Dental Caries in the Primary Dentition: Assessing Prevalence of Cavitated and Noncavitated Lesions

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Abstract

Background: *Dental caries in the primary dentition has received renewed attention in recent years because caries in the primary dentition is predictive of later caries experience, and because of efforts to address early childhood caries. More detailed caries diagnostic criteria have been developed and used for the permanent teeth; however, such criteria have not been widely adopted for caries diagnosis in the primary dentition.* ***Methods:*** *As part of the Iowa Fluoride Study, caries diagnostic criteria were developed specifically for the primary teeth. The criteria included noncavitated (d_1) lesions and cavitated (d_{2-3}) lesions. Examinations were conducted on 698 children in the primary dentition by two trained examiners who did duplicate examinations on 11 percent (n=67) of these children.* ***Results:*** *Interexaminer agreement for any d_1 and any d_{2-3} lesions at the person level was 100 percent. At the tooth level for $d_1d_{2-3}f$, there was 98.5 percent agreement and kappa was .91. For d_1 at the tooth level, agreement was 97.0 percent agreement and kappa=.24. For d_{2-3} it was 99.4 percent agreement and kappa=.81. Prevalence of untreated d_{2-3} was 16.5 percent, while that of d_1 was 24.1 percent. Nearly 73 percent had no d_{2-3} or filled surfaces, while over 63 percent had no d_1, d_{2-3}, or filled surfaces. Decay experience was most common on the primary second molars. About 56 percent of untreated d_{2-3} decay was located in the pits and fissures, while 58 percent of d_1 decay was located on smooth surfaces.* ***Conclusion:*** *Despite some concern with reliability of diagnosing d_1 lesions, it appears that the d_1d_{2-3} criteria are informative and useful in assessing the primary dentition. [J Public Health Dent 2002;62(2):109-14]*

Key Words: dental caries, primary dentition, prevalence, diagnostic criteria.

For most of the 20th century, dental caries was diagnosed largely as either present and requiring restorative treatment or absent and requiring no treatment. With this rather black and white perception of dental caries, it should not be surprising that diagnostic criteria used in epidemiologic studies generally only differentiated carious surfaces from sound ones (1). However, during much of the last century, dental caries was a rampant disease and management options were limited, so that a strict dichotomous classification system may have been appropriate.

As is well documented, a great deal of research has led to an understanding of dental caries as a reversible, biological process. Moreover, with the advent of various fluoride modalities and antimicrobial agents, it has become possible to intervene in the caries process at many stages along the continuum from sound tooth structure to frank decay. However, despite the increase in understanding of the caries process, most caries data collected in epidemiologic studies still rely on essentially the same criteria in use as early as the 1930s (2).

Recently, there has been a great deal of discussion in the dental literature about the use of more sensitive diagnostic criteria for studies of dental caries that recognize dental caries as a process such that carious lesions are categorized into stages. Specifically, these discussions have emphasized the need for including what are termed "precavitated" or "noncavitated" lesions in caries criteria (3-5), and to that end, more sensitive criteria have been developed (3-7). These criteria, sometimes referred to as the D1–D3 scale (8) reflecting the different stages of the caries process, were originally developed by the World Health Organization (WHO) (6,7), and subsequently modified, most notably by Pitts et al. (3,9) and Ismail (4,5). In brief, these criteria include lesions with evidence of demineralization but no loss of enamel structure (the D1 classification), lesions with loss of enamel structure that are confined to the enamel layer only (the D2 classification), and lesions with loss of enamel structure that penetrate into dentin (the D3 classification). In some cases, a D4 classification is included, indicating pulpal involvement, but D4 lesions are usually grouped with D3 lesions in data analysis (8). While there are subtle variations in how these basic criteria have been interpreted and used by different investigators, they all emphasize visual examination with drying of the teeth, minimal explorer probing, and careful examination of enamel surface texture (3-7,9,10).

