



# Progression of Proximal Caries in the Mixed Dentition: A 4-year Prospective Study

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## Abstract

**Purpose:** The purpose of this study was to investigate the survival rate and median survival time of different stages of proximal caries in 196 children aged 6 to 8 years at baseline examination.

**Methods:** Proximal caries and its progression were diagnosed from bitewing radiographs taken at 1-year intervals over a period of 4 years. The mesial surface of the first permanent molars, the mesial and distal surfaces of the first and second primary molars, and the distal surface of the primary canine were examined. Sound surfaces, caries lesions in the external- and internal-half of the enamel and external-, middle-, and internal-third of the dentin, as well as filled, extracted, and exfoliated teeth were recorded. A life table analysis was performed to estimate the annual and cumulative survival rates and the median survival time of each state of proximal lesions.

**Results:** For the sound mesial surfaces of the first permanent molars, the cumulative survival rate was 76% and the median survival time was over 48 months. The corresponding values for the external-half of the enamel lesions were 41% and 45 months. Regarding the sound mesial and distal surfaces of the primary teeth, the cumulative survival rate was 92% and the median survival time was over 48 months. The corresponding values for the external and internal-half of the enamel lesions were 40% and 31 months, and 29% and 22 months, respectively. The value of the cumulative survival rate for the external-third of dentin lesions was 42%, with a median survival time of 34 months, and the value for the middle-third of the dentin was 38% with a median survival time of 17 months.

**Conclusions:** The risk of developing carious lesions in the sound proximal surfaces of both primary teeth and first permanent molars is low during the mixed dentition period; the progression of the external-half of enamel lesions of the first permanent molars is low for the first 3 years and becomes faster thereafter; and as the time period that the tooth exposed to cariogenic factors increases, the progression of the proximal caries is faster for all stages of the lesion in the primary teeth. (*Pediatr Dent.* 2003;25:229-234)

**KEYWORDS:** PROXIMAL CARIES, CARIES PROGRESSION, MIXED DENTITION, PRIMARY TEETH

*Received August 27, 2002    Revision Accepted January 8, 2003*

It has been reported that the progression of caries through the enamel of posterior proximal surfaces of permanent teeth is a slow process.<sup>1-4</sup> Besides, there is evidence that the criteria for restoring dentin proximal caries are changing and a new strategy for monitoring lesion progression has been suggested.<sup>2,5-7</sup> Previous studies have found that it takes an average of at least 4 years for a lesion to progress through the enamel of permanent teeth.<sup>1,8</sup> Progression was slower for older individuals, particularly those

with long-term exposure to fluorides. Also, it has been reported that 75% of the enamel-dentin junction lesions remained in the same state for a period of 1.3 years.<sup>2</sup> To decide, however, when the time is right to apply a restorative treatment on proximal caries, it is necessary to obtain more longitudinal knowledge related to progression of caries through the enamel and into the dentin of permanent teeth. Furthermore, the progression of caries of posterior proximal surfaces of primary teeth has not been studied adequately.

**Table 1. Distribution of Subjects by Age and Gender**

Groups	Age (y)				Total
	10	11	12	13	
Boys	20	76	5	1	102
Girls	16	71	7	0	94
Total	36	147	12	1	196

The purpose of this study was to investigate longitudinally the progression of enamel and dentin caries on posterior proximal surfaces in children ages 6 to 8 up to 10 to 12 years old.

## Methods

### Study population

The original sample consisted of bitewing radiographs of 314 children—161 boys and 153 girls from 5 public schools—aged 6 to 8 years at baseline examination. The parents were invited to the schools, and the investigators explained the procedures of the study to them. A consent form, signed by the parent, was returned to the investigators. Children were followed up to 10 to 12 years of age. Two bitewing radiographs were taken annually for each child with the aid of a film holder. During the period of the study, 39 children refused to have radiographic examination, 41 were moved out of the district, and 38 were absent during the examinations. Therefore, the final sample consisted of 196 children: 102 boys and 94 girls. Table 1 shows the distribution of the subjects by age and gender. These children had complete sets of radiographs for all examinations. Permission to use human subjects in this study was obtained from the appropriate health ministry and school district authorities.

### Radiographic classification of proximal caries

All radiographs by subject were read in succession in a view box by an investigator who was a qualified pediatric dentist. The mesial surface of the first permanent molars, the mesial and distal surfaces of the primary molars, and the distal surface of the primary canines were examined. According to the radiographic appearance 1 of the following codes was assigned to each surface:

- 0=sound surface;
- 1=lesion in the external-half of the enamel;
- 2=lesion in the internal-half of the enamel;
- 3=lesion in the external-third of the dentin;
- 4=lesion in the middle-third of the dentin;
- 5=lesion in the internal-third of the dentin.

