third reason for failure. A reason for failure was indicated by the evaluating dentists for 97 % of the replaced RC restorations, while the reason for repair was indicated in 58 %. POS was observed in 1.5 % of the evaluations and no significant differences were seen between the different age groups. A higher proportion of POS as reason for replacement (this proportion of POS related to the other different reasons for failure is in the manuscript called for proportional frequency) was observed in girls (14.6 %) than in boys (5.9 %). Only six of the repaired restorations, all in girls, were performed because of POS. No differences in absolute frequencies were found between restorations replaced because of POS in premolar and molar teeth (1.5 %) or between 1-, 2–3- and >3-surface RC teeth (1.1, 1.9 and 1.7 %, respectively) ($p<0.05$). More POS was observed in restorations with base material compared to those without (1.8 and 0.6 %, respectively). The mean time to replacement/repair for post-operative sensitivity was 1.3 year (SD 1.5), followed by fracture of tooth 2.6 years

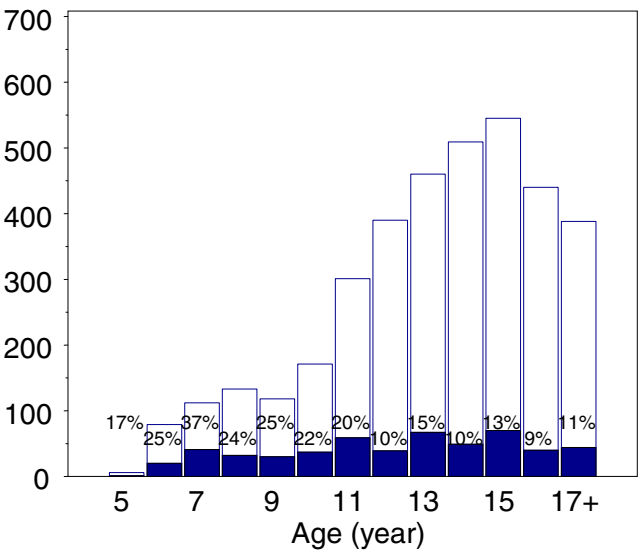

Fig. 1 Number of restorations and relative frequencies of replaced or repaired (in bars) restorations according to age of the children at the start of the study

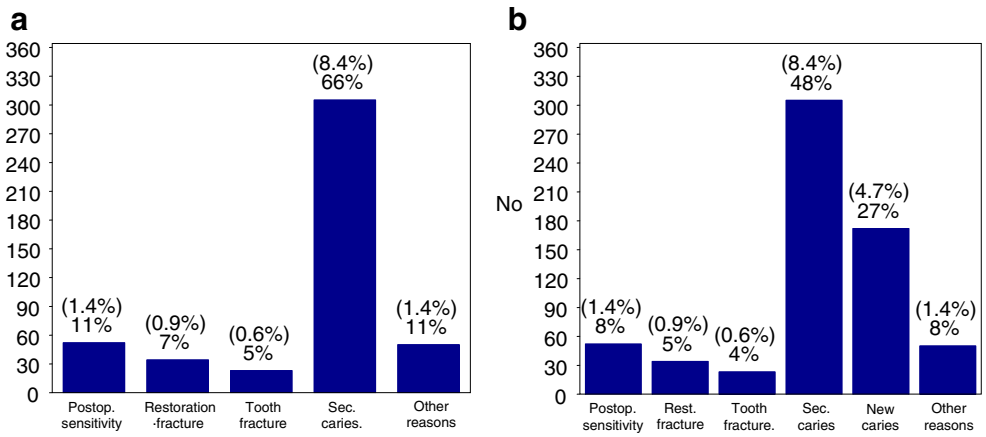

Fig. 2 **a** Relative frequencies of reasons for replacement or repair of restorations. *In parenthesis*, frequencies of revised restorations. Not included are reasons for replacement/repair because of "new caries". **b** Relative frequencies of reasons for replacement/repair of restorations. *In parenthesis*, frequencies of revised restorations. Included are reasons for replacement/repair because of "new caries"

(SD 2.1), fracture of restoration 3.1 years (SD 1.7) and secondary caries 3.7 years (SD 1.9) ($p<0.001$; Wilcoxon two sample test).

