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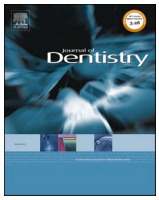

Early failures and further re-interventions of direct posterior restorations at Public Dental Service — 15-year retrospective observation

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ABSTRACT

Objectives: The aim of this register-based retrospective study was to evaluate the reasons recorded for early failures of direct posterior restorations involving two or three surfaces with extension occlusally, and to follow up the fate of these teeth after replacement or repair over 15 years.
Methods: Subjects were selected based on information from electronic patient files of 25- to 30-year-old patients with posterior restorations, either primary or re-restorations, performed in 2002 at the Helsinki City Public Dental Service (PDS). Patients with early failures, defined as any intervention procedure within the subsequent year after the 2002 restoration, were included ($N = 331$). Treatment procedures, both early failures and during follow-up, were grouped as restorations, endodontic treatments/retreatments, or extractions.
Results: Caries was the reason for re-intervention in 15.7 % of early failures, while poor restoration, e.g. fracture or poor restoration anatomy, was reported in 28.7 %, pain or emergency in 30.5 %, and reason not specified in 25.1 %. Linear regression model revealed that accumulation of further failures was associated with whether the tooth had a primary intervention or re-restoration ($p < 0.003$) as well as the patient having fewer than 28 teeth ($p < 0.001$) and none healthy CPI sextants ($p < 0.035$). Following the re-interventions, 75 % of the teeth survived over a 15-year period.
Conclusions: Within this study's limitations, we found that pain and restoration deficiencies were the main reasons for re-intervention within one year in a selected Helsinki City PDS patient group. Re-interventions were more frequent in previously restored teeth and were generally successful in preserving most teeth, even those with large composite restorations.
Clinical Significance: Pain or posterior restoration deficiencies are the most common reasons for interventions carried out within a year. Re-interventions are more common in previously restored teeth than in teeth with primary restoration. Re-interventions can be effective in preserving most teeth, even in cases with large composite restorations, over a 15-year follow-up period.

1. Introduction

Placement of direct restorations is everyday practice in Public Dental Service (PDS) in the Nordic countries. Posterior teeth with primary caries, fractures of restorations, defective restorations, or other hard tissue loss are treated with direct restorations more often than with indirect restorations, at least in PDS [1]. At PDS, almost half of dentists' clinical work is dedicated to restorative care, 50 % of which constitutes maintenance of restorations, i.e. replacement or repair of restorations [2,3]. Even half of the examined adults have at least one restoration that requires re-treatment [4,5]. In England, one in ten restorations had a re-intervention in the following year [6].

The reasons for replacement of restorations have changed little in the past 20 years, secondary caries and fractures being the most common reasons for replacement [7,8]. According to a systematic review including 12 controlled studies, early restoration failures were linked to endodontic treatment or restoration fracture [9]. Also, a 24-month follow-up prospective practice-based cohort study from the USA reported 40 % of failures for restoration-related reasons and 7 % of failures for endodontic reasons [10]. Practice-based research with nearly 6000

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original restorations revealed, however, that aggressive re-intervention (i.e. replacement of restoration, endodontic treatment, or extraction) after direct restoration was less likely to happen within the first year after restoration repair than after replacement of the original restoration [11].

Other factors behind re-interventions involve the effect of the operator, e.g. different diagnostic thresholds [12–15]. Individual patient-related factors, such as periodontal status, bruxism, or high caries risk, can increase the risk for re-intervention [4,14,15].

In this patient document-based retrospective study, we evaluated the reasons for early failures of two- and three-surface restorations, extending at least to an occlusal surface as mesio-occlusally (MO), disto-occlusally (DO) or mesio-occlusal-distally (MOD), placed in posterior teeth of 25- to 30-year-old public sector patients. In addition, we followed further events of these early failed cases over a 15-year period.

The working hypotheses were that emergency treatments are more frequent than secondary caries as a reason for early restorative re-interventions and that high caries risk patients more often have re-interventions than low caries risk patients.

