



CLINICAL DIGITAL INTRAORAL SCANNING FOR CARIES DETECTION IN PRIMARY DENTITION

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ABSTRACT

Aim
The study aimed to evaluate the efficacy of intraoral scanners (IOS) in detecting carious lesions in primary dentition compared with conventional direct visual examination using the International Caries Detection and Assessment System (ICDAS).

Design
A cross-sectional clinical study was conducted involving 36 children aged 3–12 years (20 males, 16 females) with varying caries severity. An average of 13 untreated primary teeth per subject was assessed across occlusal, buccal, and lingual surfaces using both direct visual inspection and indirect digital scanning, yielding a total of 1,478 tooth surface observations. Agreement between the two diagnostic methods was assessed using percent agreement and Cohen's Kappa statistics, with statistical significance set at $\alpha = 0.05$.

Results
Overall agreement was 89%, with indirect assessments tending to under-score compared with direct examination. Moderate to substantial agreement was observed ($\kappa = 0.64$; weighted $\kappa = 0.74$; $p = 0.041$). When scores were dichotomized as caries versus no caries, agreement increased with higher ICDAS thresholds (92–100%), with sensitivity ranging from 70–87% and specificity from 96–100%.

Conclusion
IOS may serve as a reliable adjunctive tool for caries detection across all stages, enhancing diagnosis and preventive decision-making in pediatric dentistry.

Keywords: Dental Caries; Primary dentition; Intraoral scanner; Digital dentistry; Diagnostic accuracy; ICDAS.

MATERIALS & METHODS

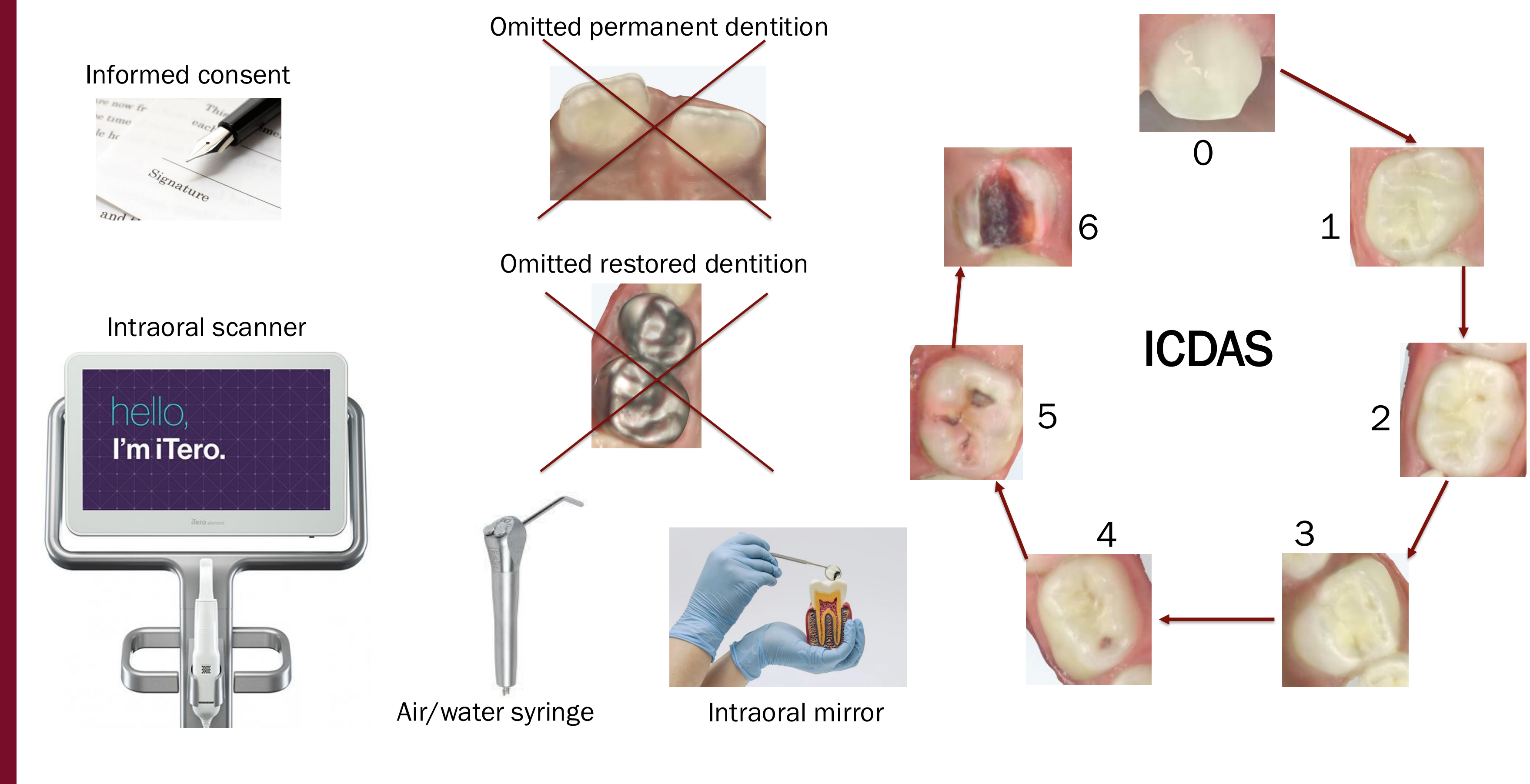
2.1 Study Design, Data Source, and Participants
This was a cross-sectional clinical study conducted at the Indiana University School of Dentistry's Pediatric Dentistry Clinic and at the Riley Outpatient Center's Pediatric Dental Clinic in Indianapolis, Indiana. Indiana University Institutional Review Board (IRB #24373) was obtained and registration was registered at ClinicalTrials.gov (Identifier: NCT06829550). Written informed consent was obtained from parents/legal guardians. Patients between 3-12 years of age at the above-mentioned clinics were eligible for inclusion. As an inclusion criterion, at least one fully erupted primary tooth had to be present and untreated at the time of the intraoral scanning. Any restored, sealed, or stainless steel crowned primary teeth were excluded, along with unerupted teeth. In total, the study population included 36 subjects, with the breakdown being 20 males and 16 females. An average of ~13 primary teeth per child met inclusion criteria. Overall, 1,478 tooth surfaces (occlusal, buccal, and lingual) were assessed.