The proportional frequency of secondary caries was higher for boys (60.9 %) than for girls (55.3 %). Boys showed slightly more replaced restorations because of RC fractures than girls, 8.5 and 6.3 %, respectively (ns; Fishers Exact test = FET). Only small gender differences (<1 %) were observed for the other reasons of failure. A slightly higher proportional frequency of restorations replaced because of secondary caries was observed for occlusal restorations compared to 2–3 surfaces and >3-surface restorations (proportional failure frequencies: 68.9, 65.4 and 61.1 %, respectively; ns, FET), while other reasons for replacement like tooth- and restoration fracture and other reasons were slightly higher in >1-surface restorations (ns). Repairs performed because of secondary caries showed similar frequencies for the different cavity types. Other reasons for failure, such as lack of approximal contact, loss of restoration and insufficient occlusal morphology, were more frequently observed in replaced >3-surface restorations (14.8 %). The highest failure frequency because of RC fracture was seen for the >3-surface restorations (9.1 %) and the lowest for the occlusal ones (5.9 %). The differences observed for the reasons of replacement/repair and the different number of surfaces per restoration were not statistically significant (Chi^2). Except for the failure reason secondary caries, all other reasons for failure of repaired restorations showed too low absolute frequencies of failed restorations to be sufficient for comparisons.

No significant differences were found between reasons for failure of the different restorative materials and adhesive systems used. Restorations with a base material showed significant lower survival rate as restorations without base material as tested with Cox regression analysis taking clustering into account in the analysis [23]. No difference was seen between the two most used base materials (Dycal vs Alkaliner; FET). Restorations with a base material showed a higher relative proportional frequency of failures because of POS (12.4 %) than restorations without base material (6.6 %) (ns, FET). No large proportional differences were seen between the restorations with and without base material for the other reasons of failure (ns).

Table 1 Absolute and proportional relative frequencies of replaced and repaired RC restorations and the reason for failures reported

				Including "New surface" caries		
Reason of replacement/repair	Replaced *n* (%)	Repaired *n* (%)	Replaced and Repaired *n* (%)	Replaced *n* (%)	Repaired *n* (%)	Replaced and Repaired *n* (%)
Secondary caries	269 (66.3)	36 (28.8)	305 (57.4)	269 (47.3)	36 (26.9)	305 (43.4)
New surface caries	–	–	–	163 (28.6)	9 (6.7)	172 (24.5)
Fracture restoration	29 (7.1)	5 (4.0)	34 (6.4)	29 (5.1)	5 (2.7)	34 (4.8)
Fracture tooth	15 (3.7)	8 (6.4)	23 (4.3)	15 (2.6)	8 (6.0)	23 (3.3)
Post-operative sensitivity	46 (11.3)	6 (4.8)	52 (9.8)	46 (8.1)	6 (4.5)	52 (7.4)
Other reasons	33 (8.1)	17 (13.6)	50 (9.4)	33 (5.8)	17 (12.7)	50 (7.1)
Not reported	14 (3.4)	53 (42.4)	67 (12.6)	14 (2.5)	53 (39.6)	67 (9.5)
Total	406 (100)	125 (100)	531 (100)	569 (100)	134 (100)	703 (100)

The rows on the left side are without replacements/repairs because of caries on a "new surface", not part of the RC restoration

