Clinical Study
Measuring Dental Caries in the Mixed Dentition by ICDAS

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Abstract
Caries has traditionally been assessed with WHO criteria including only obvious caries lesions. ICDAS has been developed to detect also the enamel caries lesions. This study aims to study caries and the associations of the number of caries lesions between the permanent and primary molars with ICDAS in the mixed dentition of the first and second grade primary school children. The clinical examinations of 485 children were conducted by four examiners with high reproducibility (inter- and intraexaminer kappas >0.9). The mean number of caries lesions—especially dentine caries—seemed to be higher in the second primary molars than in the first permanent molars. There were significant correlations between the number of lesions on occlusal and lingual surfaces between the primary and permanent molars. Enamel caries lesions, restorations, and caries experience did not increase according to age. Therefore, caries might be increasing in this population. As a conclusion, ICDAS recording seems to give appropriate information from the occurrence of caries lesions and its correlations between the primary and permanent teeth and surfaces.

1. Introduction
Reliable, reproducible, and practical detection and assessment of dental caries lesions as an outcome of dental caries disease has been a challenge for a long time [1, 2]. The lesions can be detected on all surfaces of the primary, permanent, and mixed dentitions. Surface lesions can then be counted according to the type of the teeth (incisors, canines, premolars, and molars) or according to the surfaces (occlusal, proximal, and free smooth surfaces). Mixed dentition stage normally includes the age groups from 6 to 12 years, when the permanent teeth are erupting and the primary teeth exfoliating. The exfoliation is a special problem in the prospective clinical trials, when the tooth and surfaces need to be present in both of the examinations. However, also cross-sectional clinical studies can still give important descriptive information for monitoring the trends and for giving dental health a visibility for policy makers [3]. The mixed dentition is the first stage to study an association of the number of caries lesions between the primary and permanent teeth. Several studies have shown very clear correlations in caries experience between the primary and permanent teeth [4–9].

Traditionally, caries has been measured by DMFT/S index, where only teeth or surfaces with cavitated lesions extending into the dentine have been counted [10, 11]. Over the years, DMFT index has been criticized for several reasons [12]:

(1) diagnosis of caries lesions has been shown to be unreliable,
(2) the reason for extraction for caries is very difficult to confirm at the point of examination,
(3) secondary caries lesions on surfaces with restorations are not counted,
(4) the activity of the lesions is not determined,
(5) enamel caries lesions are not included,
(6) DMF values are not related to the number of teeth/surfaces at risk,
(7) DMF index gives an equal weight to missing teeth, untreated caries, or restored teeth,
(8) DMF index can overestimate caries experience by

(9) DMFT index is of a little use for estimating treatment

(10) DMF index does not include sealants.

One additional problem with DMF index has been the

The skewed distribution of caries experience, which could be

measured by using the significant caries index (SiC) [13]. SiC

measures the mean DMF score among the third of the sub-

jects, who are the most affected by caries. The International

Caries Detection and Assessment System (ICDAS) was de-

veloped to include early enamel caries lesions according to

the stage of their progression as well as to categorize the “ob-

vious,” dentine caries lesions according to their progression

[2, 12, 14, 15]. The validity and reproducibility of ICDAS has

already been tested in several in vitro [16–18] and clinical

studies [19–21]. There are also some large epidemiological

studies conducted using ICDAS [22, 23]. ICDAS is now

the international recommendation for dental health surveys

[24]. There are still only a few studies, where ICDAS has

been used in the prospective study design [25]. This study

was concluded as a baseline for the clinical trial in Southeast

Estonia.

This baseline study aims to find out the distributions

of the caries lesions and their associations between the first

permanent molars and the second primary molars with the

ICDAS criteria among the first and the second grade school-

children with mixed dentition.

2. Subjects and Methods

This study was conducted at the University of Tartu Dental

Clinic in January 2008. The samples of the first and second

grade pupils in Southeast Estonia were included in this study.

The schools were selected from all primary schools of this

region. The sample \( N = 522 \) was drawn according to the

geographical area (county) and the size of the school (small,

average, and large). The written informed consent forms

were signed by the parent/caretaker. Altogether 485 children

(93%) participated in the clinical examinations, 45.6% being

boys and 54.4% girls. Very few parents/caretakers did not

want their child to participate, but some children were absent

on the day of the clinical examination. The mean age was

7.8 years (SD = 0.35) in the first grade and 8.8 years (0.38) in

the second grade (Table 1).