The advocates of the D1–D3 system have described many advantages over the dichotomous caries criteria used in the past. These include a better means of estimating the need for and recommending appropriate preventive and restorative treatment measures (4,9), a more sensitive measure of assessing change in caries status (10), and a better means of predicting future caries (11).

While the D1–D3 criteria offer many advantages and have been used successfully in a number of studies, they have not been widely used in studies of the primary dentition, although a recent National Institute of Dental and

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TABLE 1
Summary of $d_1d_{2\text{-}3}$ Caries Criteria

	d_1 Lesions	$d_{2\text{-}3}$ Lesions
Smooth surfaces		
Appearance/color	Chalky white	Chalky white with darker center
Surface	Intact	Cavitated—definite loss of tooth structure
Tactile	Normal (tactile exam usually not necessary)	Soft
Location	Usually adjacent to soft tissue margin	Usually adjacent to soft tissue margin
Pits and fissures		
Appearance and color	May be lightly stained, or have chalky white area adjacent to pit or fissure	Often stained light to dark brown and often with chalky white area adjacent
Surface	Intact	Cavitated—definite loss of tooth structure
Tactile	Normal	Soft
Undermining	Not present	Often evident

TABLE 2
Cavitated and Noncavitated Decay Experience at the Person, Tooth, and Surface Level

Dependent	Overall			% of Persons	Among Those with ≥ 1 Lesion	
Variable	Mean	SD	Maximum	with None	Mean	SD
Teeth						
$d_{2\text{-}3}$	0.34	0.97	7	83.5	2.03	1.49
f	0.46	1.33	10	83.0	2.72	2.07
$d_{2\text{-}3}$ f	0.78	1.78	13	72.8	2.85	2.38
d_1	0.60	1.49	12	75.9	2.48	2.13
$d_1d_{2\text{-}3}$	0.91	1.96	15	69.9	3.00	2.53
$d_1d_{2\text{-}3}$ f	1.30	2.47	16	63.2	3.53	2.94
Surfaces						
$d_{2\text{-}3}$	0.43	1.35	13	83.5	2.62	2.31
f	0.96	3.37	40	83.0	5.55	6.42
$d_{2\text{-}3}$ f	1.40	3.96	46	72.8	5.13	6.21
d_1	0.65	1.70	16	75.9	2.68	2.55
$d_1d_{2\text{-}3}$	1.08	2.46	21	69.9	3.58	3.35
$d_1d_{2\text{-}3}$ f	2.02	4.74	53	63.2	5.50	6.48

Craniofacial Research (NIDCR) conference recommended recording both noncavitated and cavitated lesions in preschool children (12). In one of the few studies to use a d_1–d_3 system in assessing the primary dentition, Pitts et al. (11) examined a group of Scottish preschool children and found dental caries to be detectable at a very early age, with 2.2 percent of 1-year-olds having d_1 lesions. Their findings were also consistent with studies of the permanent dentition in that d_1 lesions were more prevalent than d_3 lesions at all age levels. However, no other published studies of the primary dentition using the d_1–d_3 criteria exist; thus, little is known about the different stages of the caries process in the primary dentition.

