ORIGINAL ARTICLE

Epidemiological evaluation of the outcomes of initial root canal therapy in permanent teeth of a publicly insured paediatric population

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Abstract

Background: Previously published epidemiological outcome studies of nonsurgical root canal therapy (NSRCT) in the United States utilize data only from a single, private dental insurer for adult populations.

Aim: This study aimed to investigate the outcomes of initial NSRCT, performed on permanent teeth, in a publicly insured paediatric population.

Design: New York State Medicaid administrative claims were used to follow 77 741 endodontic procedures in 51 545 patients aged 6–18, from the time of initial NSRCT until the occurrence of an untoward event (retreatment, apicoectomy, and extraction). The initial treatment and untoward events were identified by Current Dental Terminology codes. The Kaplan–Meier survival estimates were calculated at 1, 3, and 5 years. Hazard ratios for time to permanent restoration and restoration type were calculated using the Cox proportional hazards model.

Results: The median follow-up time was 44 months [range: 12–158 months]. Procedural, NSRCT, survival was 98% at 1 year, 93% at 3 years, and 88% at 5 years. Extraction was the most common untoward event. Teeth permanently restored with cuspal coverage had the most favorable treatment outcomes.

Conclusions: Overall, 89% of teeth were retained and remained functional over a minimum follow-up time of 5 years. These results elucidate the expected outcomes of NSRCT in permanent teeth for paediatric patients with public-payer dental benefits.

KEYWORDS
endodontics, medicaid, paediatric dentistry, root canal therapy, survival analysis, treatment outcomes

1 | INTRODUCTION

The success of endodontic procedures, including nonsurgical root canal therapy (NSRCT), is of interest to dentists, patients, and third-party payers. Typically, the outcomes of endodontic procedures are evaluated through the presence of clinical signs and symptoms, along with radiographic interpretation. Reported success rates based on these criteria have ranged from 31% to 98%.[1,2] The outcomes of initial NSRCT also have been evaluated using epidemiological methods,[3–7] with survival rates of 94% and higher in studies based in the United States.[3,4,6,7] Epidemiological or health services research methods that leverage the use of administrative claims data allow for the simultaneous study of very large cohorts and multiple variables potentially associated with treatment outcomes.[8] Variables shown to be associated with the success of NSRCT include time to the placement of permanent restoration and type of permanent restoration.[3,4,7,9,10] Both clinical- and population-level analyses of the outcomes of endodontic treatment are important to dental practitioners and oral health advocates alike, as findings from these studies can be used to inform clinical recommendations and policy.

Dental coverage and dental care utilization by children (age 0–18) in the United States are at their highest-ever levels, since tracking began in 1999.[11–13] This increase in dental care utilization correlates with expansions in dental coverage through the Children's Health Insurance Program (CHIP) and the passage of the Affordable Care Act (ACA).[14] As of 2015, 90% of children in the United States had dental coverage, with 39% overall covered by public insurers (Medicaid/ CHIP).[15] Currently, Medicaid provides dental coverage for income-eligible children up to the age of 21 and "at a minimum, dental services include relief of pain and infections, restoration of teeth, and maintenance of dental health."[16] CHIP covers income-eligible children up to the age of 19 or 21, depending on the state, and provides dental services "necessary to prevent disease and promote oral health, restore oral structure to health and functions, and treat emergency functions."[17] These definitions of covered services do not specify procedure codes, leaving this decision largely up to individual states.

Children experiencing dental pain and infection that require root canal therapy in permanent teeth may present with unique root canal anatomy[18,19] and behavioral considerations[20,21] compared with adults. These differences often require distinct considerations and expertise, such as the ability to manage the behavior of children and adolescents[22] and the required proficiency to perform the technical aspects of endodontic treatment. There is

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Why this paper is important to paediatric dentists

- Paediatric patients are limited with regard to tooth replacement options after the extraction of compromised permanent teeth.
- It is useful to understand the efficacy root canal therapy as a treatment option to help maintain the permanent dentition.
- The findings of this study report 1, 3 and 5-year outcomes of initial root canal therapy in a publicly insured cohort of paediatric patients.
- Further, the study findings reaffirm the importance of the permanent restoration as a continuum of endodontic treatment.

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currently a dearth of literature assessing the outcomes of root canal therapy performed on permanent teeth in paediatric populations. Previously published epidemiological outcome studies of root canal therapy in the United States utilize data from a single, private dental insurer focused on adult populations. The adult-focused epidemiological literature reports tooth survival rates to be above 90% five years after the initial root canal therapy.[3,4,6,7] These findings may not be applicable to the paediatric population.

Motivated by the gaps in both the endodontic and paediatric dental literature and the increasingly large population of children with a public-payer dental insurance in the United States, the purpose of this study was to retrospectively investigate the survival of initial NSRCT performed on permanent teeth in a publicly insured paediatric population by using long-term, large-scale claims data.

2 | MATERIALS AND METHODS

The data for this study are the electronic insurance claims records and enrollment database of the New York State Medicaid program. Limiting the search to enrollees aged 6–18 with at least one year of continuous enrollment, the database yielded 2 027 196 individuals with patient encounters that occurred between January 1, 2006, and December 31, 2018. Of the total individual enrollees, 51 545 had initial NSRCTs in the permanent dentition, and 77 741 relevant procedures/teeth were available for analysis.