2.2. Direct assessment
International Caries Detection and Assessment System (ICDAS) assessments were completed under standardized clinical conditions. Prior to examination, the teeth were cleaned with prophyl paste and dried with compressed air. Each buccal, occlusal, and lingual surface was evaluated using a dental mirror, standard lighting and moisture control. The use of a sharp explorer was avoided due to the risk of causing iatrogenic damage. ICDAS scores were recorded at the time of clinical assessment.

2.3 Indirect assessment using IOS
Indirect assessments were performed using IOS (iTero Element 5D; Align Technology, San Jose, CA, USA). The scanners were calibrated according to the manufacturer's instructions before each scanning session. The same standardized lighting and moisture control techniques were used. Intraoral scans were obtained during the same visit as the direct assessment. Evaluation of three-dimensional digital images was conducted at a later time by a trained examiner to minimize recall bias. An alternating examiner design was implemented to further reduce examiner-related bias in scoring individual tooth surfaces.

2.4 Outcome Measures and Statistical Analysis
Agreement between direct (ICDAS clinical assessment) and indirect (digital image assessment) scores was evaluated using cross-tabulations, percentage agreement and Cohen's Kappa and weighted Kappa statistics. Differences in score distributions between assessments were verified using the Cochran-Mantel-Haenszel chi-square test. For diagnostic performance analysis, ICDAS scores were dichotomized at increasing diagnostic thresholds (e.g., ≥ 1 , ≥ 2 , ≥ 3). Sensitivity and specificity were calculated at each threshold, assuming the direct assessment as the reference standard. The significance level was set at $\alpha = 0.05$.

PROCESS



RESULTS

3.1 Agreement between direct and indirect ICDAS scores
Cross-tabulation of ICDAS scores obtained from direct & indirect assessments are shown in Table 2. Overall agreement of 89% was observed between the two assessments. Inter-method reliability was moderate to substantial (Cohen's $\kappa = 0.64$; weighted $\kappa = 0.74$). The Cochran–Mantel–Haenszel chi-square test demonstrated a statistically significant difference in the distribution of ICDAS scores between direct and indirect assessments ($p < 0.05$). Indirect scoring using the IOS tended to assign lower ICDAS scores compared with direct assessment, with a higher proportion of surfaces classified in lower ICDAS categories relative to direct assessment (Table 2).