2. Materials and methods

In Helsinki City PDS, young adults are entitled to the dental care services and they use them regularly [16]. Those who visit public dental clinics benefit from significantly subsidized fees compared to private sector. Treatment documentation in both public and private sectors adheres to the official codes provided by the National Institute for Health and Welfare (THL). The process of completing patient records is stringently regulated. Within the PDS, all patient records are maintained and stored in electronic patient files (EPF), with patients being identified by their personal identification numbers. In this study, the cases involved Class II (MO, DO) or larger restorations (MOD) placed in 2002 in the posterior teeth of patients aged 25–30 years who visited the Helsinki City PDS.

2.1. Ethical considerations

This study utilized EPF of Helsinki City PDS. The permission to use the data came from the administration of Helsinki City (Permission numbers: HEL 2013–005,959, HEL 2015–012,361). The data were delivered anonymized. According to Finnish legislation (Act 552/2019), patient register can be used for scientific purposes with permission of the register holder. Ethical approval was not required.

2.2. Data collection

In 2002, a total of 5542 direct posterior MO, DO or MOD restorations were made for 25- to 30-year-old patients at the Helsinki City PDS [17]. Of these direct posterior restorations, we explored early failures from EPF, i.e. intervention procedures carried out within the subsequent 12 months. In total, the study material included all posterior teeth restorations with early failures ($N = 331$) recorded in 2002, serving as the starting point of the EPF-based follow-up until the end of 2017. Fig. 1 shows the timeline scheme for assessing the early failure cases.

A tooth served as the observational unit. Information on re-intervention of restorations with early failure was collected according to tooth type (premolar or first molar or second molar), restoration material (composite, amalgam, glass ionomer), and size of re-intervened surfaces (1-, 2-, 3-, or 4-surface). Reasons for early failure of re-restorations were coded as 1 = secondary caries, 2 = fracture or loss of restoration, 3 = marginal leakage, 4 = poor restoration anatomy, 5 = caries on another surface, 6 = pain/emergency treatment, and 7 = reason not documented. The reasons were regrouped into four categories: caries (secondary caries, marginal leakage, caries on another surface), poor restoration (fracture or loss of restoration or poor restoration anatomy), pain (pain or emergency treatment), and reason not documented. The primary status of the tooth in 2002 was categorized as one of the following: untreated caries with no previous restoration or previously restored but requiring re-intervention (Fig 1). Study subjects' clinical status (number of teeth, decayed teeth, clinical periodontal index (CPI) with healthy sextants) and caries risk (low, moderate, high), determined by dentists at PDS, were collected from EPF. In addition, dental treatment codes, maintained by the THL, were categorized as restorative, endodontic, or extraction.

2.3. Re-interventions at retrospective follow-up

In the retrospective longitudinal follow-up part of this study, the fate of these 331 teeth was followed from EPF to the end of 2017, and the numbers of all re-treatments (re-restorations, endodontic treatments and retreatments, or extractions) were collected from EPF. In total, 427 different treatment procedures, mainly restorative and endodontic treatments, were provided to these teeth by end 2017. The majority of initial and re-intervention procedures were performed by different dentist each time, due to the practice-based nature of this study.

The fate outcome was defined by using a cumulative indicator for all procedures the tooth had undergone. Each additional replacement of a