All the examinations were conducted in standard dental

chairs of the Department of Stomatology of the University

of Tartu. The clinical examinations were conducted by four

trained and calibrated examiners. Before the study, a 90-

minute e-learning program of ICDAS system was sent to all

examiners. The examiners were senior academic staff with

a long clinical experience. After the e-learning training, cali-

bration sessions were arranged in the examination site dur-

ing two days before starting the study. After a joint discussion

about the ICDAS criteria, four children were examined by all

four examiners and the caries diagnoses compared with each

examiner and finally verified clinically by reexamining each

child by all examiners together. Another four children were

examined by the similar way. On the second day, altogether

25 children outside the sample were studied twice; by one

examiner (S. Honkala, R. Runnel, J. Oulak) and by the

examiner 1 (E. Honkala) and the differences were discussed.

During the study, the recorders scheduled 10 children to be

examined twice by each examiner and another 10 children by

each examiner and by the examiner 1. All the reexaminations

were done at the same day as the first examinations, because

all the children came to Tartu by a bus from their school.

The inter- and intraexaminer repeatability was high; all the

weighted kappa values being >0.9, as reported earlier [26].

The children were allocated randomly to the examiners.

The children were given a toothbrush and toothpaste and

requested to brush their teeth before the examination. The

clean teeth were then assessed according to the ICDAS crite-

ria [14], first as wet and then after drying with compressed

air. Dental mirror and WHO periodontal probe were used as

visual-tactile aids in assessing the surfaces. Two digit ICDAS

codes were determined for each tooth surface of the mixed

dentition.

The data were installed with Excel software and analyzed

by SPSS (version 17.0) and SAS (version 9.2) programs.

The first digit of the ICDAS code describes the treatment

provided, and the second digit is the actual caries code. The

occlusal surfaces with full or partial sealants were considered

as healthy (ICDAS caries code 0). In the analyses of the

caries indices ICDAS caries codes 1, 2, and 3 were counted

as dentine caries (D1−6) and 4, 5, and 6 as dentine caries (D4−6).

Caries experience (D4−6MFT and D4−6MFS) was calculated as a total

number of teeth/surfaces with dentine caries, or/and treated
caries (FT/FS) and missing teeth/surfaces (MT/MS) because of
caries. The children with D4−6MFS = 0 were determined as free from

obvious decay.

The distributions of the ICDAS codes according to the
tooth surfaces were presented by counting the means of the

prevalence on the right and the left side of the mouth to-
gether. The children, who had their permanent second pre-
molars erupted (6–7%) were excluded, when calculating the

distribution of the different ICDAS codes of the primary
teeth. The association between the first permanent molars

and the second primary molars was analyzed by Spearman

Table 1: Distribution of the children by age, grade, and gender.

| Age | n  | Girls (%) | Boys (%) |
|-----|----|-----------|----------|
| 7   | 166| 35.3      | 33.3     |
| 8   | 253| 51.1      | 53.0     |
| 9   | 66 | 13.6      | 13.7     |
| Total| 485| 100.0     | 100.0    |
| Grade | n  | Girls (%) | Boys (%) |
| I    | 224| 48.4      | 44.3     |
| II   | 261| 51.6      | 55.7     |
| Total| 485| 100.0     | 100.0    |
3. Results

There was a clear tendency that the lower ICDAS caries codes (1–3) were more prevalent in the permanent molars than in the primary molars and the higher ICDAS codes (4–6) more prevalent in the second primary molars than in the permanent molars (Table 2). The most prevalent caries code (>0) was code 2 on the occlusal surfaces of the upper permanent molars (13.6%), on the buccal surfaces of the lower permanent molars (13.6%), and on the occlusal surfaces of the lower permanent molars (13.6%). The highest ICDAS codes (4–6) were clearly most common on the second lower primary molars (3.3%–5.6%).

When analyzing the association of the distributions of ICDAS codes on the different surfaces between the first permanent molars and the second primary molars, the strongest correlations were on the lingual surfaces of the maxillary molars and on the buccal surfaces of mandibular molars (Table 3). The correlations were also significant or highly significant on the occlusal surfaces of the maxillary and mandibular molars and on the lingual surfaces of the mandibular molars.

The most prevalent ICDAS codes (>0) per child were the codes 2 and 5 (Figure 1), and the least prevalent code was 4. The highest mean number of surfaces per child with each individual ICDAS codes (>0) was the codes 2 (2.67) and 6 (1.96), and the lowest code was 4 (Figure 2).

All the mean caries indexes was not statistically different in the different age groups or grades (Table 4). However, the mean number of dentine caries lesions (d/D4−6T, d/D4−6S) seemed to decrease according to increasing age and was lower among the second grade children than among the first graders.