Codes on Dental Procedures (CDTs) were used to identify the endodontic therapy procedures (initial NSRCT) for analysis (D3310, D3320, and D3330). Further, CDTs

were used to identify the placement of a permanent restoration after endodontic treatment and/or the incidence of an untoward event. Relevant permanent restorations (D2000-D2999) were categorized as buildups, amalgam, composite, or cuspal coverage. In cases where multiple restoration types were placed (eg, buildup followed by cuspal coverage), priority categorization was given to cuspal coverage. Untoward events were defined as nonsurgical retreatment (D3346, D3347, and D3348), apicoectomy (D3410, D3421, and D3425), or extraction (D7140 and D7210), and these indicated the failure of initial NSRCT. Initial NSRCTs were considered to be successful until the occurrence of an untoward event or censored at an identified lapse in the patient's enrollment status.

The following information was collected for each initial NSRCT procedure: patient identification number, tooth number, date of initial NSRCT, patient age, patient gender, race or ethnicity, zip code, date of patient disenrollment in Medicaid, date of final restoration, type of final restoration, type of untoward event (up to the third), and date(s) of the untoward event(s). Zip codes were used to identify areas of "high poverty," rural status, and dental health provider shortage areas (DHPSAs); poverty and rural status were merged using data from the 2008-2012 American Community Survey of the 2012 US Census.[23] Enrollees who resided in a zip code where more than 20% of the population lived below the federal poverty level (FPL) were classified as "high poverty."[23] Rural areas were defined according to the Federal Office of Rural Health Policy.[24] For the purposes of this study, patients were classified as living in a DHPSA if their census tract, county, or county subdivision was deemed a geographic DHPSA at any point within our study period.[25]

The Kaplan–Meier survival estimates were calculated for 1-, 3-, and 5 years outcomes of NSRCTs, with subset analyses stratified by tooth type, time until restoration, and restoration types. The data allowed for up to 12 years of follow-up after the completion of initial NSRCT. To account for the effects of patient age, tooth type, time until restoration, and restoration type, adjusted hazard ratios (aHRs) were estimated by fitting a multivariable Cox proportional hazards model on the subsample where all treated teeth had permanent restoration placed ($N = 63$ 128). A sensitivity analysis was conducted to evaluate the potential bias resulting from censored enrollees on the survival estimates and aHR. The use of robust standard errors accounted for potential dependence between teeth within an individual. Data analysis was completed using SAS 9.4 (SAS Institute Inc, Cary, NC) software and R 4.0 (R Core Team, Vienna, Austria).

This study was approved by New York University School of Medicine's Institutional Review Board (i19-01436), under the expedited status (category 5).

3 | RESULTS

A total of 51 545 patients and 77 741 procedures were evaluated. Of the 51 545 patients, 44.1% were male and 55.9% were female. Over half (53.3%) of those included in the study resided in a zip code area where more than 20% of the people lived below the federal poverty level. Rural–urban indicators revealed that 7.0% lived in rural areas. Patients were classified by the following race/ethnicities: White/Caucasian (31.6%); Hispanic/Latino (23.3%); Black/African American (17.8%); Asian (11.1%); American Indian/Alaska Native (1.2%); or Native Hawaiian/Pacific Islander (0.3%). Race/ ethnicity data were unknown/missing for 14.6% of patients.

The mean number of initial NSRCTs per patient in this population was 1.51 with a standard deviation of 1.01 [median: 1; IQR: 1–2; range: 1–18]. The median patient age was 15 years [IQR: 13–16]. Patients aged 6–9 made up 4.0% of cases, those aged 10–12, 19.5%; the ones aged 13–15, 38.7%; and the ones aged 16–18, 37.9% of cases (Table 1). As patient age increased, there was a reduced risk of failure (Figure 1). Molars (lower first molars) were the most frequently treated tooth type (Table 1).

Survival rates of initial NSRCTs were evaluated at 1 year, 3 years, and 5 years. The median follow-up period in this cohort was 44 months [IQR: 26–79; range: 12–158]. The median follow-up time was 42 months [IQR: 25–73] for initial NSRCT procedures on teeth that did not experience an untoward event and 75 months [IQR: 45–113] for teeth with initial NSRCTs that did experience an untoward event. At 1 year, 76,171 primary root canal therapies could be evaluated, with a survival rate of 98% [95% CI: 97.9–98.1]. At 3 years, 44 052 procedures could be evaluated, with a survival rate of 92% [95% CI: 91.9 92.3]. At 5 years, 23 080 procedures could be evaluated, with a survival rate of 88% [95% CI: 87.2 87.8] (Table 2, Figure 2). Tooth retention was 98.3% at 1 year, 93.1% at 3 years, and 89.2% at 5 years.

A sensitivity analysis on the Kaplan–Meier survival estimates and adjusted hazard ratios, which removed all eligibility-censored cases, did not result in any statistically or clinically significant differences in treatment outcomes. Clustering teeth at the person level yielded slightly more conservative standard error estimates (Tables 2 and 3), with no clinically meaningful differences compared with regular, nonrobust standard errors.