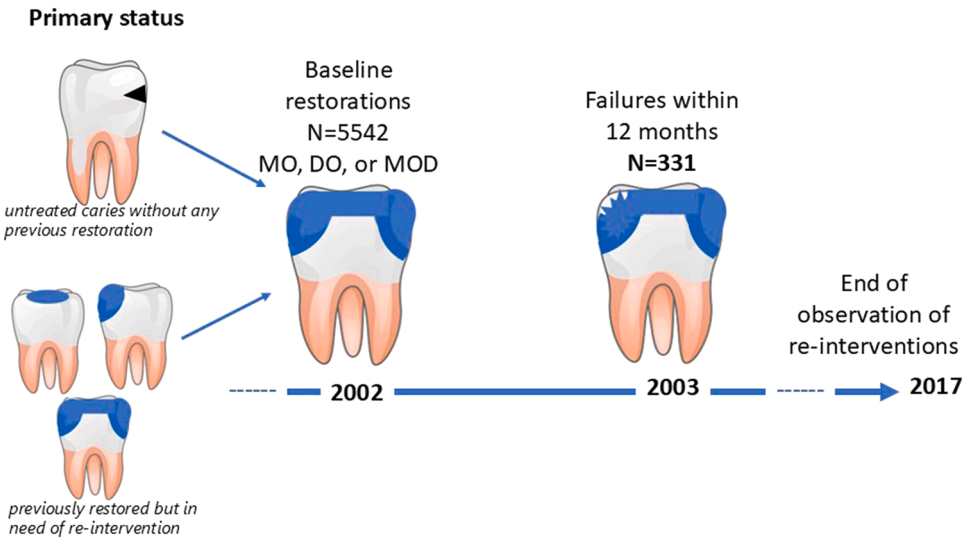

Fig. 1. Timeline scheme for the 15-year observation of the early failure cases in restorations on posterior teeth in 25- to 30-year-old patients.

restoration added a score of 1 to the tooth, and the tooth scored 2 if it required replacement, etc. If a tooth underwent completed endodontic treatment, we assigned it a score of 5. For endodontic retreatment, the tooth scored 10 points, and if the tooth was extracted, it scored 20 points, which was the maximum score for a single procedure. The explanatory variables were patient's gender and number of teeth, jaw location of tooth, caries risk determined by dentists at PDS, periodontal risk expressed by number of periodontally healthy sextants, and whether the primary status was primary restoration or re-restoration - either due to untreated caries with no previous restoration, or a previously restored tooth requiring re-intervention.

2.4. Statistical analyses

Statistical analyses were carried out using SPSS 28.0 software (SPSS Inc., Chicago, IL, USA). Descriptive statistics were reported. Correlations between variables were calculated using Pearson's correlation test. Data analyzed were then graphed using Microsoft Excel 365. A linear regression model was used to explain the accumulation of re-interventions that the teeth had during the follow-up. In the model outcome variable, sum of all procedures, was explained by patient-, tooth- and restoration-related factors.

3. Results

Prior to early failure, nearly half of the posterior restorations had already been re-restored, whereas the remainder were primary restorations. Of the first re-interventions, 80 % of posterior teeth with early failure received restorative ($n = 266$) and 17 % endodontic treatment procedures, and 3 % were extracted. Table 1 describes the background of the early failure cases for teeth and for patients at the baseline in 2002. Almost half of the failed restorations were in first molars, the vast majority were two-surface restorations and almost half had earlier history of re-restoration. According to the recorded patient information, the cases with more than three decayed teeth, high risk of caries, or no periodontally healthy sextant found, predominated in the early failure group.

Table 1
Baseline characteristics by tooth and patient for early failure cases in posterior tooth restorations performed on 25- to 30-year-olds in 2002.

BASELINE CHARACTERISTICS BY TOOTH	($N = 331$)	%
Tooth type		
Premolar	92	27.8
First molar	152	45.9
Second molar	87	26.3
Jaw location		
Upper premolars & molars	181	54.7
Lower premolars & molars	150	45.3
Restoration size		
Two-surface mesio-occlusal	132	39.9
Two-surface disto-occlusal	134	40.5
Three-surface mesio-disto-occlusal	65	19.6
Restoration type in 2002		
Primary restoration	163	51.1
Re-restoration	156	48.9
Missing	12	
BASELINE CHARACTERISTICS BY PATIENT	**($N = 331$)**	**%**
Number of decayed teeth at baseline		
0	37	13.0
1–2	89	31.3
3–5	85	30.0
6–9	54	19.0
10 or more	19	6.7
Unclassified	47	
Caries risk determined at baseline		
Low or moderate	83	34.0
High	161	66.0
Unclassified	87	
Periodontally healthy sectors at baseline		
None	168	54.9
1–6	138	45.1
Unclassified	25	
Caries and CPI risk combined		
Caries risk low or moderate & non-healthy sextants	25	10.3
Caries risk low or moderate & 1–6 healthy sextants	57	23.5
Caries risk high & non-healthy sextants	101	41.6
Caries risk high & 1–6 healthy sextants	60	24.7
Unclassified	88	

3.1. First re-interventions within 12 months after baseline

Details of the first re-interventions occurring within 12 months after baseline are shown in Table 2. The most often recorded reasons for the re-interventions were pain or emergency and fracture or poor anatomy or loss of the restoration, both reasons recorded in two out of five cases. More than half of the re-restorations involved two surfaces and almost all had previously been restored with composite resin material.

