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Survival of primary molars with pulpotomy interventions: public oral health practice-based study in Helsinki

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ABSTRACT

Objectives: To assess long-term survival of pulpotomized primary molars and factors related to the survival of the teeth.

Materials and methods: This retrospective longitudinal study was based on electronic dental health records of children who attended public health service. Eligible children were <12 years and had a pulpotomy procedure code in their dental treatment history. Data were obtained in the period between 2002 and 2016. Chi-squared test, *t*-test, and one-way ANOVA were used to assess for statistical differences. Kaplan–Meier analyses were performed to create survival estimates, and the log-rank test was performed to compare differences in survival distributions. A multivariate Cox regression was conducted, and hazard ratios were calculated to estimate the hazard rate for failure.

Results: Of interventions, 40% were registered in children 3–6 years of age; 56% were boys. Mean estimated survival of such molars was 82 months (SEM = 0.6) and differed by dental operator's work setting and choice of restorative materials used after pulpotomy intervention. Using a stainless steel crown (SSC) to restore pulp-intervened primary molars had the strongest effect on survival (111 months with SEM = 1.8), followed by if the intervention was performed by a specialist or specializing dentist in paediatric dentistry (99 months with SEM = 2.6).

Conclusions: The estimated survival time of pulpotomized primary molars is affected by dental operator-related factors, which should be considered in management of extensively carious primary molars of paediatric patients, both at the clinical and organizational decision-making levels. An increased focus on the use of SSC is recommended to be in the learning objectives of dental education programs.

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Introduction

Vital pulp therapy is often indicated for primary teeth with extensive or deep caries lesion (or both) at most with reversible pulpitis [1]. There are three viable options of vital pulp therapy, namely indirect pulp capping, direct pulp capping, and pulpotomy [1–3]. The superiority of any of these therapies has not been established due to lack of case-control studies [1] and the low quality of existing evidence [2].

Pulpotomy in primary molars is commonly practiced due to its relatively high success rates and moderate quality of evidence [1] compared with other vital pulp therapy options, such as direct or indirect pulp capping. Using mineral trioxide aggregate as a therapeutic agent [2] and restoring with stainless steel crowns (SSC) after pulpotomy [4,5] greatly improves procedure success rates after such pulp intervention. An indication of pulpotomy for primary molars with extensive or deep carious lesions (or both) is based on the fact that in such teeth [3] coronal pulp already manifests histopathological inflammation [6] even though the teeth are asymptomatic. Removing the inflamed coronal pulp of such teeth aims to preserve healthy radicular pulp [3].

Predicting further pulpal complications without knowing the extent of histopathological changes in the pulp chamber is challenging for clinicians and requires risk-based decision making [7]. However, in proximal caries lesions, marginal ridge breakdown of more than half of the buccolingual intercuspal distance [3] is used as a clinical sign of possible pulpal inflammation in primary molars, indicating need for pulpotomy procedure.

There are numerous studies, comparing the effect of vital pulp techniques and therapeutic agents used in the pulpotomy intervention procedure of primary molars [1,2,8–10]. However, the evidence for long-term survival of primary

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molars with such interventions is scarce. Therefore, the aim of this study was to assess the long-term survival of primary molars with pulpotomy interventions and to investigate survival in relation to patient-, patient visit- and dental operator-related factors.

Materials and methods

Study design

This retrospective observational public health practice-based study was based on electronic dental health records in the Oral Health Care of the City of Helsinki from 2002 to 2016. All children <12 years with a pulpotomy procedure code in their dental treatment history of primary molars were eligible. Based on these criteria, after exclusion of four cases due to chronological discrepancies between pulp intervention and tooth extraction dates, 7704 pulpotomized primary molars were selected, belonging to 5932 children with an age range of 3–11.

Pulp therapies performed on children ≥12 years were excluded assuming that in those cases primary molars were persistent due to missing permanent successors or any other reasons. Moreover, the estimated age for natural exfoliation of primary molars was considered to be 12 years based on a previous similar study [7].