3.1 | Tooth type

The case distribution consisted of 11 272 (15%) anterior teeth, 10 681 (14%) premolars, and 55 788 (72%) molars (Table 1). There was a significant difference in survival

based on tooth type ($p < .0001$) (Figure 1). Compared with molars, premolar (aHR = 0.65 ($p < .001$)) and anterior (aHR = 0.58 ($p = .007$)) teeth both had a reduced risk of failure, controlling for the presence of a permanent restoration (Figure 1).

The survival of initial NSRCT for all anterior teeth was 99% [95% CI: 98.7–99.1] at 12 months; 96% [95% CI: 96.0–96.7] at 36 months; and 94% [95% CI: 93.8–94.8] at 60 months. For all treated premolars, the survival of initial NSRCT at 12 months was 99% [98.3–98.7]; at 36 months, 94% [93.9–94.9]; and at 60 months, 91% [90.5–91.9]. For all molars, the survival of initial NSRCT at 12 months was 98% [97.6–97.8]; 36 months, 91% [90.5–91.0]; and 60 months, 85% [85.0–85.7] (Table 2, Figure 3).

3.2 | Coronal restoration

Teeth without the placement of a permanent restoration after initial NSRCT represented 14 613 (19%) of all cases (Table 1). There was a statistically significant difference in survival, at every time point, when permanent restorations were not placed ($p < .001$) (Table 2). The mean time from the completion of initial NSRCT to the placement of a permanent restoration was 93 days, with a median of 20 days (range: 0 days–158 months). There was a significant difference in procedural survival by time until restoration, but the association was not monotonic (Figure 1). The majority of teeth with permanent restorations did not have cuspal coverage (68%) (Table 1). Compared to teeth with cuspal coverage, the teeth with composite or amalgams as final restorations, but without cuspal protection, had a greater risk of failure (aHR = 1.36 ($p < .001$) or aHR = 1.17 ($p = .010$)) (Figure 1).

3.3 | Untoward events

For initial NSRCTs that did not have the survival rate of at least 1 year, the untoward events included surgical retreatment ($n = 85$, 0.1%), nonsurgical retreatment ($n = 142$, 0.18%), or extraction ($n = 1157$, 1.49%).

For all of the treated teeth ($n = 26\ 245$) of patients continuously enrolled in Medicaid for at least five years, the incidence of surgical retreatment was 173 (0.66%); nonsurgical retreatment, 406 (1.6%); and extraction, 3065 (12%). Eighty-four teeth (0.32%) underwent endodontic retreatment (nonsurgical or surgical) prior to extraction. The number and type of untoward events per year in patients followed at least 5 years are shown in Table 4. Untoward events by tooth type were analyzed for this subset of cases. Of the treated anterior teeth ($n = 3874$, 15%),

TABLE 1 Description of study cohort (A. tooth level; B. patient level)