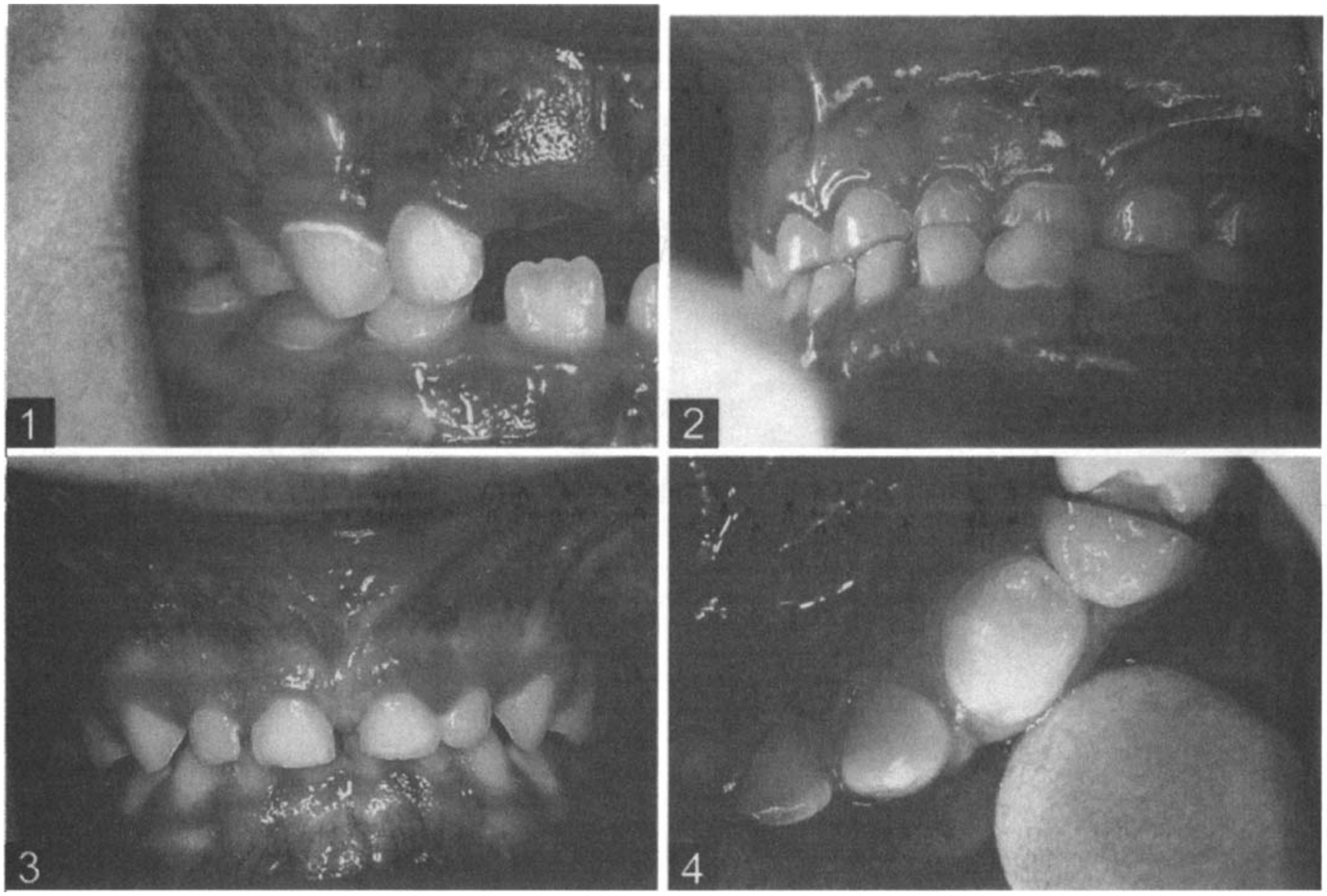
This paper describes a modification of the d_1–d_3 criteria for use in the primary dentition, and uses these criteria to report the prevalence of different stages of the dental caries process in a group of 4–5-year-old children.

Methods

Children in the present study were recruited at birth in post-partum wards of eight Iowa hospitals as part of the Iowa Fluoride Study (13-16). In the recruitment process, nearly 3,400 mothers were approached to participate; of these, 1,882 agreed to do so, and 1,368 actually provided data. Through periodic parental questionnaires, the children were followed prospectively from birth until the time of the first study examination of the primary dentition at 4 1/2 to 5 years of age (mean age=4.63 years), at which time about 800 children remained active in the study. Of these, 698 children were examined, including 360 females and 338 males. Thus, the study used a convenience sample as part of a longitudinal cohort study design. In general, children who remained in the study cohort were from families with higher socioeconomic status in terms of parental education and income levels.