Variables

Patient-related variables were children's age, gender, tooth type (first or second primary molars), and tooth location (maxilla or mandible). Age was expressed in years and was further categorized into three groups (3–5, 6–8, and 9–11 years, representing primary or early and late mixed dentitions) for descriptive statistics. For multivariate analyses, age was handled as a continuous variable.

Dental operator-related factors were operator's work setting, where they delivered health services, whether they took preoperative radiographs prior to pulpotomy, and their choice of dental materials used to restore the primary molars following the interventions. Dental operator's work settings were categorized as primary care setting, general anaesthesia (GA) service in primary care, or specialized care in paediatric dentistry. Pulpotomies performed in a university teaching clinic were excluded, as the operator could be a student, instructor, or both. Restorative materials were categorized into the following four groups according to the electronic health record system classification: 1) SSCs, 2) glass-ionomer cement (GIC)/polyacid-modified resin composite or compomer (PAMRC)/resin-modified GIC (RMGIC), 3) resin composite (RC), or 4) temporary fillings. Fillings were considered permanent if they were placed either at the intervention visit or within 30 days from the pulpotomy interventions. Radiological examination codes entered at the intervention visit or prior (from 1 day up to 3 months) were counted as preoperative x-ray examination performed.

Patient visit-related factor was the nature of pulpotomy intervention visits, which were divided into ordinary or of emergency or challenging. The nature of the visits was possible to be determined based on specific codes dentists enter in the dental health record of patients, if needed. Ordinary appointment visits were those, where the dentists did not enter any additional code, and visits of emergency or challenging nature, if dentists entered the specific code.

Statistical evaluation

The extracted data were compiled into statistical software packages IBM SPSS Statistics for Windows (version 25.0, IBM Corp., Armonk, N.Y., USA) and STATA 15.1 (StataCorp LLC; College Station, TX, USA) for statistical analyses. For descriptive statistics, chi-squared test for differences of groups, *t*-test, and one-way ANOVA test for differences of means were used. Missing values of any variable were excluded when the variable was used for analyses. Unadjusted Kaplan-Meier analyses were used to create survival means and curves. Differences in survival rates between groups were assessed with the log-rank test with pairwise comparisons and Bonferroni correction. The tooth was considered as survived if there was no record of extraction by the year the child turned 13 years of age. Tooth extraction was considered as failure. The observation period ended at the estimated age of natural exfoliation of primary molars; this was when the child turned 13 years of age. Mean annual failure rates (AFR) were calculated according to the formula $(1–y)^z = 1–x$, where "x" expresses the total number of failures at "z" years, with "y" being the mean AFR.

To identify different factors associated with failures of pulpotomized primary molars, a multivariate Cox proportional hazards regression analysis was conducted with clustering data for patients with multiple pulpotomized teeth. Hazard ratios (HRs) with corresponding 95% confidence intervals were determined to estimate the hazard rate for failure. In multivariate analyses, children's age served as a continuous variable; all other variables were categorical. The reference groups were boys for gender, the first primary molars for tooth type, maxilla for jaw location, GA service for dental care setting, SSCs for restorative material, presence of preoperative radiographs for radiological examination, and emergency or challenging visits for nature of pulpotomy visit. Preoperative radiograph variable was excluded after descriptive analyses due to a strong association with and nature of patient visit. Potential multicollinearity was examined, and no covariates were found to exceed the variance inflation factor value of 3. A statistical level of 5% was used for significance for all analyses.

Ethical considerations

This study was based on encrypted summary data of electronic health records. The use of data for this study was approved by the City of Helsinki in Finland (research permission decision registration number HEL-2017-000965-T130201). Individuals could not be identified and therefore ethical permission was not applicable.