3.2 Dichotomized diagnostic performance
When ICDAS scores were dichotomized into “sound” and “caries” categories at increasing diagnostic thresholds, agreements between assessments improved. Percentage agreement increased as higher ICDAS cutoffs were applied, ranging from 92% to 100% depending on the threshold used (Table 3). Sensitivity and specificity values calculated at each dichotomized threshold are presented in Table 4. Sensitivity ranged from 70% to 87%, increasing at higher ICDAS cutoffs, while specificity ranged from 96% to 100% and remained consistently high across thresholds. None of the kappa coefficients reached or exceeded the predefined hypothesis value of 0.80. The 95% confidence intervals for all kappa statistics extended below 0.80, with upper confidence limits below 0.80, indicating that agreement did not meet the hypothesized level of substantial agreement.

TABLES AND FIGURES

IOS–based ICDAS assessment in primary teeth demonstrated high overall agreement with direct assessment but did not achieve the predefined threshold for substantial reliability. Diagnostic performance showed high specificity and moderate sensitivity, with reduced reliability for early, non-cavitated lesions. Agreement improved when lesions were categorized as sound or carious. IOS may therefore serve as a complementary adjunct rather than a replacement for conventional visual examination in pediatric caries assessment.

Table 1. Diagnostic indices and scoring criteria used in the study

Condition	Index	Code	Description
Dental Caries	ICDAS	0	No visible lesion
		1	Initial caries, first visual change in enamel
		2	Distinct visual change in enamel
		3	Localized enamel breakdown, no visible dentine
		4	Underlying dark shadow from dentine
		5	Distinct cavity with visible dentine
		6	Extensive cavity with visible dentine

* ICDAS: International Caries Detection and Assessment System

Table 2. Cross-tabulation of ICDAS scores from direct and indirect assessments (n = 1,484 tooth surfaces).

Indirect	Direct							Total
	0	1	2	3	4	5	6	
0	1177 (80%) [96%]	44 (3%) [44%]	29 (2%) [39%]	2 (1%) [5%]	3 (1%) [10%]	0 (0%) [0%]	0 (0%) [0%]	1255 (85%)
1	22 (1%) [2%]	47 (3%) [47%]	6 (1%) [39%]	1 (1%) [2%]	1 (1%) [3%]	1 (1%) [10%]	0 (0%) [0%]	78 (5%)
2	11 (1%) [1%]	6 (1%) [6%]	36 (2%) [49%]	2 (1%) [5%]	0 (0%) [0%]	0 (0%) [0%]	0 (0%) [0%]	56 (4%)
3	10 (1%) [1%]	3 (1%) [3%]	3 (1%) [4%]	30 (2%) [33%]	3 (1%) [10%]	1 (1%) [10%]	0 (0%) [0%]	50 (3%)
4	0 (0%) [0%]	0 (0%) [0%]	0 (0%) [0%]	6 (1%) [15%]	22 (1%) [23%]	1 (1%) [10%]	0 (0%) [0%]	29 (2%)
5	1 (1%) [1%]	0 (0%) [0%]	0 (0%) [0%]	0 (0%) [0%]	0 (0%) [0%]	7 (1%) [70%]	0 (0%) [0%]	8 (1%)
6	0 (0%) [0%]	0 (0%) [0%]	0 (0%) [0%]	0 (0%) [0%]	0 (0%) [0%]	0 (0%) [0%]	2 (1%) [100%]	2 (1%)
Total	1221 (83%)	100 (7%)	74 (5%)	41 (3%)	30 (2%)	10 (1%)	2 (1%)	1478

Table 3. Agreement between direct and indirect ICDAS index scores by severity category.

	% Agree	% Under for Indirect relative to Direct	% Over for Indirect relative to Direct	Kappa (95% CI)	Weighted Kappa (95% CI)	p-value
Overall	89	6	4	0.64 (0.59-0.68)	0.74 (0.69-0.78)	0.041
Direct ICDAS=0	96	---	4			
Direct ICDAS=1	47	44	9			
Direct ICDAS=2	49	47	4			
Direct ICDAS=3	73	12	15			
Direct ICDAS=4	73	27	0			
Direct ICDAS=5	70	30	0			
Direct ICDAS=6	100	0	---			

Table 4. Diagnostic performance of indirect assessment at different ICDAS thresholds.

Caries Cutoff	% Agree	Specificity	Sensitivity	Kappa (95% CI)	p-value
ICDAS ≥ 1	92	96	70	0.70 (0.65-0.75)	0.002
ICDAS ≥ 2	95	98	73	0.73 (0.67-0.79)	0.163
ICDAS ≥ 3	98	99	87	0.83 (0.76-0.89)	0.257
ICDAS ≥ 4	99	100	76	0.78 (0.68-0.88)	0.467
ICDAS ≥ 5	100	100	75	0.82 (0.64-0.99)	0.317

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BRING ON TOMORROW