Examinations were conducted us-

FIGURES 1–4
Smooth Surface Lesions
1. A d_1 smooth surface lesion adjacent to the soft tissue margin. Note the white band of demineralized enamel, most prominently on the maxillary canine, but also on the primary molars and incisors. 2. Smooth surface d_{2-3} lesions are also frequently adjacent to the soft tissue margin; but in contrast to the d_1 smooth surface lesions, there is demonstrable loss of tooth structure. In this photograph, the maxillary lateral incisor, as well as the mandibular canine and first molar have d_{2-3} lesions. 3. An interproximal d_{2-3} lesion on the mesial surface of the maxillary lateral incisor. Note the ring of white demineralized enamel surrounding the area of lost tooth structure. 4. The distal surface of the primary first molar has a d_{2-3} lesion detected via transillumination.



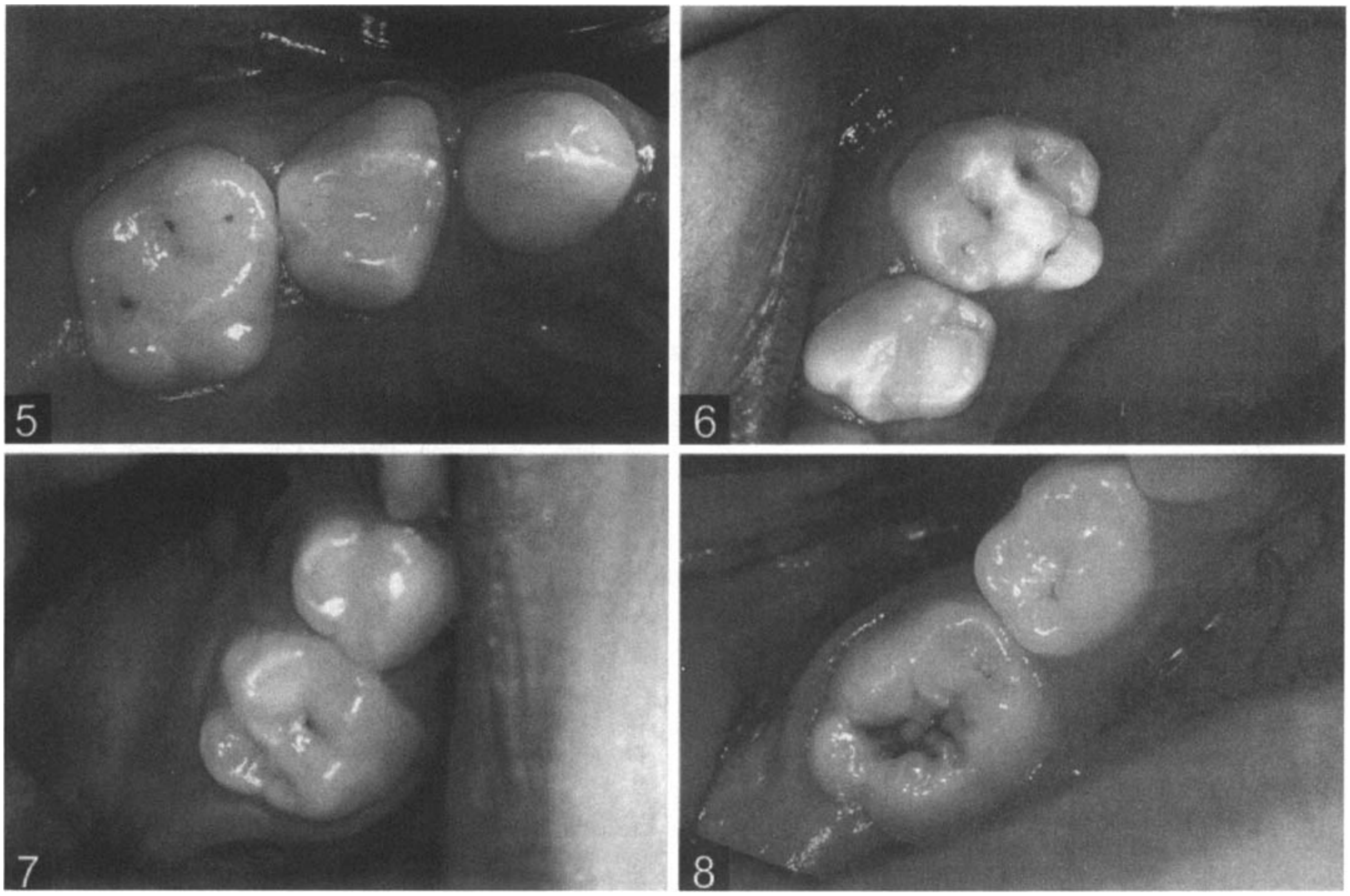
ing a portable chair and exam light by one of two trained and calibrated examiners. The teeth were dried, and a DenLite® (Welch-Allyn Medical Products, Inc., Skaneateles Falls, NY) mirror was used for enhanced lighting. The examination was visual, but used an explorer to confirm questionable findings. In addition to the visual/tactile examination, transillumination was used via the DenLite® system.