Of the restorative re-interventions, following early failures, 39 % involved replacement, 16 % involved repair, and the remainder required restorations of greater size than those placed before the failure. Regarding restorative materials chosen by dentists for the first re-interventions, the most frequently used material was composite (91 %), followed by amalgam and glass-ionomer (Table 2).

The reasons for intervention occurring within 12 months after baseline varied depending on whether the re-intervened tooth initially had untreated caries or had been previously restored and required

Table 2
Characteristics of re-interventions performed on 25- to 30-year-olds within 12 months, according to the primary status at the baseline restoration in 2002.

CHARACTERISTICS OF FIRST RE-INTERVENTION	Primary status: untreated caries only or previously restored			
	Total	Caries	Restored	
	$N = 331$ (%)	$n = 163$ (%)	$n = 156$ (%)	p-value
Reasons for re-intervention				<0.001
Caries	52 (20.1)	47 (39.2)	27 (21.1)	
Poor restoration	95 (38.3)	19 (15.8)	54 (42.2)	
Pain or emergency	101 (40.7)	54 (45.0)	47 (36.7)	
Not documented[a]	83	43	28	
Extent of re-intervention required				0.001
One-surface	46 (19.0)	19 (15.3)	23(21.7)	
Two-surface	137 (56.6)	86 (69.4)	49 (46.2)	
Three-surface	36 (14.9)	15 (12.1)	19 (17.9)	
Four-surface	23 (9.5)	4 (3.2)	15 (14.2)	
Unclassified[a]	89	39	50	
Restoration material in re-intervention				0.645
Composite resin	236 (91.1)	121 (91.0)	105 (92.1)	
Amalgam	18 (6.9)	10 (6.9)	6 (5.3)	
Glass-ionomer	5 (1.9)	2 (1.9)	3 (2.6)	
Not documented[a]	72	30	42	
Change in size of restoration				0.123
Small repair, no change	39 (16.1)	19 (15.3)	17 (16.0)	
Same-size replacement	95 (39.3)	57 (46.0)	35 (33.0)	
One new surface	88 (36.4)	41 (33.1)	41 (38.7)	
Two new surfaces	20 (8.2)	7 (5.6)	13 (12.3)	
Unclassified[a]	89	39	50	

[a] Category excluded from %-distribution.

further treatment ($p < 0.001$). When the primary status of the tooth was untreated caries, the most frequent reasons for re-intervention were pain (45 %) and caries (39 %). In contrast, for previously restored teeth, the main reasons were tooth or restoration fracture, poor restoration anatomy (42 %), and pain (37 %).

The reasons for re-intervention did not differ by tooth type ($p = 0.121$) or by patient periodontal status, expressed by numbers of healthy sextants ($p = 0.989$) or the highest CPI score ($p = 0.206$), caries risk ($p = 0.701$), or decayed teeth ($p = 0.437$) determined by the dentist at most recent oral examination. Among the re-intervention patients, those with non-healthy periodontal sextants and high caries risk were more common than those with one or more healthy periodontal sextants and low caries risk ($p < 0.001$).

3.2. Re-interventions at retrospective follow-up

The fate of the re-intervention teeth was followed until the end of 2017. Fig. 2 shows all re-treatments ($n = 427$, comprising re-restorations, endodontic treatment and re-treatment, or extraction). Over the 15-year follow-up, 107 teeth needed no further intervention, while the end point for the re-intervention mixture was restorative (65 teeth), endodontic (77 teeth), or extraction (67 teeth) procedure.