| A	
Patient sample (*n*)	51 545
Age category (%)	
6–9	2065 (4.0)
10–12	10 039 (19.5)
13–15	19 928 (38.7)
16–18	19 513 (37.9)
Age (median [IQR])	15.00 [13.00, 16.00]
Gender (% male)	22 753 (44.1)
Race or ethnicity (%)	
White	16 367 (31.8)
Hispanic	12 069 (23.4)
Black or African American	9241 (17.9)
Asian	5812 (11.3)
Other	499 (1.0)
Missing	7557 (14.7)
High poverty (%)	
No	23 968 (46.5)
Yes	27 363 (53.1)
Not reported	214 (0.4)
Rural (%)	
No	47 881 (92.9)
Yes	3606 (7.0)
Not reported	58 (0.1)
HPSA (%)	
No	597 (1.2)
Yes	50 894 (98.7)
Not reported	54 (0.1)
B	
Entire Sample (*n*)	77 741
Tooth type (%)	
Anterior	11 272 (14.5)
Molar	55 788 (71.8)
Premolar	10 681 (13.7)
Time until restoration (%)	
0–14 days	28 489 (36.6)
15–59 days	17 248 (22.2)
60 + days	17 391 (22.4)
Never placed	14 613 (18.8)
Restoration type (%)	
Amalgam	3845 (4.9)
Buildups	37 827 (48.7)
Composite	7472 (9.6)
Cuspal	13 984 (18.0)
Never placed	14 613 (18.8)
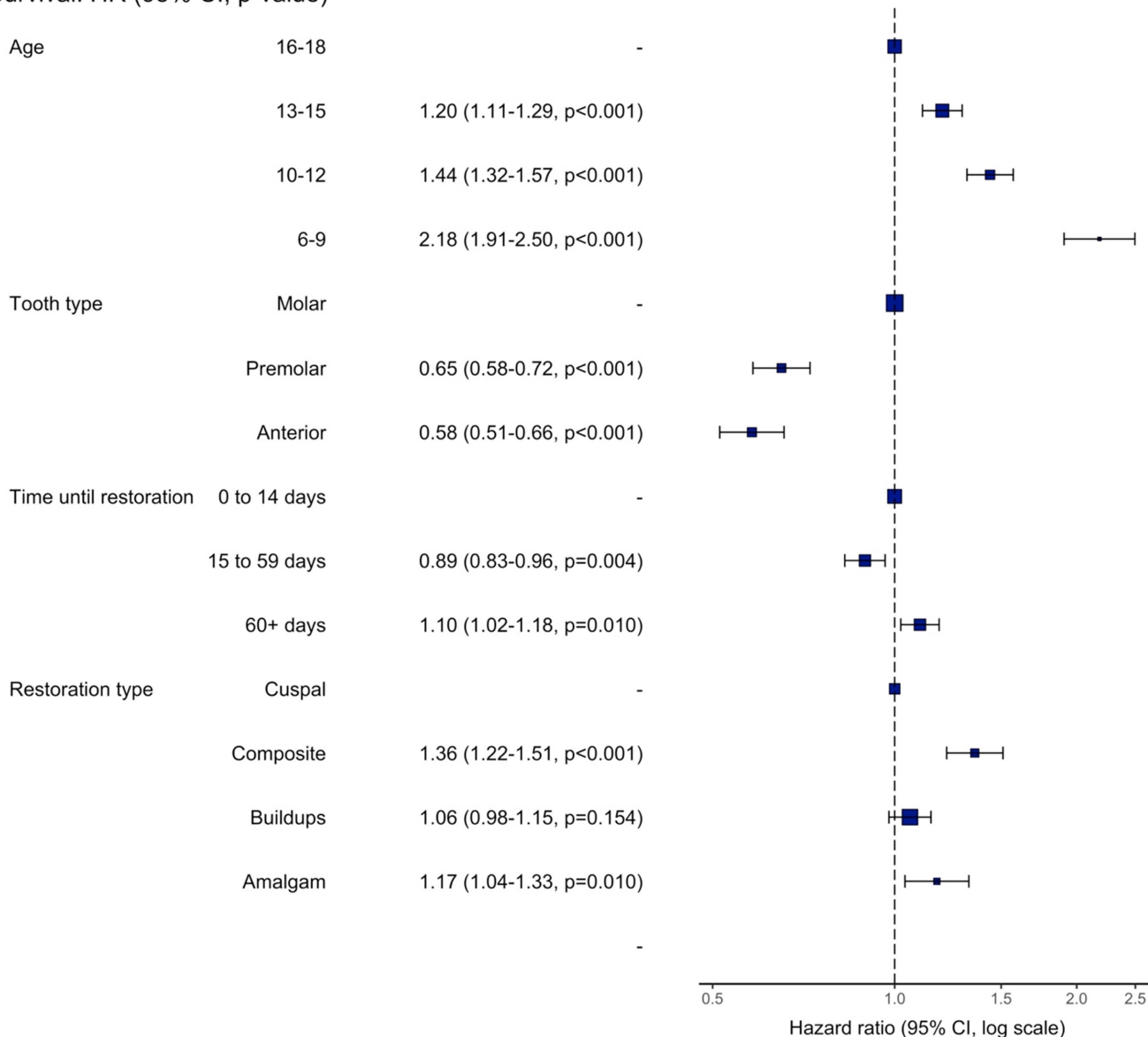
FIGURE 1 Hazard ratio forest plot based on the Cox proportional hazards model

the incidence of nonsurgical retreatment was 51 (1.3%); surgical retreatment, 79 (2.0%); and extraction, 123 (3.2%). Of the treated premolars (n = 3235, 12%), 41 (1.3%) underwent nonsurgical retreatment; 18 (0.6%), surgical retreatment; and 263 (8.1%), extraction. Of the treated molars (n = 19,136; 72.9%), the incidence of nonsurgical retreatment was 314 (1.6%); surgical retreatment, 76 (0.4%); and extraction, 2679 (14%).

4 | DISCUSSION

Recent increases in dental care utilization by children in the United States are largely a result of the passage of the Affordable Care Act (ACA) and coincide with increased government spending on dental care.[14] As state and federal governments continually re-evaluate their commitments to dental spending, the impact and outcomes of various aspects of dental treatment should be assessed for these large populations undergoing care provided in communities.[8]

This study analyzed the outcomes of initial NSRCT of over 50 000 children (and over 77 000 permanent teeth) who were continuously enrolled in the New York State Medicaid for at least 1 year. The survival rate of initial NSRCT was 98% at 1 year, 92% at 3 years, and 88% at 5 years for those with a long enough follow-up. At 10 years, 6422 teeth could be evaluated and the survival rate was 80.3% [95% CI: 79.8–80.8]. The 10 years data were not included in the results due to the comparatively small sample size