There were also statistically significant differences between the schools (Table 5) in the mean numbers of enamel (d/D1−3T, d/D1−3S) and dentine caries lesions (d/D4−6T, d/D4−6S) and restorations (f/FT, f/FS), but not in the mean numbers of caries experience teeth (dmft/DMFT) or surfaces (dmfs/DMFS).

4. Discussion

This study was conducted among the first and second grade children in 10 primary schools of Southeast Estonia, where only a few epidemiological studies have been conducted. All earlier studies from Estonia have used WHO criteria in detecting caries [27–29] and this is the first study in Estonia to use ICDAS method. ICDAS is currently a recommended...
Table 3: The Spearman correlation coefficients ($r$) between the first permanent molars and the second primary molars according to the surfaces.

| Teeth no. | Surfaces | $r$  | $P$ value | Teeth no. | $r$  | $P$ value |
|-----------|----------|------|-----------|-----------|------|-----------|
| 16/55     | M        | 0.00 | 0.936     | 26/65     | 0.00 | 1.000     |
|           | O        | 0.15 | 0.001     |           | 0.13 | 0.006     |
|           | D        | 0.00 | 1.000     |           | 0.09 | 0.040     |
|           | B        | 0.08 | 0.076     | 46/75     | 0.25 | <0.0001   |
|           | L        | 0.19 | <0.0001   | 46/75     | 0.16 | 0.001     |

Table 4: The caries indices by age and grade.

| Age | $d/D_1-T$ | $d/D_1-S$ | $d/D_4-T$ | $d/D_4-S$ | $f/FT$ | $f/FS$ | dmft/DMFT | Dmfs/DMFS |
|-----|-----------|-----------|-----------|-----------|--------|--------|-----------|-----------|
| 7   | 3.7       | 4.6       | 2.2       | 4.0       | 3.9    | 6.4    | 5.9       | 12.0      |
| 8   | 3.8       | 5.1       | 1.8       | 3.3       | 4.2    | 6.7    | 6.0       | 11.9      |
| 9   | 4.3       | 5.7       | 1.5       | 2.2       | 4.3    | 7.2    | 5.7       | 11.4      |
| Mean| 3.8       | 5.0       | 1.9       | 3.4       | 4.1    | 6.7    | 5.9       | 11.9      |
| $P^*$| 0.411     | 0.339     | 0.281     | 0.220     | 0.785  | 0.657  | 0.653     | 0.685     |
| Grade|          |           |           |           |        |        |           |           |
| I    | 3.7       | 4.7       | 2.3       | 4.1       | 3.9    | 6.3    | 6.0       | 12.3      |
| II   | 3.9       | 5.3       | 1.6       | 2.7       | 4.3    | 7.0    | 5.9       | 11.5      |
| Mean | 3.8       | 5.0       | 1.9       | 3.4       | 4.1    | 6.7    | 5.9       | 11.9      |
| $P^*$| 0.565     | 0.374     | 0.053     | 0.101     | 0.150  | 0.112  | 0.403     | 0.304     |

* Kruskal-Wallis test.

method globally to assess caries in dental studies [24]. The enamel caries lesions can still be healed by demineralization process, but more prospective studies are needed to determine how many lesions will remineralize and how many from the unhealed lesions do or do not progress. ICDAS is especially valuable method for detecting the enamel caries lesions for planning the individual remineralization therapy or for monitoring the caries pattern at the population level.

This study confirmed the high caries level in this region. The total caries experience indicators are normally higher in the mixed dentition, because the primary teeth have been exposed longer for the risk factors of dental caries, for example, frequent sugar snacks, drinks, and sweets. This longer exposure time also explains why the primary molars had higher mean number of dentin caries lesions than the permanent molars. The second primary molars have been shown to be more affected than the first primary molars [8]. Therefore, they were compared with the ICDAS codes of the first permanent molars in this study. The higher number of enamel caries lesions in the permanent molars can be explained with the high caries risk period soon after the eruption of the teeth. The proximal surfaces of the second primary molars were more affected than the first primary molars [8].

High number of caries on the primary molars could be expected to predict caries in the permanent molars. However, in this cross-sectional study, only the associations could be studied. The association of the number of caries lesions between the first permanent molars and the second primary molars was analyzed by Spearman correlation coefficient. Correlation was statistically significant on the occlusal and lingual surfaces on all quadrants and on the lingual surfaces of all quadrants, except between the teeth 16 and 55. The correlation coefficients were not high, but this obviously follows from the lower prevalence of the caries lesions in the first permanent molars, which have not been exposed as long as the second primary molars. The proximal surfaces of the first permanent molars did not have caries lesions at this age. However, for some reason, the correlation was significant on the distal surfaces of the teeth 46 and 75.