Fig. 3 shows re-interventions of the follow-up period according to whether the primary status of tooth was untreated caries with no previous restoration or previously restored but requiring re-intervention in 2002. Those teeth already restored before intervention in 2002 tended to have further endodontic treatment (43 % vs. 31 %; $p = 0.003$) or extraction (26 % vs. 17 %; $p = 0.053$), compared to the teeth untreated before year 2002. Tendency of having restorative procedure was rather similar in both groups ($p > 0.05$).

As shown by the linear regression model, accumulation of further failures was positively associated with the primary status of the tooth previously restored, the patient had <28 teeth, and all sextants were periodontally non-healthy, while statistically non-significant were patient's gender, caries risk and jaw location of tooth (Table 3). In cases with untreated caries as the primary status, the model demonstrated strong explanatory power for subsequent restoration failures associated with having fewer than 28 teeth. Conversely, for cases in which the primary status was previously restored, the model did not identify any statistically significant predictors of subsequent restoration failures.

4. Discussion

The purpose of this retrospective study of specific teeth among selected patients was to investigate detailed reasons for early re-interventions of direct posterior restorations. The results and survival of all original restorations have been reported earlier [17,18]. To our knowledge, this is the first time that the fate of replacement of restorations has been retrospectively followed in detail for 15 years from EPF at PDS, and in which replacement or repair was not considered to be a failure of treatment.

During the first 12 months after the baseline restorative procedure, the most common detailed reason detected from EPF for re-intervention was pain or restoration deficiencies (e.g. fracture). This is in line with a systematic review and meta-analysis where study settings were controlled and only a few operators were involved [9] and with the prospective practice-based cohort study by McCracken [10] in which the mean follow-up was 24 months. The proportions of different reasons for re-intervention can be different depending on the practice setting: private or university clinic versus general dental practice or PDS. Standardized conditions, few and calibrated operators, and excluded high caries risk and bruxism patients can give different results compared with a setting with several uncalibrated dentists working with strict timetables and heterogeneous populations, but the short follow-up period seems to decrease these differences. The operator has an influence on restoration longevity [12–14]. In the Netherlands, annual failure rates varied from 3.6 % to 11.4 % among 22 different dentists during a 2-year follow-up in a practice-based cohort study [14]. It is well known that dentists do not agree with especially caries treatment decisions unless thorough calibration is performed, but again a short follow-up period could explain why results are analogous in different study settings.

Could some of these early failures have been prevented if the indirect restoration had been placed at the start? In our study, 6 % of posterior two-surface or larger restorations had an intervention during the first 12 months. This is in line with results from a practice-based study from the Netherlands where failures of posterior class II restorations were 14.9 % after 2 years and the annual failure rate was 7.8 % [14]. Today, the current care guideline of restorative treatment and the Council for Choices in Healthcare in Finland both propose indirect restoration for posterior teeth when three or more surfaces are restored [19,20]. However, these guidelines were not yet published in the early 2000s. Still, single crowns and onlays are rare in Finland; among the 1961 adult members of the Northern Finland Birth Cohort, approximately 4 % had