Missing and restored teeth as well as unreadable surfaces and exfoliated teeth had separate codes. Small radiolucencies that disappeared on subsequent radiographs were coded as sound surfaces. No lesions appeared to return to a less deep state on the radiographs.

### Preventive measures

All children lived in an area with less than 0.03 ppm water fluoride content. The subjects received a 4-minute topical application of acidulated phosphate-fluoride gel contained in trays as well as oral hygiene instructions once a year for 4 consecutive years. Also, toothpaste with fluoride was distributed to them in each examination. A letter was sent to the parents to inform them of the child's dental needs.

### Intraexaminer reliability test

The radiographs of 15 children were randomly re-examined within 15 days of the first examination, and an intraexaminer reliability test was carried out.

### Statistical methods

The observations of all surfaces at each examination period were entered into an Excel spreadsheet using the codes defined previously. Then, a follow-up life table was constructed to generate the appropriate survival data for the statistical analysis. A follow-up life table is a statistical technique used to analyze data in which the event of interest may not occur in all subjects during the period in which they are observed and in which subjects are observed for different periods of time (not every tooth develops dental caries and not every tooth lesion progresses to a higher stage at the same time). Life tables were computed using the SPSS statistical package, which include estimates of the annual survival rates, the cumulative rates, and the median survival time. The annual survival rate is the probability of surviving within a 1-year interval, while the cumulative survival rate is an estimate of the probability of surviving to the end of an interval. The latter is computed as the product of the proportion surviving this interval and the proportion surviving all previous intervals. Median survival time is the time point by which half of the cases are expected to experience the event (lesion progression).

Surfaces that remained sound to the end of the study or did not progress to a higher stage were treated as censored observations in the analysis of survival data. Furthermore, all surfaces recorded as restored at the baseline examination were excluded from the study, but when found restored at any other examination period were considered censored observations. Although the state of the lesion was known in the radiograph preceding the restoration, it was not possible to determine whether the lesion would have made the transition to a higher state if it had been restored. Likewise, exfoliated teeth, extracted teeth, and unreadable surfaces at baseline examination were excluded, while at subsequent intervals they were treated as censored observations. For the censored observations, it can be said that no progression was made from the time a surface entered in the analysis in a certain state until the time it was censored. Finally, the intraexaminer reliability agreement was evaluated using the kappa statistic.

## Results

### First permanent molars

Table 2 presents the distribution of mesial surfaces of first permanent molars as recorded at each examination. The life table analysis showed that the cumulative survival rate of the sound surfaces was 76% and the median survival time was 48+ months (Table 3). The cumulative survival rate for each tooth surface ranged from 71% to 82%. The lower survival rate was found for the mandibular right permanent molar followed by the mandibular left molar, the maxillary right molar, and the maxillary left molar. The median survival time was the same for each tooth surface separately with a value of 48+ months. The cumulative survival rate for the mesial surfaces of the teeth erupted during the period of the study was 82%, and the median survival time was 36+ months.

With respect to the lesions of the external-half of the enamel, the cumulative survival rate was 41%, and the median survival time was 45 months (Table 4). Statistical analysis for the other categories of enamel and dentin lesions was not performed due to lack or insufficient number of cases in each category.

### Primary teeth

Table 5 presents the distribution of proximal surfaces of primary teeth as recorded at each examination. The life table analysis showed that the cumulative survival rate of all sound surfaces was 92% with a median survival time of 48+ months (Table 6). The survival rate ranged from 81% to 99% for the sound maxillary surfaces and 67% to 99% for the mandibular surfaces. The mesial and distal surfaces of the maxillary molars had a cumulative survival rate ranging from 81% to 99%, and the corresponding values for the mandibular surfaces ranged from 67% to 98%. The values of the cumulative survival rate for the distal surface of the maxillary canines ranged from 97% to 99%, while the corresponding figures for the mandibular canines

**Table 2. Distribution of the Recorded Surfaces in the First Permanent Molars**

State of the surfaces	Examinations				
	Baseline	First	Second	Third	Fourth
Sound	658	693	630	583	556
External-half enamel	51	83	122	139	120
Internal-half enamel	-	1	9	11	29
External-third dentin	-	-	2	6	7
Middle-third dentin	-	-	1	-	1
Internal-third dentin	-	-	-	1	1
Restored	-	3	4	4	5
Unreadable	8	3	15	40*	65*
Not erupted	67	1	1	-	-
Total	784	784	784	784	784

\*Twelve children were receiving orthodontic treatment.

**Table 3. Life Table Analysis of the Sound Surfaces of the First Permanent Molars**

Time interval(m)	Analyzed surfaces	Censored surfaces	Risk set	No. of lesions	Survival rate %	Cumulative survival rate %	Hazard rate %
0-12	658	1	657	29	96	96	0.4
12-24	628	4	626	52	92	88	0.7
24-36	572	18	563	25	96	84	0.4
36-48	529	505	276	24	91	76	0.8

Median survival time=48+ months.