TABLE 2 Summary of survival estimates of initial NSRCT

Time (year)	Group	Category	Cases	Survival distribution function estimate	Lower 95% confidence interval	Upper 95% confidence interval
1	Overall		76 378	0.980	0.979	0.981
	Tooth type	Anterior	11 166	0.989	0.987	0.991
		Premolar	10 535	0.985	0.983	0.987
		Molar	54 677	0.977	0.976	0.978
	Time to permanent restoration	0–14 days	28 269	0.991	0.990	0.992
		15–59 days	17 125	0.992	0.990	0.993
		60 + days	17 216	0.988	0.987	0.990
		never placed	9362	0.933	0.929	0.938
	Restoration type	Amalgam	3808	0.988	0.984	0.991
		Buildups	37 560	0.992	0.991	0.993
		Composite	7375	0.985	0.982	0.988
		Cuspal	13 867	0.991	0.989	0.992
		Never placed	9362	0.933	0.929	0.938
3	Overall		44 052	0.921	0.918	0.923
	Tooth type	Anterior	6885	0.964	0.960	0.967
		Premolar	5912	0.944	0.939	0.949
		Molar	31 255	0.907	0.905	0.910
	Time to permanent restoration	0–14 days	16 737	0.956	0.953	0.959
		15–59 days	10 297	0.961	0.958	0.965
		60 + days	10 691	0.947	0.944	0.951
		never placed	6327	0.767	0.759	0.775
	Restoration type	Amalgam	2584	0.944	0.936	0.952
		Buildups	22 265	0.959	0.956	0.961
		Composite	4303	0.936	0.930	0.943
		Cuspal	8573	0.958	0.954	0.962
		Never placed	6327	0.767	0.759	0.775

TABLE 2 (Continued)

Time (year)	Group	Category	Cases	Survival distribution function estimate	Lower 95% confidence interval	Upper 95% confidence interval
5	Overall		23 080	0.875	0.871	0.878
	Tooth type	Anterior	3688	0.943	0.936	0.950
		Premolar	2967	0.912	0.904	0.919
		Molar	16 425	0.854	0.850	0.858
	Time to permanent restoration	0–14 days	8690	0.916	0.912	0.921
		15–59 days	5493	0.924	0.919	0.930
		60 + days	5941	0.903	0.898	0.909
		never placed	2956	0.691	0.680	0.701
	Restoration type	Amalgam	1635	0.893	0.881	0.905
		Buildups	11 697	0.919	0.915	0.923
		Composite	2279	0.897	0.888	0.906
		Cuspal	4513	0.920	0.913	0.925
		Never placed	2956	0.691	0.680	0.701

to those reported at 1, 3, and 5 years (76 171; 44 052; and 23 080 teeth, respectively). The subset cohort with at least 5 years of follow-up showed tooth retention of 89% at 5 years. In comparison with other epidemiological studies of root canal therapy outcomes in US populations, we found generally lower procedural survival and tooth retention rates five and ten years after treatment.[3,4,6,7] When assessing the clinical significance of this study and contextualizing its findings, several things should be considered: (1) the patient population and (2) reported clinical trends.

First, it is important to note that the patient population in this study differs from previous studies with regard to patient age and type of insurance coverage. For example, the median patient age in this study was 15 years. In the previously referenced epidemiological studies of root canal therapy outcomes in US populations, the median age of the patients was over 40 years[3,7] or not reported.[4,6] Further, the patient population in this study had public-payer dental coverage (Medicaid). All of the previously mentioned studies[3,4,6,7] report the outcomes of patients covered by a single private-payer dental insurance (Delta Dental). Future research into the outcomes of endodontic treatment in a paediatric patient cohort with a private-payer dental insurance would allow for a more direct comparison of outcomes between paediatric and adult populations and highlight potential disparities in treatment outcomes between beneficiaries of public-payer and private-payer dental benefits. A comparison of the outcomes of endodontic treatment in both paediatric and adult cohorts insured by a public-payer dental insurance would be more difficult, as many states do not cover endodontic treatment for Medicaid-eligible adults.[26] In New York State, NSRCTs of anterior and premolar teeth are covered.[27] Molar root canal therapy in the overwhelming majority of this study's sample (71.8%), however, is not covered for Medicaid beneficiaries aged 21 years and older.[27] Exceptions are made when tooth extraction would be medically contraindicated or the tooth is a critical abutment for an existing serviceable prosthesis provided by the New York State Medicaid program.[27]

Second, although the overall long-term survival rates in this study were lower than the outcomes reported in other epidemiological studies in US populations, several clinical trends corresponded. Consistent with previous studies, molars had the poorest outcomes and extraction was the most common type of untoward event, immediately following the failure of the initial nonsurgical root canal therapy.[3,4,28] Our findings on permanent restorations coincide with Lazarski et al, which state that teeth with no subsequent restoration after NSRCT had the lowest survival rates.[3] Further, similar to Salehrabi and Rotstein, we found that teeth restored with cuspal coverage had better outcomes than teeth without cuspal coverage after
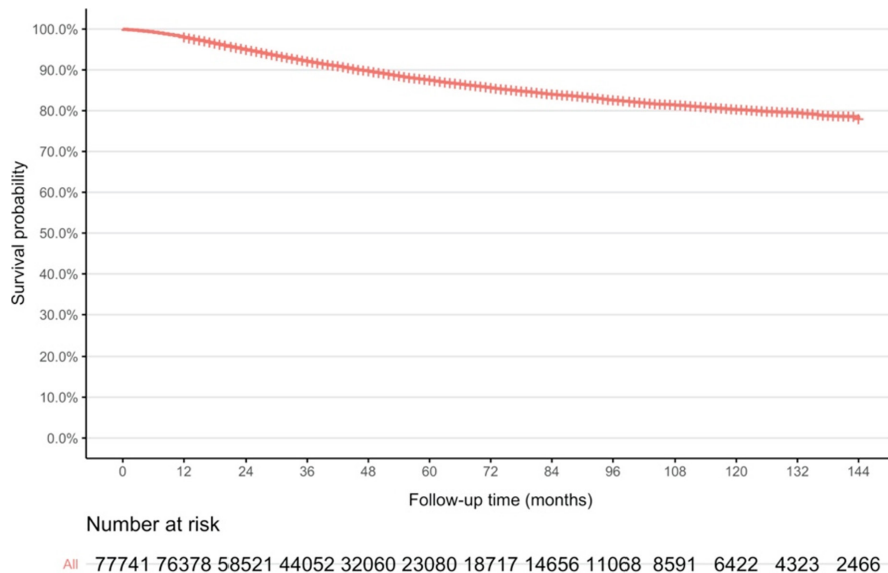
FIGURE 2 Collective survival of initial NSRCT over the study period (the Kaplan–Meier survival estimates)