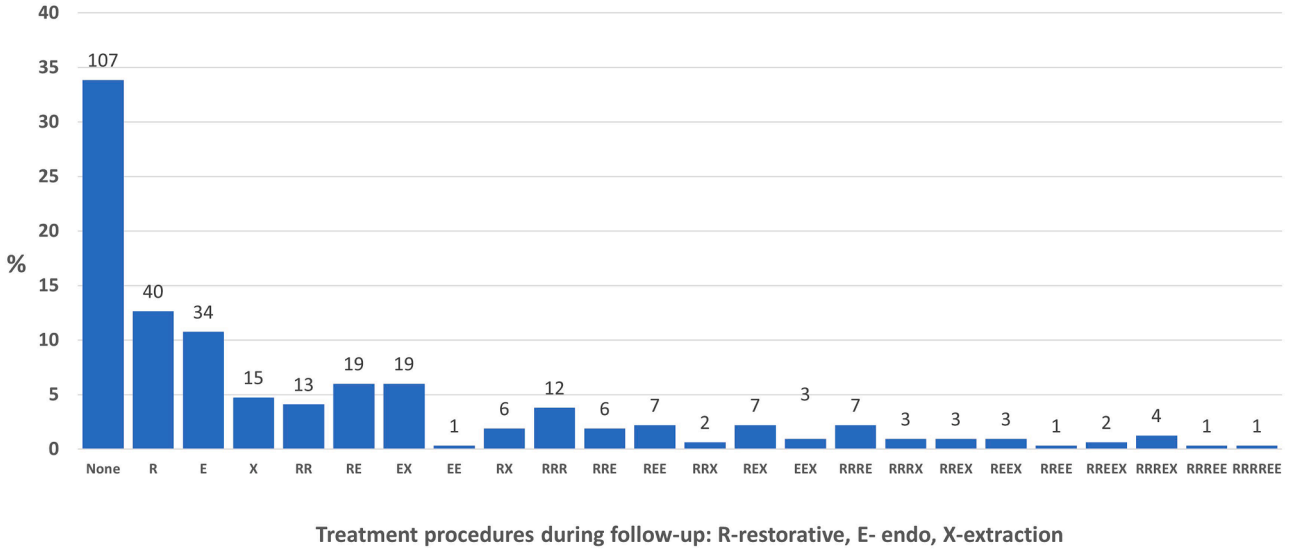

Fig. 2. Distribution of treatment procedures and combinations performed on 25- to 30-year-old patients during the 15-year follow-up period. Frequencies are indicated at the top of each bar.

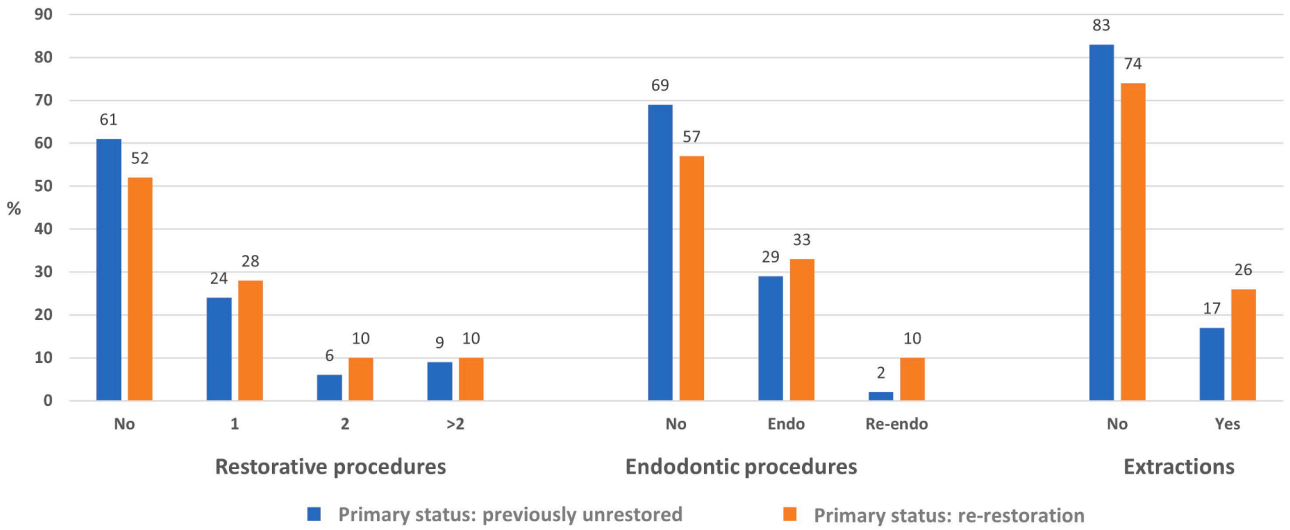

Fig. 3. Different treatment procedures of teeth during the follow-up according to type of restoration at baseline in 2002. endo= endodontic treatment, re-endo= endodontic retreatment.

indirect restorations when examined in 2012–2013 [21]. At the Oulu PDS only 2.8 % of endodontically treated teeth were crowned [22]. In our study, there were no indirect restorations during follow-up, not even after endodontic treatment. Indirect posterior restorations have been reported to have better longevity than direct ones [23], but survival in moderate or high caries risk patients can be compromised [9,14]. In addition, indirect restoration at the Helsinki City PDS costs about ten times more than direct restoration (personal communication), presenting an obstacle to routine use at PDS, where lower income patients visit more often than patients with higher income [24].