The two oldest age groups of dentist showed lower proportion of replaced restorations because of secondary caries (64.1 and 61.2 %) compared to the two younger groups of dentist (78.8 and 76.0 %). No correlation was observed between post-operative sensitivity and age of the dentists. The highest proportions were found in the oldest and youngest age groups (17.9 and 16.0 %, respectively), while lower percentages were found in the 1945–1959 (10.5 %) and 1960–1969 (7.7 %) age groups. All fractured RC restorations were observed in the restorations placed by dentists in the two oldest age groups. The mean ratio numbers of replaced/repaired restorations per dentist versus the total number of placed restorations per dentist increased from the older to the younger age groups : before till 1944, 8.3; 1945–1959, 12.4; 1960–1969, 13.4; and 1970 onwards, 15.6 (ns). Dentists who placed a low number of class I restorations (1–10) showed more tooth fractures (7.3 %) than dentists placing higher numbers of class I restorations (>10) (3.1 %). The number of restorations placed by the individual dentist showed no correlation with the relative frequencies of reasons of failure (ns, FET).

Primary caries in a non-filled surface of a tooth with a RC restoration occurred for girls in 104 and for boys in 68 teeth, giving relative reason for replacement/repair frequencies of 24.0 and 25.2 %, respectively. Of these replaced restorations, 116 were in teeth with class I restorations, 28 in class II and 19 in teeth with >3 surfaces (relative proportional frequencies 41.0, 13.1 and 26.0 %, respectively). The highest relative frequency of primary caries in teeth restored with RC was observed in the >55 years dentist age group.

Discussion

The present study concerns a prospective evaluation of all posterior RC restorations, placed during the late 1990s and early 2000 in all children and adolescents attending PDHS clinics in Copenhagen and Frederiksberg. The Danish PDHS provides free oral health care to individuals up to the age of 18 years. All salaried PDHS dentists participated, in contrast to replacement studies where participating dentists were self-selected [9–11] or randomised, e.g. from a membership register, or asked to participate [13, 14]. These samples often ended up with low response rates and are therefore seldom representative for the chosen dentist population [11, 14, 25, 26]. The present study reflects “real-life” or everyday clinical practice and is categorised as practice-based [12, 13]. No dropout of dentists was seen during the placement period, excluding those who were not employed during the whole study period. The dentists diagnosed the need for replacement or repair of the RC restorations based on their own judgement and diagnostic methods they typically used in their practice, consisting of visual–tactile and radiographic examinations. Factors such as education level, experience level, gender of practitioner and practice characteristics result in a wide variation in diagnoses and treatment decisions of the dentists [26]. The experience of the dentists varied dependent on education level, working years, etc. At the start of the study, amalgam was still the material of choice for many dentists in Denmark and represented therefore the majority of restorations placed during the study period, while in other Scandinavian countries higher proportions of RC restorations were used [14, 21, 24–26]. Burke et al. reported that for dental practitioners in Glasgow RC comprised only 27 % of the class I and 9 % of the class II restorations placed [14]. It may be assumed that the dentists who placed few restorations preferred also amalgam in high caries risk children due to lack of evidence for RC in posterior teeth in practice-based dentistry, expected secondary caries risk or an uncertain feeling using resin composites in posterior cavities.

In earlier cross-sectional studies, secondary caries was reported as the main reason for failure of replaced restorations, including RC [9–11, 14, 27]. Due to the high frequency of anterior and almost absence of posterior RC restorations placed, these studies do not reflect today's operative situation including high numbers of posterior RC restorations and improved adhesive systems. The majority of randomised longitudinal posterior RC evaluations of the last 20 years, reported follow-up times of 3 years or less, and accordingly yielded proportionally different reasons for failure frequencies than long-time follow-ups [28–30]. In many recent longitudinal prospective and retrospective evaluations, the clinical diagnosis of secondary caries was also the main reason for failure of posterior RC restorations [8, 13–17, 21, 31]. However, many other randomised clinical follow-up studies observed RC fracture as the most common reason for failure [17, 18, 32–40]. Almost all studies have focused on adults and only few recent studies investigated children and adolescents [19–22]. In a cross-sectional survey questionnaire, sent to Finnish PDHS dentists treating children younger than 17 years, fractures of filling and tooth comprised 7 % of treatments in permanent teeth and secondary caries in 5.2 % [19]. Soncini et al. evaluated occlusal RC restorations in 6–10-year-old children (Boston, USA) over a period of 3.4 years [20]. Of the 753 RC restorations, 112 (14.9 %) were replaced and 21 (2.8 %) repaired. The most common replacement reason observed was also secondary caries (proportional 52 %); RC fracture was observed in 2 % and loss of restoration in 1 %. Other reasons were reported as 12 %. In the present study, the proportional frequency of secondary caries was also high (57 %), while the absolute frequency was low. Our AFR of 2 % can be compared with the 4.4 % found by Soncini et al. [20]. The higher AFR in the Boston study can be caused by a high frequency of high caries risk children. Another reason may be the more conservative restorative treatment approach of the Scandinavian