Some of the lesions have obviously already been remineralized.

There were no statistical differences in the mean number of dentine caries lesions according to the age. The older children could have been expected to have higher caries experience than the younger ones. However, the older children and the children in the second grade had less dentine caries than the younger ones and the children in the first grade. This could be a warning sign of the rapidly changing diet. Estonia has faced quick changes, when it became independent second
time and a member of the European Union in 2004. On average, 3.9–4.3 teeth/child had been restored in all age groups and 5.7–6.0 teeth/child had caries experience. These can be considered very high caries indicators. Similarly, high caries levels have been reported from all the Baltic countries, Estonia [27, 28], Latvia [30], and Lithuania [30, 31].

All the caries indicators (except caries experience) seemed to differ significantly between the schools. One school, Elva, had the highest mean caries experience and highest mean number of untreated obvious carious teeth and surfaces. However, the differences in caries experience were not statistically different, which might be explained by the equal availability of the restorative treatment. The high number of restorations in two schools (Melliste and Rõngu) might reflect overtreatment.

The distribution of the ICDAS codes is difficult to explain. The code 2 (enamel caries detected on a wet tooth surface) might be easier to detect than the code 1 (enamel caries visible only when tooth surface is dry) and code 3 (minor cavitation on enamel only). This has been confirmed also in the other ICDAS studies [21]. It has been shown earlier that the ICDAS method requires more time for assessment than the WHO method [19], but the difference is quite small because by both methods every surface needs to be assessed.

It can be concluded that the ICDAS method gives much more relevant information about caries process than WHO method, when the enamel caries lesions can consistently be detected. The distribution of the ICDAS codes correlated between the primary and permanent molars of the mixed dentition.

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References

[1] A. I. Ismail, “Visual and visuo-tactile detection of dental caries,” Journal of Dental Research, vol. 83, pp. C56–C66, 2004.

[2] N. Pitts, “ICDAS”—an international system for caries detection and assessment being developed to facilitate caries epidemiology, research and appropriate clinical management, Community Dental Health, vol. 21, no. 3, pp. 193–198, 2004.

[3] B. A. Burt, “How useful are cross-sectional data from surveys of dental caries?” Community Dentistry and Oral Epidemiology, vol. 25, no. 1, pp. 36–41, 1997.

[4] A. ter Pelkwijk, W. H. van Palenstein Helderman, and J. W. van Dijk, “Caries experience in the deciduous dentition as predictor for caries in the permanent dentition,” Caries Research, vol. 24, no. 1, pp. 65–71, 1990.

[5] J. M. Broadbent, W. M. Thomson, and S. M. Williams, “Does caries in primary teeth predict enamel defects in permanent teeth? A longitudinal study,” Journal of Dental Research, vol. 84, no. 3, pp. 260–264, 2005.

[6] M. N. Dos Santos, L. K. A. Rodrigues, R. C. R. Peres, R. T. Yokoyama, J. C. C. Gavazzi, and M. B. D. Gavião, “Relationships between occlusal or free-smooth and approximal caries in mixed dentition,” Acta Odontologica Scandinavica, vol. 63, no. 5, pp. 308–313, 2005.

[7] M. S. Skeie, M. Raadal, G. V. Strand, and I. Espelid, “The relationship between caries in the primary dentition at 5 years of age and permanent dentition at 10 years of age—a longitudinal study,” International Journal of Paediatric Dentistry, vol. 16, no. 3, pp. 152–160, 2006.

[8] M. M. Braga, S. Martignon, K. R. Ekstrand, D. N. J. Ricketts, J. C. P. Imparato, and F. M. Mendes, “Parameters associated with active caries lesions assessed by two different visual scoring systems on occlusal surfaces of primary molars—a multilevel approach,” Community Dentistry and Oral Epidemiology, vol. 38, no. 6, pp. 549–558, 2010.

[9] J. C. Noronha, M. L. Massara, B. Q. Souki, and A. P. Nogueira, “First permanent molar: first indicator of dental caries activity in initial mixed dentition,” Brazilian Dental Journal, vol. 10, no. 2, pp. 99–104, 1999.

[10] M. Klein and C. E. Palmer, “Studies on dental caries. V. Familial resemblance in the caries experience of siblings,” Public Health Report, vol. 53, pp. 1353–1364, 1938.