Number at risk

All   77741 76378 58521 44052 32060 23080 18717 14656 11068 8591 6422 4323 2466

TABLE 3 Hazard ratio estimates from univariable and multivariable Cox regression models with robust standard errors

		N (%)	HR, univariable model (95% CI and *p*-value)	HR, multivariable model (95% CI and *p*-value)
Age	16–18	26 501 (42.0)	–	–
	13–15	24 224 (38.4)	1.25 (1.16–1.34, $p < .001$)	1.20 (1.11–1.29, $p < .001$)
	10–12	10 509 (16.6)	1.61 (1.49–1.74, $p < .001$)	1.44 (1.32–1.57, $p < .001$)
	6–9	1894 (3.0)	2.57 (2.26–2.91, $p < .001$)	2.18 (1.91–2.50, $p < .001$)
Tooth type	Molar	44 492 (70.5)	–	–
	Premolar	8841 (14.0)	0.58 (0.53–0.65, $p < .001$)	0.65 (0.58–0.72, $p < .001$)
	Anterior	9795 (15.5)	0.58 (0.52–0.63, $p < .001$)	0.58 (0.51–0.66, $p < .001$)
Time to restoration	0–14 days	28 489 (45.1)	–	–
	15–59 days	17 248 (27.3)	0.92 (0.86–0.99, $p = .025$)	0.89 (0.83–0.96, $p = .004$)
	60 + days	17 391 (27.5)	1.14 (1.07–1.22, $p < .001$)	1.10 (1.02–1.18, $p = .010$)
Restoration type	Cuspal	13 984 (22.2)	–	–
	Composite	7472 (11.8)	1.33 (1.20–1.47, $p < .001$)	1.36 (1.22–1.51, $p < .001$)
	Buildups	37 827 (59.9)	1.01 (0.94–1.09, $p = .740$)	1.06 (0.98–1.15, $p = .154$)
	Amalgam	3845 (6.1)	1.32 (1.17–1.48, $p < .001$)	1.17 (1.04–1.33, $p = .010$)

endodontic treatment.[4] Lastly, we found that time to final restoration influenced the survival rate of primary NSRCT, similar to Yee et al[7]

The primary limitation of this study is one that applies to other outcome studies utilizing administrative claims: the nonclinical nature of the data. It is possible that data are missing resulting from events that may not be captured in the claims, such as out-of-pocket payments to providers who do not participate in Medicaid. This would result in an overstatement of successful outcomes. Additionally, incorrect coding may contribute to potential errors in the data. Another limitation related to dental claims specifically is the absence of diagnostic codes. The lack of diagnostic information results in the inability to evaluate

prognostic predictors that impact endodontic treatment outcomes, including preoperative pulpal and periapical diagnosis, or reasons for treatment failure, such as recurrent decay, tooth fracture, tooth restorability, or quality of the initial endodontic treatment/coronal restoration.[2,29] The large sample size, however, allows us to draw broad conclusions in an important cohort to evaluate for its policy implications.

This study is the first of its kind to explore survival rates of initial nonsurgical root canal therapy in a paediatric population in the United States and include a person-level analysis. The findings demonstrate that endodontic treatment maintains the permanent dentition in the long term. This is particularly important for paediatric patients who

FIGURE 3 Survival of initial NSRCTs by tooth type (the Kaplan–Meier survival estimates)
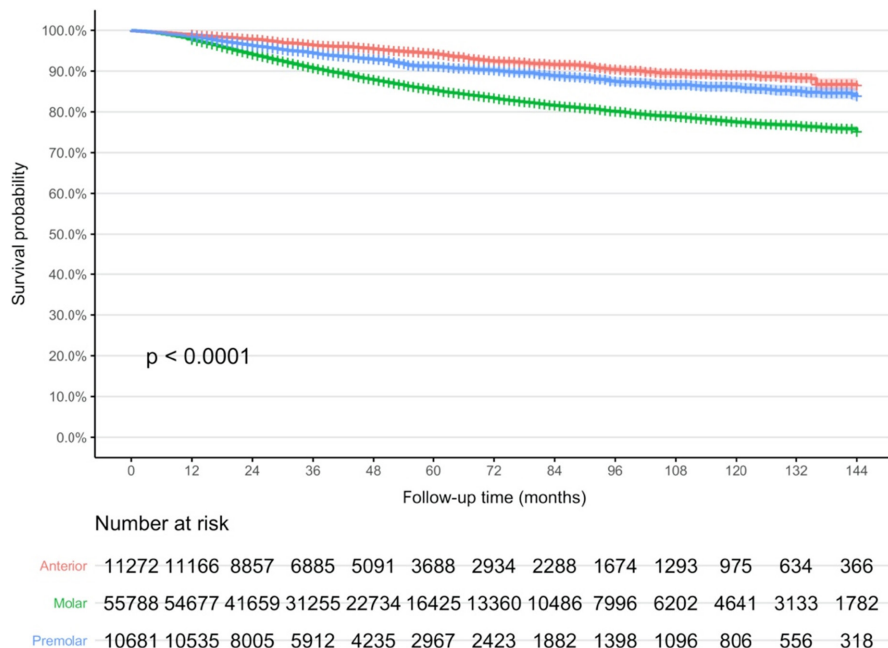