Results

Of all pulpotomy interventions ($n = 7704$), 4073 (40%) were performed in primary molars of children aged 6–8 years and 4337 (56%) were in boys (Table 1). Similar numbers of primary first and second molars were pulpotomized. Slightly more interventions were registered in the mandible (53%; $n = 4059$) than in the maxilla. Of all pulpotomies, 74% ($n = 5676$) were being performed in primary care settings. Operator's first choice of restorative material after pulpotomy was GIC/compomer/RMGIC (70%; $n = 5396$), followed by temporary fillings (25%; $n = 1895$). More than four-fifths of the pulpotomies (81%; $n = 6256$) were performed in ordinary appointment patient visits (Table 1).

Of all pulpotomized primary molars, 332 (4%) were radiographically examined, either previously ($n = 97$) or at the pulpotomy visit ($n = 235$). Of pulpotomy intervention visits, 1448 (19%) were recorded as emergency or challenging patient visits. Preoperative radiographs were strongly associated with the nature of patient visit ($p < .001$); dental operators more frequently taking x-rays when the intervention visits were emergencies or related to challenges (9%) than in ordinary appointments (3%).

The mean estimated survival time of pulpotomized primary molars during the observation period was 82 months (SEM = 0.8); survival time was 99 months (SEM = 2.6) when the interventions were performed in specialized care, 95 months (SEM = 1.0) in GA service, and 77 months (SEM = 0.7) in primary care settings (Figure 1(A)). Thus, there was a statistically significant difference in survival distributions of pulpotomized primary molars by dental care settings; teeth that were treated in specialized care or under GA survived longer than those in primary care ($p < .001$) .

The mean estimated survival time of pulpotomized primary molars differed by materials chosen to restore the teeth after pulp interventions; the mean was 111 months (SEM = 1.8) for SSCs, 87 months (SEM = 4.3) for RC, and 85 months (SEM = 0.7) for GIC/compomer/RMGIC (Figure 1(B)). These differences were statistically significant; teeth restored with SSCs survived longer than those with RC or GIC/compomer/RMGIC ($p < 0.001$).

Primary molars pulpotomized at emergency or challenging visits survived for a shorter period (71 months with SEM = 1.5) than those performed in an ordinary appointment visit (84 months with SEM = 0.7) ($p < .001$) (Figure 1(C)).

The overall mean AFR during the 15-year observation was 8.7% (95% CI 8.4–9.1%). The mean AFRs were 3.9% (95% CI 3–5%) when the interventions were performed in specialized care, 4.9% (95% CI 4.4–5.4%) in GA service, and 10.8% (95% CI 10.3–11.2%) in primary care.

Of patient-related factors, first primary molars and younger age expressed lower hazard rate for failure compared with the corresponding reference groups in comparisons (Table 2), whereas gender and jaw location did not. All operator-related factors and nature of patient visit were statistically significantly related to the hazard rate for failure, except when the intervention was performed in a GA service compared to a specialized care setting ($p = .906$). Interventions performed in the primary care setting (HR = 1.64 with 1.44–1.87 CI 95%) compared to those in GA care and dentists choosing materials other than SSCs (HR = 2.83 with 1.64–4.89 CI 95% to 5.10 with 3.30–7.89) had higher hazard rate for failure (Table 2).