[11] World Health Organization, Oral Health Surveys—Basic Methods, WHO, Geneva, Switzerland, 4th edition, 1997.

[12] N. Pitts, “The impact of diagnostic criteria on estimates of prevalence, extend and severity of dental caries,” in Dental Caries. The Disease and Its Clinical Management, O. Fejerskov and E. Kidd, Eds., Blackwell Munksgaard, Singapore, 2008.
[13] D. Bratthall, “Introducing the Significant Caries Index together with a proposal for a new global oral health goal for 12-year-olds,” International Dental Journal, vol. 50, no. 5, pp. 378–384, 2000.

[14] International Caries Detection and Assessment System Coordinating Committee, “Criteria Manual. International Caries Detection and Assessment System (ICDAS II) Workshop,” Baltimore, Md, USA, March 2005.

[15] N. B. Pitts, “Detection, assessment, diagnosis and monitoring of caries,” in Monographs in Oral Science, N. B. Pitts, Ed., vol. 21, p. 222, Karger, Basel, Switzerland, 2009.

[16] A. Jablonski-Momeni, V. Stachniss, D. N. Ricketts, M. Heinzel-Gutenbrunner, and K. Pieper, “Reproducibility and accuracy of the ICDAS-II for detection of occlusal caries in vitro,” Caries Research, vol. 42, no. 2, pp. 79–87, 2008.

[17] M. B. Diniz, J. A. Rodrigues, I. Hug, R. De Cássia Loiola Cordeiro, and A. Lussi, “Reproducibility and accuracy of the ICDAS-II for occlusal caries detection,” Community Dentistry and Oral Epidemiology, vol. 37, no. 5, pp. 399–404, 2009.

[18] L. Shoaiib, C. Deery, D. N. J. Ricketts, and Z. J. Nugent, “Validity and reproducibility of ICDAS II in primary teeth,” Caries Research, vol. 43, no. 6, pp. 442–448, 2009.

[19] M. M. Braga, L. B. Oliveira, G. A. V. C. Bonini, M. Böecker, and F. M. Mendes, “Feasibility of the international caries detection and assessment system (icdas-ii) in epidemiological surveys and comparability with standard world health organization criteria,” Caries Research, vol. 43, no. 4, pp. 245–249, 2009.

[20] P. Mitropoulos, C. Rahiotis, H. Stamatakis, and A. Kakaboura, “Diagnostic performance of the visual caries classification system ICDAS II versus radiography and micro-computed tomography for proximal caries detection: an in vitro study,” Journal of Dentistry, vol. 38, no. 11, pp. 859–867, 2010.

[21] M. M. Mendes, M. M. Braga, L. B. Oliveira, J. L. F. Antunes, T. M. Ardeghni, and M. Böecker, “Discriminant validity of the International Caries Detection and Assessment System (ICDAS) and comparability with World Health Organization criteria in a cross-sectional study,” Community Dentistry and Oral Epidemiology, vol. 38, no. 5, pp. 398–407, 2010.

[22] A. G. Schulte, A. Momeni, and K. Pieper, “Caries prevalence in 12-year-old children from Germany. Results of the 2004 national survey,” Community Dental Health, vol. 23, no. 4, pp. 197–202, 2006.

[23] H. Agustsdottir, H. Gudmundsdottir, H. Eggertsson et al., “Caries prevalence of permanent teeth: a national survey of children in Iceland using ICDAS,” Community Dentistry and Oral Epidemiology, vol. 38, no. 4, pp. 299–309, 2010.

[24] EGOHID II, Health Surveillance in Europe, Oral Health Interviews and Clinical Surveys: Guidelines, European Global Oral Health Indicators Development Programme, Lyon University Press, Lyon, France, 2008.

[25] A. I. Ismail, S. Lim, and W. Sohn, “A transition scoring system of caries increment with adjustment of reversals in longitudinal study; evaluation using primary tooth surface data,” Community Dentistry and Oral Epidemiology, vol. 39, no. 1, pp. 61–68, 2011.

[26] R. Runnel, E. Honkala, S. Honkala et al., “Caries experience in permanent dentition among the first and the second grade schoolchildren in south-eastern Estonia,” submitted to Acta Odontologica Scandinavica.

[27] J. Wolf, J. S. Peltola, T. Seiddre et al., “Dental health in 14- to 17-year-old Estonian schoolchildren in Tartu and Tallinn,” Acta Odontologica Scandinavica, vol. 54, no. 4, pp. 242–246, 1996.