Number at risk

Anterior	11272	11166	8857	6885	5091	3688	2934	2288	1674	1293	975	634	366
Molar	55788	54677	41659	31255	22734	16425	13360	10486	7996	6202	4641	3133	1782
Premolar	10681	10535	8005	5912	4235	2967	2423	1882	1398	1096	806	556	318

TABLE 4 Number of untoward events for subjects with a 5 years minimum follow-up

Months	0–12	12–24	25–36	37–48	49–60	Cumulative total (%)
Overall (n = 26 245)						
Apicoectomy, n(%)	37 (0.14)	30 (0.11)	36 (0.14)	32 (0.12)	38 (0.14)	173 (0.66)
Extraction, n(%)	509 (1.94)	773 (2.95)	734 (2.8)	566 (2.16)	483 (1.84)	3065 (11.68)
Retreat, n(%)	52 (0.2)	86 (0.33)	86 (0.33)	94 (0.36)	88 (0.34)	406 (1.55)
Anterior (n = 3874)						
Apicoectomy, n(%)	22 (0.57)	13 (0.34)	18 (0.46)	10 (0.26)	16 (0.41)	79 (2.04)
Extraction, n(%)	20 (0.52)	32 (0.83)	30 (0.77)	21 (0.54)	20 (0.52)	123 (3.18)
Retreat, n(%)	8 (0.21)	11 (0.28)	12 (0.31)	7 (0.18)	13 (0.34)	51 (1.32)
Premolar (n = 3 235)						
Apicoectomy, n(%)	7 (0.22)	3 (0.09)	3 (0.09)	3 (0.09)	2 (0.06)	18 (0.56)
Extraction, n(%)	45 (1.39)	69 (2.13)	60 (1.85)	47 (1.45)	42 (1.3)	263 (8.13)
Retreat, n(%)	6 (0.19)	12 (0.37)	9 (0.28)	6 (0.19)	8 (0.25)	41 (1.27)
Molar (n = 19,136)						
Apicoectomy, n(%)	8 (0.04)	14 (0.07)	15 (0.08)	19 (0.1)	20 (0.1)	76 (0.4)
Extraction, n(%)	444 (2.32)	672 (3.51)	644 (3.37)	498 (2.6)	421 (2.2)	2679 (14)
Retreat, n(%)	38 (0.2)	63 (0.33)	65 (0.34)	81 (0.42)	67 (0.35)	314 (1.64)

are limited with regard to tooth replacement options after compromised permanent teeth are extracted. Further, the findings reaffirm the importance of the final restoration as a continuum of endodontic treatment. Clear opportunities for improvement in the treatment of this paediatric population are apparent and include the following: (1) increased frequency in the placement of permanent restorations after root canal therapy; (2) decreased time to the placement of definitive restorations after the completion of endodontic treatment; and (3) increased use of cuspal coverage, when definitive restorations are placed.

represent the official views of the National Institutes of Health. The views and opinions expressed in this article are those of the authors and do not necessarily reflect the official policy or position of the New York State Department of Health. Examples of analysis performed within this article are only examples. They should not be utilized in real-world analytic products.

AUTHOR CONTRIBUTIONS

LEB, AS, and HTG conceived the ideas; KT and CS cleaned the data or organized analytic data set; YW and LEB analyzed the data; and LB and HG led the writing.

DATA AVAILABILITY STATEMENT

The data that support the findings of this study are provided to the Health Evaluation and Analytics Lab at the New York University by the New York State Department of Health. The Department of Health restricts the use of the data and authorized its use for this study. Hence, any use of the data requires permission from the New York State Department of Health.