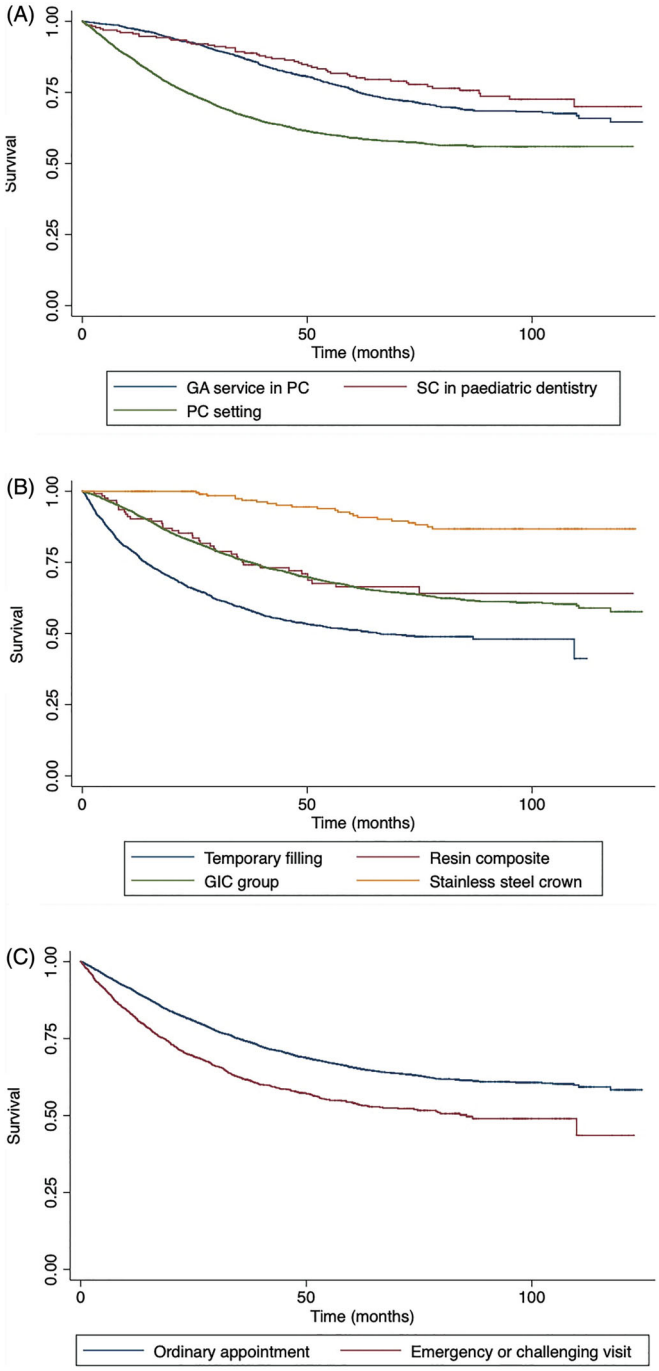
Discussion

In this study, operator-related factors had greater impacts on survival of pulpotomized primary molars, as seen with the high HR values (Table 2), while patient-related factors had minor ones or none. Choosing SSCs over other restorative materials after pulp intervention related to the longest

Table 1. Survival of pulpotomized primary molars according to patient-, operator-, and patient visit-related factors after the observation period ($n = 7704$).

	Total $n = 7704$	Survived 5060 (66%)	Failure 2644 (34%)
Age:			
3–5	1810	1178 (65%)	632 (35%)
6–8	4073	2633 (65%)	1440 (35%)
9–11	1821	1249 (69%)	572 (31%)
Gender:			
Boys	4337	2892 (67%)	1445 (33%)
Girls	3367	2168 (64%)	1199 (36%)
Tooth type:			
First primary molars	3842	2573 (67%)	1269 (33%)
Second primary molars	3862	2487 (64%)	1375 (36%)
Jaw location:			
Maxilla	4059	2659 (65%)	1400 (35%)
Mandible	3645	2401 (66%)	1244 (34%)
Dental care setting:			
Primary care setting	5676	3527 (62%)	2149 (38%)
General anaesthesia in primary care	1800	1358 (75%)	442 (25%)
Specialized care in paediatric dentistry	228	175 (77%)	53 (23%)
Operator's choice of restorative material following pulpotomy:			
Resin composite	124	86 (69%)	38 (31%)
GIC group	5396	3666 (68%)	1730 (32%)
Stainless steel crowns	289	267 (92%)	22 (8%)
Temporary fillings	1895	1041 (55%)	854 (45%)
Nature of patient visit			
Visit related to emergency or challenge	1448	842 (58%)	606 (42%)
Ordinary appointment visit	6256	4218 (67%)	2038 (33%)

GIC group includes glass-ionomer cement/polyacid-modified resin composite or compomer (PAMRC)/resin-modified glass-ionomer (RMGIC).