dentists who are more likely to choose "no treatment" and preventive treatment options and are more comfortable with monitoring restorations that deviate from the ideal, as reported recently by Gordan et al. [2]. Bernardo et al. studied 892 posterior RC, including 450 class I, placed in 8–11-year-old Portuguese school children, for a period of up to 7 years [21]. A similar survival rate (85.5 %) as in the present study (84.9 %) was reported. Secondary caries was the main reason for failure in 113 of 129 failures (88 %), followed by restoration fracture. The 14 dentists in the Portugal study used rubber dam isolation whenever possible while cotton rolls were used by the dentists in our study, confirming that equal clinical results can be obtained with both isolation methods [8, 41]. The 2 % AFR in the Portugal study as in the present study of posterior RC restorations in children is in agreement with results of long-term studies of posterior RC restorations in adults [13, 15–17, 28–30, 32]. Kopperud et al., who reported a 1.6 % AFR in a 4–5-year practice-based class II RC follow-up in Norwegian children, observed also that the most common reason of replacement was secondary caries (73.9 %), followed by lost restorations (8.0 %) and material fracture (5.3 %) [22]. The durability observed is in contrast with the lower longevity figures of replaced RC restorations in many cross-sectional studies [1, 9–11, 13, 14, 19, 20], confirming that these studies give an underestimation of the average lifetime of routine restorations [42, 43]. The proportional caries frequencies varied considerably (29–72 %) in cross-sectional and practice-based studies in adults [11–14, 18], there most studies reported levels around 50 %. Looking at the influence of patient factors, the relative proportional frequency of secondary caries observed was higher for girls than for boys and higher in younger children compared to older. The first hypothesis was therefore not accepted. No differences were seen in the proportional relative frequencies of secondary caries between class I and class II RC restorations which seems to be in contrast to a recent long-term evaluation of class I restorations in adults which showed excellent durability with low secondary caries rate [44]. The type of RC material or adhesive system and number of placed RC restorations by the participating dentists did not influence the proportional frequencies of secondary caries.

In the present study, primary caries in another surface of the tooth was a reason for replacement or repair in 172 restorations (proportional relative frequency, 24.5 %). The proportional frequency was higher for one-surface than for >1-surface restorations. In class I restorations, the proportional frequency was as high as that for secondary caries (41 %). The higher proportional frequency for class I restorations is caused by lower frequencies of other reasons of failure like tooth and material fracture in the occlusal restorations and should not be mixed up with absolute or relative caries frequencies which are normally lower in class I restorations. Boys and girls showed rather similar frequencies (25.2 and 24.0 %, respectively). To define primary caries in a non-restored surface as a reason for failure of a restoration in the same tooth is not common in adult studies and is controversial [31]. The removal or repair of the still intact and acceptable RC restoration is not caused by a failure of the RC, but is performed due to technical reasons by the treating dentist and is therefore indeed a reason for replacement/repair. The problem highlighted by the occurrence of the new caries lesions is "the total treatment" of caries risk children. Most of the restorations were placed because of primary caries and the children involved are therefore caries active. Even if the absolute frequency of emphasised primary and secondary caries was low, it is still confirmed that in this patient group a more active preventive treatment is necessary. Beside the optimal performance of the restoration, the general caries prophylaxis including oral hygiene, fluoride prophylaxis and diet information, which all children will receive, needs to be intensified.