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REFERENCES

1. Friedman S. Prognosis of initial endodontic therapy. *Endod Topics*. 2002;2:59-88. 10.1034/j.1601-1546.2002.20105
2. Ng YL, Mann V, Rahbaran S, Lewsey J, Gulabivala K. Outcome of primary root canal treatment: systematic review of the literature - Part 1. effects of study characteristics on probability of success. *Int Endod J*. 2007;40:921-939. 10.1111/j.1365-2591.2007.01322
3. Lazarski MP, Walker WA, Flores CM, Schindler WG, Hargreaves KM. Epidemiological evaluation of the outcomes of nonsurgical root canal treatment in a large cohort of insured dental patients. *J Endod*. 2001;27:791-796. 10.1097/00004770-200112000-00021
4. Salehrabi R, Rotstein I. Endodontic treatment outcomes in a large patient population in the USA: an epidemiological study. *J Endod*. 2004;30:846-850. 10.1097/01.don.0000145031.04236.ca
5. Chen SC, Chueh LH, Kate HC, sai M, Ho S, Chiang C. An epidemiologic study of tooth retention after nonsurgical endodontic treatment in a large population in Taiwan. *J Endod*. 2007;33:226-229. 10.1016/j.joen.2006.11.022
6. Burry JC, Stover S, Eichmiller F, Bhagavatula P. Outcomes of primary endodontic therapy provided by endodontic specialists compared with other providers. *J of Endod*. 2016;42:702-705. 10.1016/j.joen.2016.02.008
7. Yee K, Bhagavatula P, Stover S, et al. Survival rates of teeth with primary endodontic treatment after core/post and crown placement. *J Endod*. 2018;44:220-225. 10.1016/j.joen.2017.08.034
8. Eriksen HM, Kirkevang L, Petersson K. Endodontic epidemiology and treatment outcome: general considerations. *Endod Topics*. 2002;2:1-9.
9. Stavropoulou AF, Koidis PT. A systematic review of single crowns on endodontically treated teeth. *J Dent*. 2007;35:761-767. 10.1016/j.jdent.2007.07.004
10. Pratt I, Aminoshariae A, Montagnese TA, et al. Eight-year retrospective study of the critical time lapse between root canal completion and crown placement: its influence on the survival of endodontically treated teeth. *J Endod*. 2016;42:1598-1603. 10.1016/j.joen.2016.08.006
11. Vujicic M, Nasseh K. A decade in dental care utilization among adults and children (2001–2010). *Health Serv Res*. 2014;49:460-480. 10.1111/1475-6773.12130
12. Nasseh K, Vujicic M. *Dental Care Utilization Steady Among Working-Age Adults And Children, Up Slightly Among The Elderly*. American Dental Association Health Policy Institute; 2016.
13. *Dental Care use Among Children: 2016*. American Dental Association Health Policy Institute; 2018
14. Office of Disease Prevention and Health Promotion. The role of law and policy in increasing the use of the oral health care system and services. https://www.healthypeople.gov/sites/default/files/OH_report_2020-07-13_508_0.pdf Accessed Jul 6, 2020.
15. *Dental Coverage Benefits in the U.S.* American Dental Association Health Policy Institute; 2017.
16. Benefits: early and periodic screening, diagnostic, and treatment. baltimore, MD: department of health and human services centers for medicare & medicaid services. Available at https://www.medicaid.gov/medicaid/benefits/early-and-periodic-screening-diagnostic-and-treatment/index.html. Accessed March 2, 2021.
17. Dental care. Baltimore, MD; department of health and human services centers for medicare & medicaid services. Available at https://www.medicaid.gov/medicaid/benefits/dental/index.html. Accessed February 2, 2021.
18. AlQahtani SJ, Hector MP, Liversidge HM. Brief communication: the London atlas of human tooth development and eruption. *Am J Phys Anthropol*. 2010;142(3):481-490.
19. Schour I, Massler M. The development of the human dentition. *J Am Dent Assoc*. 1940;27(11):1778-1931.
20. Klingberg G, Broberg AG. Dental fear/anxiety and dental behaviour management problems in children and adolescents: a review of prevalence and concomitant psychological factors. *Int J Paediatr Dent*. 2007;17(6):391-406.
21. Roberts JF, Curzon MEJ, Koch G, Martens LC. Behaviour management techniques in paediatric dentistry. *Eur Arch Paediatr Dent*. 2010;11(4):166-174.
22. Sharma A, Tyagi R. Behavior assessment of children in dental settings: a retrospective study. *Int J Clin Pediatr Dent*. 2011;4(1):35-39.
23. U.S. Census Bureau. Selected housing characteristics, 2008-2012 American community survey 5-year estimates. https://www2.census.gov/. Accessed December 1, 2020.
24. Health Resources and Services Administration. Federal office of rural health policy data files. https://www.hrsa.gov/rural-health/about-us/definition/datafiles.html. Accessed October 7, 2020.
25. Health Resources and Services Administration. Area health resource files. https://data.hrsa.gov/tools/shortage-area/hpsa-find. Accessed June 30, 2021.
26. Medicaid and CHIP Payment and Access Commission. Medicaid coverage of dental benefits for adults. 2015 https://

www.macpac.gov/wp-content/uploads/2015/06/Medicaid-Coverage-of-Dental-Benefits-for-Adults.pdf

27. New York State Medicaid Program. Dental policy and procedure code manual 2013 and 2021. https://www.emedny.org/ProviderManuals/Dental/PDFS/Dental_Policy_and_Procedure_Manual.pdf. Accessed November 8, 2021.

28. Chen SC, Chueh LH, Hsiao CK, et al. First untoward events and reasons for tooth extraction after nonsurgical endodontic treatment in Taiwan. *J Endod*. 2008;34:671-674. 10.1016/j.joen.2008.03.016

29. Vire DE. Failure of endodontically treated teeth: classification and evaluation. *J Endod*. 1991;17:338-342.