The criteria were adapted from those of Pitts et al. (3,9,11) and others (4,5), but unlike the D1–D3 system, did not differentiate between cavitated enamel and dentin lesions. Instead, lesions were categorized as cavitated (d_{2-3}), similar to the D2 and D3 classifications combined, or noncavitated (d_1) lesions, similar to the D_1 classifications used by others. The criteria also distinguished between smooth surface and pit and fissure decay. A summary of the criteria is presented in Table 1.

Specifically, smooth surface d_1 lesions were those that presented as distinct chalky white enamel, usually adjacent or close to the soft tissue margin with no clinically visible or irreversible loss of enamel structure or break in the enamel surface (Figure 1). In contrast, smooth surface d_{2-3} lesions presented with demonstrable loss of enamel structure, often present with distinct chalky white enamel, and again usually adjacent or close to the soft tissue margin (Figure 2). For approximal smooth surfaces, d_{2-3} lesions were scored only after confirmation using direct vision or transillumination, and/or after observing undermining with discoloration under the marginal ridge and either direct extension onto the proximal surface, or evidence of a break in the proximal enamel surface. Figure 3 demonstrates an interproximal d_{2-3} lesions confirmed with direct vision, while Figure 4 demonstrates an interproximal d_{2-3} lesion diagnosed via transillumination.

For pit and fissure surfaces, d_1 lesions often presented as distinct chalky white enamel directly adjacent to or into a pit or fissure, which were typically stained light to dark brown. The d_1 lesion had to have no clinically visible or irreversible loss of enamel

FIGURES 5–8
Pit and Fissure Lesions
5. There is a d_1 lesion in the distal pit of the second primary molar. Note the staining, and slight area of demineralization with no apparent loss of enamel structure. The other lightly stained pits appear less involved, and would be considered as sound with no d_1 decay. 6. The primary second molar presents two separate areas of d_1 decay. There is a d_1 lesion on the lingual aspect of the occlusal surface that has a chalky white border, with no clear loss of enamel structure, as well as an area of d_1 decay in the distal pit. 7. In contrast to d_1 lesions, d_{2-3} lesions have demonstrable loss of enamel. In this photograph, the central pit of the primary second molar has an area where tooth structure has been lost surrounded by demineralized enamel, so that this lesion would be considered a d_{2-3} lesion. 8. The primary second molar demonstrates some small loss of tooth structure, but in this case, the undermining of the enamel provides more conclusive evidence of d_{2-3} decay.



structure upon explorer probing in pits and fissures, and no resistance of removal of explorer during tactile examination with controlled modest pressure. In addition, no evidence of undermining could be present. Figure 5 demonstrates a d_1 lesion in the distal pit of the second primary molar. Note the staining with no apparent loss of enamel structure. Figure 6 shows a d_1 lesion on the lingual aspect of the occlusal surface that has a chalky white border, with no clear loss of enamel structure.