Survival means and curves with unadjusted Kaplan–Meier analyses; Differences in survival rates between groups with the log-rank test with pairwise comparisons; Significance of differences in survival distributions with Bonferroni correction; statistically significant differences by dental operators' work setting (A), their choice of restorative materials (B) and nature of patient visit (C) at the level of p<.001. PC: primary care; GA: general anaesthesia; SC: specialized care; GIC group includes glass-ionomer cement/polyacid-modified resin composite or compomer (PAMRC)/resin-modified glass-ionomer (RMGIC).

Figure 1. Kaplan–Meier survival estimate curves of pulpotomized primary molars by dental operators' care setting (A) and choices of restorative materials (B) and by nature of pulpotomy intervention visit (C).

survival of primary molars (Table 2). Pulpotomized primary molars also survived longer than the mean expected survival time when the interventions were performed in a specialized care setting in paediatric dentistry and GA service. The longer survival time of molars in these settings is partly due to the abundant placement of SSCs under GA in both services. Recent questionnaire surveys performed in Finland and Norway also revealed that dentists' choice of restorative materials were greatly influenced by patient cooperation [11,12]. Dentists chose different materials when the same clinical cases were presented in two alternative settings (outpatient clinic or under GA). Amin et al. [13] assessed survival of restorations performed under GA and concluded that SSCs and amalgam restorations were clinically more successful and had better survival times than composite. In this study, amalgam fillings were not placed at all in pulpotomized primary molars. In Finland, amalgams are not used in paediatric patients <15 years due to a ban by the European Union. However, consistent with Amin et al., our study revealed that choosing SSCs as restoration after pulpotomy is the most important factor for further survival of the teeth. In a recent systematic review on longevity of restorations in primary teeth, the main reason for failure was secondary caries (except for SSCs), with high variation among the studies and materials [14].

On the other hand, it should be noted that in specialized care settings, treating behaviourally challenging and medically compromised cases requires specialized experience. The oral health of these children is compromised even after treatment as these children do not practice adequate oral self-care. Thus, children treated in a GA service are referred because of multiple carious lesions, poor cooperation, or both.

There may be several explanations for the lower mean survival time of primary molars with pulp interventions performed in primary care. General dentists are in the frontline position for primary dental care, where all behaviourally challenging children also initiate dental treatment. Attempts to treat these children may result in temporary fillings. This partly explains the number of temporary fillings placed in primary care. Moreover, dentists in primary care treat children in need of emergency dental care between their scheduled patients without actual appointments, which causes time constraints. Moreover, the tooth can be sealed with temporary fillings if pulpotomy intervention is recommended, extraction is declined by the child or carer, or the procedure cannot be done immediately. In primary care, 4% of the restorations following pulp interventions were SSCs. The reasons for the minimal use of SSCs should be explored in further studies. The most plausible explanations are that the dentists did not learn or did not become confident with the use of SSCs during their undergraduate training or the patients were not cooperative [11,12].

Primary molars treated by Finnish general dentists in this study survived longer than those treated with vital pulp therapy in Australia [14]. This may be partly explained by differences in pulpotomy techniques and therapeutic agents used in Australia versus those used in Finland. In addition, in the Australian study, GIC was used as the only alternative for restorations, which may influence survival of the primary teeth. Therefore, we would like to emphasize the role of undergraduate dental education to encourage the use SSCs and HALL technique in paediatric patients when appropriate [7,8].

Table 2. Hazard ratios with 95% confidence intervals for failure of pulpotomized primary molars ($n = 7704$) according to patient-, dental operator-, and patient visit-related factors (Cox regression model).