**Table 4. Life Table Analysis of the External-half of Enamel Lesions of the First Permanent Molars**

Time interval(m)	Analyzed surfaces	Censored surfaces	Risk set	No. of lesions	Survival rate %	Cumulative survival rate %	Hazard rate %
0-12	51	2	50	1	98	98	0.2
12-24	48	3	47	7	85	83	1.4
24-36	38	0	38	5	87	72	1.2
36-48	33	24	21	9	57	41	4.6

Median survival time=45 months.

ranged from 98% to 99%. The lowest cumulative survival rate was found for the distal surfaces of the left mandibular second molar, and the highest cumulative survival rate was reported for the distal surface of the right mandibular canine.

Regarding the lesions of the external and internal-half of the enamel, the cumulative survival rate and the median

**Table 5. Distribution of the Recorded Surfaces in Primary Teeth**

State of the surfaces	Examinations				
	Baseline	First	Second	Third	Fourth
Sound	2,637	2,444	2,145	1,732	1,340
External-half enamel	276	243	206	126	68
Internal-half enamel	149	170	116	79	41
External-third dentin	288	275	244	146	75
Middle-third dentin	64	97	80	52	17
Internal-third dentin	29	60	114	60	29
Restored	113	125	132	123	86
Extracted	86	147	152	152	152
Exfoliated	37	168	627	1,261	1,935
Unreadable	126	115	104	189	177
Total	3,920	3,920	3,920	3,920	3,920

**Table 6. Life Table Analysis of the Sound Surfaces of the Primary Teeth**

Time interval(m)	Analyzed surfaces	Censored surfaces	Risk set	No. of lesions	Survival rate %	Cumulative survival rate %	Hazard rate %
0-12	2,637	95	2,590	98	96	96	0.3
12-24	2,444	229	2,330	70	97	93	0.3
24-36	2,145	393	1,949	20	99	92	0.1
36-48	1,732	1,729	868	3	99	92	0.0

Median survival time=48+ months.

**Table 7. Life Table Analysis of the External-half of the Enamel Lesions in Primary Teeth**

Time interval(m)	Analyzed surfaces	Censored surfaces	Risk set	No. of lesions	Survival rate %	Cumulative survival rate %	Hazard rate %
0-12	276	16	268	82	69	69	3.0
12-24	178	21	167	34	80	55	1.9
24-36	123	38	104	16	85	47	1.4
36-48	69	64	37	5	86	40	1.2

Median survival time=31 months.

**Table 8. Life Table Analysis of the Internal-half of the Enamel Lesions in Primary Teeth**

Time interval(m)	Analyzed surfaces	Censored surfaces	Risk set	No. of lesions	Survival rate %	Cumulative survival rate %	Hazard rate %
0-12	149	13	143	49	66	66	3.5
12-24	87	24	75	22	71	46	2.9
24-36	41	24	29	4	86	40	1.2
36-48	13	11	8	2	73	29	2.6

Median survival time=22 months.

survival time were 40% and 31 months (Table 7), and 29% and 22 months (Table 8), respectively. The value of the cumulative survival rate was 42% with a median survival time of 34 months for the external-third of dentin lesions (Table 9) and 38% with a median survival time of 17 months for the middle-third of the dentin (Table 10). No statistical analysis was performed for the internal-third of the dentin lesions since the great majority of the teeth were either extracted or exfoliated so that the sample was too small to get meaningful results.

#### Intraexaminer reliability test

The value of the kappa-statistic for the permanent teeth was 0.87 with a confidence interval ranging between 0.78 and 0.96, while for the primary teeth the corresponding value was 0.86 with an interval between 0.82 and 0.89.

### Discussion

The present study investigated survival rates and median survival times of different stages of proximal caries in the mixed dentition period. Proximal caries and its progression were diagnosed by bitewing radiographs. Although bitewing radiographs are an invaluable aid in the diagnosis of proximal caries, some intra- and interexaminer variability is inevitable.<sup>9-11</sup> The use of radiographs with diagnostic value, well-defined diagnostic criteria, and calibrated examiners, however, reduce the possibility of errors and variations in the process of diagnosing and evaluating the progression of proximal caries.<sup>9,12</sup> In this study, the intraexaminer reliability test showed high reproducibility in diagnosing proximal lesions.