We originally assumed that baseline restorations in 2002 were all initial restorations, but when we examined EPF in detail, we discovered that nearly half had as primary status "previously restored". Therefore, half of the "first" interventions at baseline were in fact re-restorations. In the analysis, tendency of a tooth requiring further intervention differed significantly depending on whether it had been previously treated. Teeth that had already been restored before 2002 had higher tendency of needing re-intervention compared to those that had not been restored but required a primary restoration in 2002. Pain and fractures were more often the reasons for re-intervention in the group of previously restored primary status than in the group of caries as primary status. When a cavity becomes even deeper and the walls thinner, these conditions predispose to new fractures and pupal complications naturally. For example, one specific molar tooth received four re-restorations, later primary endodontic treatment with re-restoration, and finally endodontic re-treatment with once more re-restoration (not crown) during the 15-year follow-up. In all, one of three endodontically treated teeth were extracted. A follow-up at the Oulu City PDS showed that in 94.5 % of 20- to 39-year-old patients, endodontically treated teeth reached 5-year-survival and all types of teeth were included [22]. In our study, four of five teeth survived at least 15 years – either with no intervention or with re-interventions. Re-restoration, therefore, is not always a catastrophe for an individual, but the cost-effectiveness and individual caries management of this kind of practice are questionable. We can further speculate whether all re-restorations during the follow-up were truly patient-oriented. It is known that change of treating dentist can influence restoration longevity [13–15]. In our study, the dentist changed nearly every time, and unfortunately, no details were available regarding the dentists' proactive or reactive approaches, nor any background information.

In our study, one of three re-intervention restorations needed no further re-interventions during the follow-up. One of six baseline restorations were, however, re-intervened during the subsequent 12 months because of caries. This is surprising considering the slow progress of caries in general. This proportion of caries is in line with a prospective cohort study from the USA that found 14 % of failed restorations to have secondary caries [10]. In their study, the follow-up period was two years. A systematic review and meta-analysis showed that the proportion of secondary caries starts showing only after two years in controlled study settings [9]. The majority of our selected patients belonged to the moderate or high caries risk group. Therefore, the caries risk factors are more likely related to eating habits or inadequate oral self-care, as regular medications or severe illnesses that could affect salivary flow are usually rare in this age group. One explanation, therefore, could be that the baseline restoration procedure was hastily prepared and residual caries or caries on another surface was left behind, or even that the caries lesion was so large at the first site that adequate restoration was not possible, but the dentist chose to restore inadequately.

For a considerable proportion of restorations (45 %), the size of the re-restoration relative to the previous restoration increased, while only a minority (16 %) were small repairs. Globally, dental undergraduate teaching involves restoration repair protocols [25], however, dentists are slowly adapting to perform repairs [26–28]. In the early 2000s, restoration repair was an uncommon procedure. In addition, in these early re-interventions, small repairs can also mean temporary restorations due to emergency pulpal treatment. Repair of restoration can increase survival of posterior composite restorations in the hands of dental students when neither refurbishment nor sealing was an option [29]. Systematic reviews and meta-analyses have found low certainty of evidence that repair of restoration is as good an alternative as replacement of restoration [30,31]. In addition, repair of composite restoration was more effective than replacement of restoration in the German health care setting [32]. Cost-effective and evidence-based treatments should be implemented at PDS, which is largely financed by tax money in Finland.

One of our aims was to evaluate detailed reasons for replacement or repair, which cannot be retrieved automatically from EPF. Unfortunately, the detailed reason for re-intervention was missing for one of four cases (25 %) because the documenting of the reason for replacement is not mandatory. In addition, for part of these patients the recordings of caries and periodontal findings by sextant were deficient or remained unclassified. On the contrary the code for the treatment procedure was well documented (100 %). These treatment codes act as incentives on dentists' salaries at PDS. Our earlier finding at the Vantaa PDS was that the detailed reason for replacement was missing for only

Table 3
Linear regression model showing explanations for further restoration failures ($N = 331$) and two models separately by primary status, among 25- to 30-year-olds during the 15-year follow-up.