Several other earlier reported reasons for failure such as wear, marginal defects or ditching, marginal and bulk discolorations were not reported in the present study [12]. Dentist factors such as time since graduation, gender and practice characteristics have been indicated to influence replacement of restorations [11, 13, 25]. Mjör et al. observed that female dentists replaced more restorations than male dentists [11]. In the present study, all dentists were female. In agreement to Mjör et al. [11], the two oldest age groups of dentist showed lower proportions of secondary caries (64.1 and 61.2 %) compared to the two younger groups (78.8 and 76.0 %). The private dentists who took care of the adolescents after they finished the PDHS reported a higher proportion of secondary caries than their colleagues in the PDHS and the second hypothesis was therefore rejected. Similar differences have been reported earlier [11, 13]. However, in a recent study, Palotie and Vehkalahti showed no variation for caries and fracture versus dentist's year of graduation [25]. General practitioners use visual and tactual inspection, X-ray and their own experience and knowledge, which vary and contribute to differences in outcome. It has been stated that the clinical diagnosis of secondary caries was poorly defined [2, 6]. Only clinically frank caries lesions at the margin of restorations and lesions visible on radiographs constitute a reliable diagnosis. Stained margins or marginal defects have been diagnosed as secondary caries but were poorly related to the development of secondary caries. Burke et al. reported that 18 % of the replacements were due to marginal fractures [14]. It can be assumed that dentists with a shorter experience did not want to "wait and see" as long as the more experienced dentists. There is no formal training in the diagnosis of secondary caries other than that given in dental school training or in continuing education courses. Differences in secondary caries appearance, patients with different caries susceptibility and oral hygiene, experience of the dentists including their possibility to gain knowledge of the individual patient's caries

risk during many years of treatment, make it highly difficult to introduce more defined guidelines.

In the 1990s, POS was mentioned to be a problem with RC restorations [45–49]. It has been attributed to factors such as effects of shrinkage stress on the marginal integrity, etching of dentin, cusp deformation and interfacial bacterial penetration. The use of hydrophilic adhesive systems introduced during the mid-1990s resulted in improved interfacial adaptation and together with a more familiar placing technique for practitioners decreased the frequency reported POS [8, 13, 17, 18, 27–39, 44, 50]. Overall, the prevalence of POS in the present study was 1–2 %. This can be compared with 1–5 % POS observed in recent cross-sectional studies [13, 14]. In several studies, the low frequency POS was included in "other reasons". The present study reported a rather high proportional frequency POS of 11 % for replaced restorations, which can be explained by the low frequencies of other reasons for failure besides secondary caries. Opdam et al. recently showed in a retrospective study a similar low POS frequency in adults for RC placed with three-step etch & rinse adhesives and amalgam [8]. Perdigão et al. concluded that POS depends more on the restorative technique rather than on the type of adhesive [51]. It seems that experience and increased knowledge of adhesive procedures of dentists involved makes the sensitivity problem less prominent [50]. Tooth localisation or number of surfaces of the restorations had no influence on the proportional distributions of POS. In 73 % of the RC restorations, the participating dentists traditionally placed a base material, in most cases calcium hydroxide cements. The restorations with a base showed twice as many restorations with failures because of POS compared to those without (12.4 and 6.6 %, respectively). Inferior seal of the dentin below and/or dissolution of the base materials may explain the higher complains. A higher proportional frequency failed restorations by POS was reported for girls (15.2 %) than for boys (6.1 %).