The d_{2-3} pit and fissure lesion could also have distinct chalky white enamel adjacent to a pit or fissure (as in Figure 7); but, in contrast to d_1 lesions, there is demonstrable loss of enamel structure upon visual examination, with evidence of active decay such as demineralization or undermining of enamel (as in Figure 8). Tactile examination revealing softness at the base of the lesion upon explorer probing with controlled modest pressure may also be sufficient evidence, by itself, of a d_{2-3} lesion.

Interexaminer reliability was assessed by examinations of approximately 10 percent of subjects by both examiners periodically throughout data collection, which took place from August 1997 through March 2000. Percent agreement and kappa statistics were computed at the subject and tooth levels.

Data were entered using SPSS® Data Entry software, and descriptive statistics were generated using SPSS® (17,18).

Results

At the person level, percent agreement was 100 percent for any d_{2-3} lesion, 100 percent for any filled surfaces, and 100 percent for any d_1 lesion. At the tooth level, percent agreement was 99.4 percent for any d_{2-3}, with kappa=.81. For d_1 at the tooth level, agreement was 97.0 percent agreement and kappa=.24. For filled surfaces at the tooth level, there was 99.3 percent agreement and kappa=.88. For any $d_1d_{2-3}f$, percent agreement at the tooth level was 98.5 percent, with kappa=.91.

Table 2 presents data on d_1, d_{2-3}, and filled teeth and surfaces. Overall, more than 63 percent of the children had no dental caries experience of any kind—no d_1, d_{2-3}, or filled surfaces. In the more traditional sense of caries experience as determined by $d_{2-3}f$, 73 percent of the children were caries free. The mean number of teeth and the mean number of surfaces with d_1 lesions were nearly double the number of teeth/surfaces with untreated d_{2-3} lesions, although the number of d_1 lesions was less than the mean number of $d_{2-3}f$ teeth or surfaces.

Figure 9 depicts the prevalence of d_1 lesions and $d_{2-3}f$ decay experience by individual primary tooth. Both types of decay experience were most common on the second molars, with the mandibular central incisors unaffected by either d_1 or d_{2-3} decay experience. In addition, 56 percent of untreated d_{2-3} decay was located in the pits and fissures, while 58 percent of d_1 decay was located on smooth surfaces.

Table 3 presents results of chi-square analyses comparing those with any d_1 lesions to those with any $d_{2-3}f$ decay experience. Those with any d_1 lesions were more likely to also have $d_{2-3}f$ decay experience than were those with no d_1 lesions.

FIGURE 9
Prevalence of d_1 and d_{2-3} Decay Experience by Tooth (%)

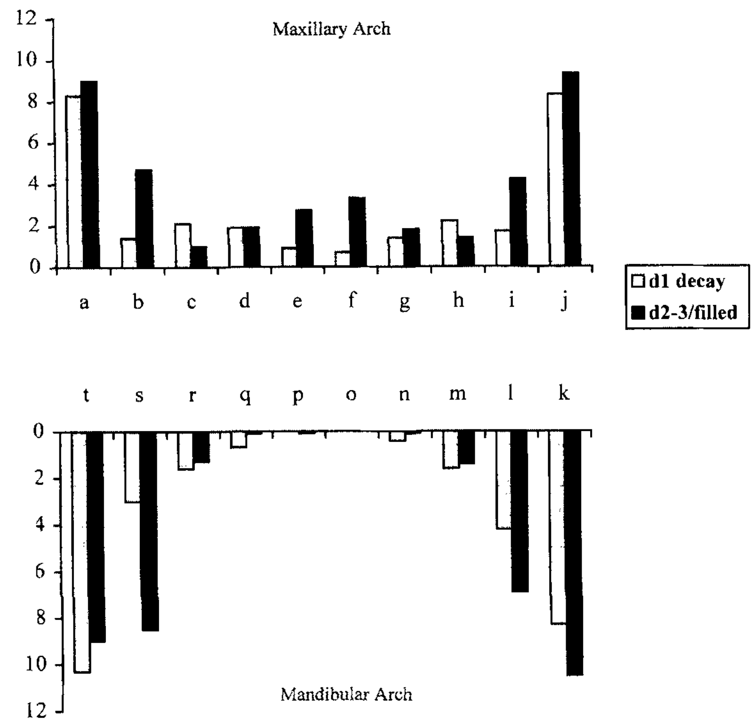


TABLE 3
Relationships Among Individuals by d_1 vs $d_{2-3}f$ Decay Experience

	Any d_{2-3} or f Surfaces		
Any d_1 surfaces	No	Yes	Total
No	441	88	529
Yes	67	102	169
Total	508	190	698