Explanatory factors	Regression coefficient (95 % CI)	SD	t	p
Model for all failures ($n = 331$)				
Primary status (in 2002): re-restoration	3.252 (1.158 – 5.386)	1.084	2.999	0.003
Number of teeth: <28 teeth	4.636 (1.839 – 7.433)	1.421	3.262	0.001
Healthy CPI sextants: none	2.376 (0.169 – 4.583)	1.121	2.119	0.035
Gender	-0.584 (-2.896 – 1.728)	1.175	-0.497	0.620
Caries risk	-0.490 (-2.134 – 1.153)	0.835	-0.587	0.557
Jaw location	-0.194 (-2.355 – 1.966)	1.098	-0.177	0.860
Constant term 5.828 (SD 3.496)				
Model for failures with primary status untreated caries only ($n = 163$)				
Number of teeth: <28 teeth	6.972 (3.103 – 10.841)	1.957	3.562	<0.001
Healthy CPI sextants: none	2.376 (-1.240 – 4.427)	1.434	1.111	0.268
Gender	0.251 (-2.716 – 3.219)	1.501	0.168	0.867
Caries risk	-0.345 (-2.448 – 1.758)	1.064	-0.324	0.746
Jaw location	2.216 (-0.588– 5.020)	1.419	1.562	0.121
Constant term 0.796 (SD 4.538)				
Model for failures with primary status previously restored ($n = 156$)				
Number of teeth: <28 teeth	2.743 (-1.366 – 6.852)	2.079	1.320	0.189
Healthy CPI sextants: none	2.569 (-0.874– 6.012)	1.742	1.475	0.142
Gender	-1.148 (-4.726 – 2.430)	1.810	-0.634	0.527
Caries risk	-0.304 (-2.899– 2.291)	1.313	-0.232	0.817
Jaw location	-2.462 (-5.764– 0.841)	1.671	-1.473	0.143
Constant term 2.868 (SD 23.594)				

14 % of cases [33]. At that time, however, patient records were in paper format and not EPF, as in the current study. Nowadays, however, many EPF software programs use structured and standardized documentation. Unclassified documentation in our results indicates that data were recorded, but it was not possible to categorize them into the corresponding subgroups. Thorough documentation could help dentists to understand the reasons behind previous restorations and facilitate better treatment decisions since the ICD-10 diagnosis does not always contain needed information. Many EPF software programs do not show previous treatments unless the dentist reviews multiple appointments. The utilization of FDI [34] or USPHS, i.e. Ryge criteria [35], to assess restorations outside the laboratory or randomized controlled trials is rare [36]. EPF software programs combined with the reason for the restoration tool, e.g. FDI criteria or Artificial Intelligence (AI), could support comprehensive and evidence-based dental care. These kinds of tools can be useful if they are at hand, but in the early 2000s they were not yet available at the Helsinki City PDS. For future evidence-based guidelines and treatment decisions, it would behoove dentists to use EPF software programs with structured and standardized documentation, including specific reasons for re-intervention, with the help of AI.

5. Conclusion

We conclude that pain or restoration deficiencies were the most common reasons for interventions carried out within a year after restoration among a selected group of patients at the Helsinki City PDS. Deficient direct posterior restorations were replaced rather than repaired or the tooth extracted. Re-interventions were more common in previously restored teeth than in teeth with primary restoration; only one of three restorations did not need further interventions during the 15-year follow-up. Re-interventions were successful in retaining or preserving the majority of teeth even with large composite restorations.

CRediT authorship contribution statement

Ulla Palotie: Writing – original draft, Methodology, Investigation, Conceptualization. **Battsetseg Tseveenjav:** Writing – review & editing, Visualization, Formal analysis, Data curation. **Miira M. Vehkalahti:** Writing – review & editing, Supervision, Methodology, Conceptualization.

Declaration of competing interest

The authors declare the following financial interests/personal relationships which may be considered as potential competing interests: Ulla Palotie reports that financial support was provided by Finnish Dental Society Apollonia. If there are other authors, they declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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