Fracture of the restoration, recorded as any fracture through the bulk of the RC, has been indicated as one of the main reasons for failure of RC restorations. The 29 bulk fractures resulting in replacement presented a proportional 7 % frequency, while five smaller chip fractures resulted in repair (4 %). The participating dentists did not specify the type of material fracture in the data sheets. Cross-sectional reports from the late 1990s reported a 7–19 % variation in proportional bulk fracture frequencies, but these studies contained only few posterior restorations [10–12, 14, 26]. In longitudinal 4- to 9-year follow-up studies in adults, the absolute frequencies varied between 0 and 8.3 % [8, 13, 15–17, 27, 30, 33, 34, 38]. In several of these studies, RC fracture was the main reason for failure [17, 33, 34, 38]. In children, evaluated in practice-based evaluations, RC fracture has been a minor reason of failure [20, 21]. The smaller size of the restoration in children, placed in most cases due to primary caries, in contrast to the larger sized restorations in adults, will reduce the fracture risk. Fracture of tooth has also been reported as a reason for replacement in several earlier replacement studies with frequencies between 4 and 9 % [10–12]. Recent longitudinal 4- to 9-year follow-up studies reported absolute tooth fracture frequencies between 0.6 and 2.6 % [13, 15–18, 28–30, 34, 38, 39], despite the fact that the posterior RC restorations were placed in most cases in traditional amalgam cavities. Rather high frequencies, 19 and 7.7 % respectively, have been observed in a 3- and a 6-year follow-up of RC with inferior material properties [35, 52]. In the present study, no amalgam cavities were used in contrast to most adult studies and only 23 tooth fractures were observed (proportional frequencies for replacements 3.7 % and for repairs 6.4 %). Two other practice-based studies of posterior RC in children reported no tooth fractures at all in a period of up to 7 years [20, 21]. No differences in RC or tooth fracture were observed between boys and girls. A slightly lower RC fracture frequency was observed in class I restorations compared to >1-surface restorations. Almost all RC fracture failures, except for one, were reported by the two older and most experienced dentist groups. No difference was seen for tooth fracture versus dentist age, number of restorations placed by the individual dentists or placement of base material. It has to be observed that the dentists indicated only one reason for failure of the failed restorations. A rather common reason for failure with both secondary caries and RC fracture was therefore not reported.

Conclusions

It was concluded that posterior RC restorations placed in children and adolescents in Public Dental Health clinics in Denmark showed a good durability with annual failure rates comparable to those of randomised controlled RC studies in adults. The main reason for failure was secondary caries followed by post-operative sensitivity and resin composite fracture. A high proportion of replaced/repaired RC restorations were caused by primary caries in a non-filled surface.

Acknowledgments The authors sincerely thank the clinicians for all the time and effort spent on completing the recordings. The support from the New Danish Dental Association, the Danish Dental Association, the Swedish Dental Association and the County Council of Västerbotten is gratefully acknowledged.

Conflict of interest The authors declare that they have no conflicts of interest.

References

1. Sunnegårdh-Grönberg K, van Dijken JWV, Funegårdh U, Lindberg A, Nilsson M (2009) Selection of Dent Mat and longevity of replaced restorations in Public Dental Health clinics in northern Sweden. J Dent 37:673–678