In this investigation, the life table was used for the statistical analysis. Previous studies either reported the percentage of lesions

which remain at a certain stage of disease over a period of time or used the Kaplan-Meier<sup>13</sup> approach (1958) to estimate the average time that a lesion needs to progress from one state to another. However, as reported in the literature,<sup>1,2</sup> the time needed for a lesion to progress from one state to another is extremely variable not only between individuals but also between lesions of the same individual. Therefore, it is clinically more meaningful to report the survival rate of a lesion in relation to time achieved by the life table analysis.

Regarding the mesial surfaces of the first permanent molars, the results showed that the values of annual and cumulative survival rates for all sound surfaces (Table 3) and for each tooth separately were high in each time interval as well as for the total period of the study.

These findings imply that the caries initiation rate in the mesial surface of the first permanent molars during the mixed dentition period is very low. Also, a clinical implication of these results is that sealants placed on the occlusal surfaces of first permanent molars with sound mesial surfaces during the mixed dentition period are at low risk of being replaced by a restoration due to caries in the mesial surface of the tooth. One could argue, however, that the status of the mesial surfaces of the first permanent molar was affected by the early loss of the second primary molar. It should be pointed out that the number of extracted teeth was small throughout the study, and the exfoliation of the great majority of the teeth took place at the last examinations (9-11 years old), reflecting a normal transitional period of the dentition. For the lesions of the external-half of the enamel, the annual and cumulative survival rates were high during the first 3 years of the study and dropped considerably at the fourth year (Table 4). An explanation of this finding may be that the time period of 3 years is a critical value in which the resistance of the enamel to demineralization is reduced, resulting in a faster progression of the lesion.

With respect to the primary teeth, the annual and cumulative survival rates for the sound proximal surfaces were high, with a median survival time greater than 48 months (Table 6). This finding implies that, if the proximal surfaces of the primary teeth did not become carious at the ages studied in this investigation at baseline examination, the risk of developing dental disease is very low for the remaining mixed-dentition period. For all stages of the lesions, the annual survival rates are considered high, which

**Table 9. Life Table Analysis of the External-third of the Dentin Lesions in Primary Teeth**

Time interval(m)	Analyzed surfaces	Censored surfaces	Risk set	No. of lesions	Survival rate %	Cumulative survival rate %	Hazard rate %
0-12	288	34	271	71	74	74	2.5
12-24	183	42	162	37	77	57	2.2
24-36	104	42	83	12	86	49	1.3
36-48	50	46	27	4	85	42	1.3

Median survival time=34 months.

**Table 10. Life Table Analysis of the Middle-third of the Dentin Lesions in Primary Teeth**

Time interval(m)	Analyzed surfaces	Censored surfaces	Risk set	No. of lesions	Survival rate %	Cumulative survival rate %	Hazard rate %
0-12	64	13	58	24	58	58	4.4
12-24	27	12	21	7	67	38	3.3
24-36*	-	-	-	-	-	-	-
36-48*	-	-	-	-	-	-	-

Median survival time=17 months.

\*The number of remaining surfaces was too small for the statistical analysis.

shows that the progression of a lesion in a yearly interval is low. On the other hand, the cumulative survival rates dropped considerably, implying that the risk time of the tooth (the period of time the tooth is exposed to cariogenic factors) plays a significant role in the rate of progression of these lesions.

The present study differs from previous investigations in the risk time of the teeth included in the sample, the preventive measures applied to the individuals, and in the statistical approach. Although a direct comparison of the results is not feasible, the general finding is the retardation of the progression of enamel lesions in permanent teeth. An interesting question, however, emerges about the clinical implication of the results of the present and the previous studies regarding the treatment of proximal caries. Other investigators<sup>2,5-7</sup> have suggested using remineralizing rather than restorative measures to monitor proximal enamel and dentin lesions in permanent teeth. In a recent review study<sup>14</sup> related to the effectiveness of preventive treatment on the progression of proximal caries, it has been reported that different preventive measures, especially fluoride, have a significant effect on the retardation of the progression of proximal lesions. The retardation implies that the lesion will develop to a restorative stage some time in the future. Since preventive treatment cannot change pre-established patterns of proximal lesions, it is important to know the health and economic benefits derived from the delay of the restorative treatment. This issue, however, requires investigation. Considering the primary teeth, the results of this study are clinically meaningful if the expected lifetime of the tooth is taken into consideration.

## Conclusions

1. The risk of developing carious lesions in the sound proximal surfaces of both primary teeth and first permanent molars is low during the mixed dentition period.
2. The progression of the external-half of enamel lesions of the first permanent molars is low for the first 3 years and becomes faster thereafter.
3. As the time that a tooth is exposed to cariogenic factors increases, the progression of proximal caries is faster for all studied stages of the lesion in the primary teeth.

## Acknowledgments

This study was funded in part by Unilever Hellas Corporation. The authors would like to thank Dr. S. Dimelis, Department of Informatics, Athens University of Economics and Business, for the statistical analysis.

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