Chi-square=123.6; P<.001.

Discussion

Because of the limited number of studies assessing dental caries prevalence in the primary dentition, particularly studies that included noncavitated lesions, making comparisons to other studies is difficult. In their study of Scottish preschool children, Pitts et al. (11) found that 47 percent of 4-year-olds had d_1 caries, a considerably greater percentage than in the present study (22 percent). Similarly, while Scottish children had the greatest caries experience on the second molars, as in the present study, the prevalence of caries on the second molars was much higher than found for Iowa children. A study using different gradients of caries diagnostic criteria in 5-year-olds in Norway also reported much greater caries experience than in the present study; however, the Norwegian study utilized radiographs and somewhat different criteria, so that comparisons must be made with caution (19).

The $d_{2-3}f$ criteria are similar to criteria traditionally used in epidemiologic studies such as the Third National Health and Nutrition Examination Survey (NHANES III), so that some comparisons—limited to $d_{2-3}f$—are possible. The present study found that 73 percent of 4–5-year-olds had no d_{2-3} or filled surfaces (i.e., were caries-free), which is generally consistent with NHANES III findings of 83 percent caries-free 2–4-year-olds and 50 percent caries-free 5–9 year-olds (20). The present study found a mean number of $d_{2-3}f$ surfaces of 1.4, which closely matches the findings for 2–4-year-olds in the NHANES III study of 1.2, although the mean dfs for 5–9-year-olds was much higher in NHANES III, 4.1 surfaces. In addition, NHANES III reported a greater proportion of dfs that was "decayed" than in the present study. It should be noted that in contrast to the NHANES III sample, children in the present study were part of a largely self-selected cohort participating in a longitudinal study, and were not representative of any defined population.

The criteria developed for this study were adapted from previous work, except that cavitated enamel and dentin lesions were not differentiated. This was done because the investigators did not feel they could reliably agree on such differentiation, particularly given the difficulties in assessing 4–5-year-old children. This adaptation appears to have been prudent, as interexaminer reliability for cavitated lesions (d_{2-3}) was very good, with kappa values exceeding .80. On the other hand, while percent agreement for d_1 lesions was high and reached 100 percent at the person level, kappa values were low (.24) at the tooth level. This relatively low value was likely due to the more exacting and complex criteria for d_1 lesions, as well as the examiners being less familiar with these criteria than with the more traditional ones. Unfortunately, previous studies did not report specific interexaminer kappa values for d_1 lesions in the primary dentition (11,19). However, one study reported that interexaminer kappa values for permanent dentition D1 lesions were consistently lower than for D3 lesions, with kappa values for D3 lesions of .64 and .62, while for D1, kappa values were .53 and .61 (21).

Despite these concerns with d_1 reliability, with enough training and calibration of examiners, the d_1d_{2-3} criteria have promise for future studies in that these more sensitive criteria offer several advantages described earlier, including a better means of predicting future caries. To that end, future examinations among cohort children from the present study will be conducted when children reach 8 1/2 to 9 years of age, and at that time the current d_1 or d_{2-3} lesions will be tracked longitudinally for changes in caries diagnoses at individual tooth surface levels.

In conclusion, dental caries prevalence in the primary dentition was low among children in the study, and noncavitated lesions were more common than cavitated ones. Despite some concern with reliability of diagnosing $d_1$lesions, it appears that the d_1d_{2-3} criteria are informative and useful in assessing the primary dentition.

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