2. Gordan VV, Garvan CW, Riley JL, Worley DC, Gilbert GH, for the DPBRN Collaborative group (2009) How dentists diagnose defective restorations: evidence from the dental practice-based research network. Oper Dent 34:664–673
3. Clarkson JE, Worthington HV, Davies RM (2000) Restorative treatment provided over five years for adults regularly attending general dental practice. J Dent 28:233–239
4. ADA Council on Scientific Affairs (1998) ADA Council on Dental Benefit programs, statement on posterior resin-based composites. JADA 129:1627–1628
5. Burke FJT (2004) Amalgam to tooth-coloured materials—implications for clinical practice and dental education: governmental restrictions and amalgam-usage survey results. J Dent 32:343–345
6. Mjör IA (2005) Clinical diagnosis of recurrent caries. JADA 136:1426–1433
7. Mjör IA (2005) Reasons for replacement of restorations. Oper Dent 30:409–416
8. Opdam NJ, Bronkhorst EM, Roeters JM, Loomans BA (2007) A retrospective clinical study on longevity of posterior composite and amalgam restorations. Dent Mat 23:2–8
9. Qvist J, Qvist V, Mjör IA (1990) Placement and longevity of tooth-colored restorations in Denmark. Acta Odont Scand 48:3105–3116
10. Mjör IA (1997) The reasons of replacement and the age of failed restorations in general dental practice. Acta Odont Scand 55:58–63
11. Mjör IA, Shen C, Eliasson ST, Richter S (2002) Placement and replacement of restorations in general dental practice in Iceland. Oper Dent 27:117–123
12. Burke FJT, Cheung SW, Mjör IA, Wilson NHF (1999) Restoration longevity and analysis of reasons for the placement and replacement of restorations provided by vocational dental practitioners and their trainers in the United Kingdom. Quint Int 30:234–242
13. Opdam NJ, Bronkhorst EM, Roeters JM, Loomans BA (2007) Longevity and reasons for failure of sandwich and total-etch posterior composite resin restorations. J Adh Dent 9:469–475
14. Burke FJT, Wilson NHF, Cheung SW, Mjör IA (2001) Influence of patient factors on age of restorations at failure and reasons for their placement and replacement. J Dent 29:317–324
15. Forss H, Widström E (2004) Reasons for restorative therapy and the longevity of restorations in adults. Acta Odont Scand 62:82–86
16. van Dijken JWV, Pallesen U (2011) Clinical performance of a hybrid resin composite with and without an intermediate layer of flowable resin composite: a 7-year evaluation. Dent Mat 27:150–156
17. van Dijken JWV, Pallesen U (2011) Four-year clinical evaluation of class II nano-hybrid resin composite restorations bonded with a one-step self-etch and a two-step etch-and-rinse adhesive. J Dent 39:16–25
18. van Dijken JWV, Lindberg A (2009) Clinical effectiveness of a low shrinkage resin composite. A five-year study. J Adh Dent 11:143–148
19. Forss H, Widström E (2003) The post-amalgam era. A selection of materials and their longevity in the primary and young permanent dentitions. Int J Ped Dent 13:158–164
20. Soncini JA, Maserejian NN, Trachtenberg F, Tavares M, Hayes C (2007) The longevity of amalgam versus compomer/composite restorations in posterior primary and permanent teeth. Findings from the New England Children's Amalgam Trial. JADA 138:763–772
21. Bernardo M, Luis H, Martin MD, Leroux BG, Rue T, Leitão J, DeRouen TA (2007) Survival and reasons for failure of amalgam versus composite posterior restorations placed in a randomized clinical trial. JADA 138:775–783
22. Kopperud SE, Tveit AB, Gaarden T, Sandvik L, Espelid L (2012) Longevity of posterior dental restorations and reasons for failure. Eur J Oral Sci 120:539–548
23. Pallesen U, van Dijken JWV (2013) Longevity of posterior resin composite restorations in permanent teeth in Public Dental Health Service. A prospective 8 years follow up. J Dent 4:297–306
24. Qvist V, Strøm C (1993) 11-year assessment of class-III resin restorations completed with two restorative procedures. Acta Odont Scand 51:253–262
25. Palotie U, Vehkalahti MM (2009) Finnish dentists' perceptions of the longevity of direct dental restorations. Acta Odont Scand 67:44–49
26. Palotie U, Vehkalahti MM (2012) Reasons for replacement of restorations: dentists' perceptions. Acta Odont Scand 70:478–484