	HR	95% CI	*p*-Value
Age (continuous variable)	0.98	0.95–1.00	.050
Gender (reference = boys)			
Girls	1.05	0.97–1.14	.253
Tooth type (reference = first molars)			
Second molars	1.13	1.04–1.23	.002
Jaw (reference = maxilla)			
Mandible	1.02	0.94–1.10	.668
Dental care setting: (reference = general anaesthesia service in primary care)			
Primary care setting	1.64	1.44–1.87	<.001
Specialized care in paediatric dentistry	1.02	0.76–1.37	.906
Restorative material (reference = SSCs)			
Resin composite	2.83	1.64–4.89	<.001
GIC group	3.37	2.20–5.16	<.001
Temporary fillings	5.10	3.30–7.89	<.001
Nature of pulpotomy visit (reference group = ordinary appointment)			
Visit related to either emergency or challenge	1.24	1.13–1.37	<.001

HR: Hazard ratio; CI: confidence interval; SSCs: stainless steel crowns; GIC group includes glass-ionomer cement/polyacid-modified resin composite or compomer (PAMRC)/resin-modified glass-ionomer (RMGIC).

Of the patient-related factors, the second primary molars had a slightly greater hazard rate for failure of pulpotomized primary molars than the first primary molars. However, the clinical relevance of differences between tooth types may be minor due to the low hazard ratios. Age did not have an impact on survival of pulpotomized primary teeth in our study. This contrasts with the Australian study, where each year of age increase reduced the likelihood of survival by 31% [14]. In the Australian study, tooth type was a non-significant factor, in contrast to the present study.

The strength of this study is that data were obtained from a large practice-based database, with complete treatment history of all children <18 years who attended the Helsinki public oral health service. Therefore, this is a representative estimate of the magnitude of pulpotomy treatment and long-term survival of pulpotomized primary molars, since practically all children and adolescents in Finland are treated at the public oral health service.

Another strength of this study is the design, which is appropriate for this particular research question. Since pulpotomy cannot be applied to teeth prospectively as planned in a real-life clinical situation, the retrospective design and practice-based nature of our study provides a reliable view of current clinical practice. This design is also the most suitable way to explore long-term outcomes of pulp therapy, as this is based on public health service experience of 15 years of period between 2002—2016.

In addition, the interventions included in this study and the dental operators' decision-making regarding treatment alternatives were not influenced by financial concerns, since all children and adolescents in Helsinki are treated free-of-charge in the public health sector, which is highly subsidized and administered by municipalities in Finland.

A limitation of the present study is that potential recording error entered by the operator in the patient record system could not be corrected due to the nature of our data, as the data were analyzed as they were recorded. In addition, the data did not provide the therapeutic agents used in pulpotomy procedures, which is another weakness of this study.

Based on our results, we would like to emphasize that choosing SSC to restore pulp intervened primary molars guarantees longer survival of such teeth due to its good sealing and full coverage. We encourage increased use of SSC, which is also strongly recommended in best practice guidelines for the management of extensively carious primary molars [1,3,15,16].

Conclusion

The mean estimated survival time of pulpotomized primary molars during the observation period was 82 months. Choosing SSC to restore a pulp intervened primary molar had the strongest effect on survival, followed by if the intervention was performed by a dentist specialized in paediatric dentistry. Clinicians should consider factors that influence the long-term survival of pulpotomized primary molars in management of extensively carious primary molars of paediatric patients. At the organizational level, decision makers might consider the greater impact of dental operator- and patient visit-related factors over patient-related factors to allocate resources to ensure long-term successful outcomes. In our opinion, an increased focus on the use of SSCs for pulpotomized primary molars should be recommended for inclusion in the learning objectives of undergraduate and continuing dental education programs.

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Disclosure statement

No potential conflict of interest reported by the author(s).

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