27. Mjör IA, Moorhead JE, Dahl JE (2000) Reasons of replacement of restorations in permanent teeth in general dental practice. Int Dent J 50:360–366
28. van Dijken JWV, Sunnegårdh-Grönberg K (2006) Fiber-reinforced packable resin composites in class II cavities. J Dent 34:763–769
29. Lindberg A, van Dijken JWV, Lindberg M (2006) Nine-year evaluation of a poly-acid-modified resin composite open sandwich technique in class II cavities. J Dent 35:124–129
30. Bottenberg P, Jacquet W, Alaerts M, Keulemans F (2009) A prospective randomized clinical trial of one bis-GMA-based and two ormocer-based composite restorative systems in class II cavities: five-year results. J Dent 37:198–203
31. Kiremitci A, Alpaslan T, Curgan S (2009) Six-year clinical evaluation of packable composite restorations. Oper Dent 34:11–17
32. Van Nieuwenhuysen J-P, D'Hoore W, Carvalho J, Qvist V (2003) Long-term evaluation of extensive restorations in permanent teeth. J Dent 31:395–405
33. Manhart J, Chen H, Hamm G, Hickel R (2004) Buonocore memorial lecture. Review of the clinical survival of direct and indirect restorations in posterior teeth of the permanent dentition. Oper Dent 29:481–508
34. Opdam NJ, Loomans BA, Roeters JM, Bronckhorst EM (2004) Five-year clinical performance of posterior resin composite restorations placed by dental students. J Dent 32:379–383
35. van Dijken JWV, Sunnegårdh-Grönberg K (2005) A four-year clinical evaluation of a highly filled hybrid resin composite in class II cavities. J Adh Dent 7:343–349
36. Poon EC, Smales RJ, Yip KH (2005) Clinical evaluation of packable and conventional hybrid posterior resin-based composites: results at 3.5 years. JADA 136:1535–1540
37. Wilson NH, Gordon VV, Brunton PA, Wilson MA, Crisp RJ, Mjör IA (2006) Two-centre evaluation of a resin composite/self-etching restorative system: three-year findings. J Adh Dent 8:47–51
38. Loguercio AD, Reis A, Hernandez PA, Macedo RP, Busato AL (2006) 3-year clinical evaluation of posterior packable composite resin restorations. J Oral Reh 33:144–151
39. van Dijken JWV, Pallesen U (2011) Clinical performance of a hybrid resin composite with and without an intermediate layer of flowable resin composite: a 7-year evaluation. Dent Mater 27:150–156
40. van Dijken JWV, Pallesen U (2013) A six-year prospective randomized study of a nano-hybrid and a conventional hybrid resin composite in class II restorations. Dent Mat 29:191–198
41. van Dijken JWV, Hörstedt P (1987) Effect of use of rubberdam versus cotton rolls on marginal adaptation of composite resin fillings to acid-etched enamel. Acta Odont Scand 45:303–308
42. Downer MC, Azli NA, Bedi R, Moles DR, Setchell DJ (1999) How long do routine dental restorations last? A systemic review. Brit Dent J 187:432–429
43. van Dijken JWV, Pallesen U (2010) Fracture frequency and longevity of fractured resin composite, polyacid modified resin composite and resin modified glass ionomer cement class IV restorations. An up to 14 years follow-up. Clin Oral Inv 14:217–222
44. Opdam NJM, Bronkhorst EM, Cenci MS, Huysmans M-C DNJM, Wilson NHF (2011) Age of failed restorations: a deceptive longevity parameter. J Dent 39:225–230

45. van Dijken JWV (2010) Durability of resin composite restorations in high C-factor cavities. A 12-year follow-up. J Dent 38:469–474
46. Stangel I, Barolet RY (1990) Clinical evaluation of two posterior composite resins: two-year results. J Oral Rehab 17:257–268
47. Wilson NH, Norman RD (1991) Five year findings of a multiclinical trial for a posterior composite. J Dent 19:153–159
48. Barnes DM, Blank LW, Thompson VP, Holston AM, Gingell JC (1991) A 5- and 8-year clinical evaluation of a posterior composite resin. Quint Int 22:143–151
49. Shimuzu T, Kitano T, Inoue M, Narikawa K, Fujii B (1995) Ten year longitudinal clinical evaluation of a visible light cured posterior composite resin. Dent Mat J 14:120–134
50. Hayashi M, Wilson NHF (2003) Failure risk of posterior composites with post-operative sensitivity. Oper Dent 28:681–688
51. Perdigão J, Geraldeli S, Hodges J (2003) Total-etch versus self-etch adhesive. Effect on postoperative sensitivity. JADA 134:1621–1629
52. van Dijken JWV (2002) Three-year performance of a calcium-, fluoride- and hydroxyl ions releasing resin composite. Acta Odont Scand 60:155–159