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ORIGINAL RESEARCH

Assessment of early childhood caries using ICDAS and Snyder caries activity test among preschool children: a cross-sectional study

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Abstract

The aim of the present study was to elucidate the correlation between the International Caries Detection and Assessment System (ICDAS) and the Snyder caries activity test (SCAT) for the assessment of early dental caries in preschool children. Dental health status of 153 children aged 3–5 years was evaluated by oral examination. The ICDAS stage (enamel opacity stage to cavitated dentine caries stage (stages 1–6)) was assigned based on the evaluation of each tooth surface by a trained dentist based on the number of decayed (d) and filled teeth (ft). In this study, scores of d3–6t (t, teeth), d3–6s (s, tooth surface), d3–6ft and d3–6fs were the cut-off points for enamel caries, set to ICDAS code 3 (d3). SCAT score was assigned based on the acid production level of lactic acid bacteria in plaque (scores: 1–4). Linear correlation analysis was used to determine the correlation between ICDAS and SCAT scores. The proportion of children for each of the dental caries status were as follows: d0, 46.4%; d1–2, 28.1%; d3–4, 9.8%; d5–6, 15.7%. Regarding SCAT scores, 30%, 30.1%, 26.8% and 12.4% children had no, mild, moderate and severe caries activity, respectively. The d3–6t, d3–6s, d3–6ft and d3–6fs indices increased with age and were 0.56, 0.82, 2.03 and 5.05, respectively. Children with a higher SCAT score had higher ICDAS scores ($p < 0.05$). Our findings suggest that a combination of ICDAS and SCAT scores is beneficial for diagnosing caries progression and highly active caries. Early childhood caries should be managed early to prevent the enamel opacity stage to progress to cavitation.

Keywords

Dental caries; ICDAS; Snyder caries activity test; Child; Oral health; Prevention

1. Introduction

The World Health Organization (WHO) has ranked dental caries as a chronic non-communicable disease that requires worldwide attention for prevention and treatment [1]. Early childhood caries in primary teeth can begin early in life, progress rapidly in those at high risk, and maybe left untreated [2, 3]. Its consequences can affect the child and family's immediate and long-term quality of life and have significant social and economic consequences [4]. The primary teeth have masticatory, phonetic, and cosmetic functions; they enable the smooth and timely eruption of permanent teeth and facilitate normal development of the jaw bones [5–7]. Untreated caries in the primary teeth can lead to early exfoliation before permanent teeth eruption [8]. Consequently, it is necessary to detect and control primary dental caries from the time of eruption of primary teeth, to ensure their proper functioning, until permanent teeth eruption.

The incidence of primary early childhood caries among 5-year old children in Korea was 67.7% in 2006 [9], 61.5% in 2010 [10], 62.2% in 2012 [11], 64.4% in 2015 [12], and 68.5% in 2018 [13], and this incidence of dental caries in children continues to increase. In the same set of surveys, in 5-year-old children, the number of decayed and filled teeth in the primary dentition was 2.85 in 2006 [9], 2.99 in 2010 [10], 2.80 in 2012 [11], 3.07 in 2015 [12], and 3.43 in 2018 [13], indicating that there has been no improvement in children's oral health over the last decade.

Early detection and treatment of dental caries is crucial. International Caries Detection and Assessment System (ICDAS) criteria were developed to standardize the visual detection of carious lesions based on their severity and to provide the correct associated treatment [14, 15]. The ICDAS criteria evaluate the non-cavitated and cavitated stages of carious lesions in more detail than the traditional DMFT index (sum of the number of Decayed, Missing due to caries, and Filled Teeth in the permanent teeth). Many studies have been conducted to prevent dental caries by early detection using ICDAS [16, 17]. These studies have emphasized the significance of early caries detection before the initiation of cavitation, and therefore, ICDAS has garnered increasing attention for dental caries prevention in children.

Generally, caries formation is associated with the imbalance of acid production by the biofilms on the tooth surface [18]. The acid production resulting from carbohydrate metabolism by bacteria and the subsequent decrease in environmental pH are responsible for the demineralization of tooth surfaces [19]. To confirm these changes in the oral environment and to assess caries risk, various tests can be performed. Recent studies on the diagnosis and prediction of oral diseases using saliva or oral bacteria are attracting attention for early disease detection [20, 21]. The oral acid production index is an important method to predict the occurrence of dental caries. Low salivary pH, evaluated independently of buffer capacity, was also linked to caries experience [22, 23]. The modified Snyder's caries activity test (SCAT), which colorimetrically evaluates the acid-producing ability of bacteria in dental plaque and oral saliva, is a simple and accurate method of obtaining results from among the plethora of available dental caries activity tests [24, 25]. In this context, many studies use acidity of saliva as one of the caries risk indices [26, 27]. A clinician can easily check the patient's oral acidity levels to confirm the risk of dental caries, *i.e.*, the SCAT, and can perform the ICDAS chairside. By examining the relationship between these two indices, the relationship between dental caries and the present oral condition may be inferred. Particularly, it is possible to confirm the acidity levels of the oral cavity of the children, reflected by the dental carries, according to the ICADS system. Consequently, we postulated that a study of the relationship between these two indicators is needed. Few studies have reported SCAT results for early childhood caries [28, 29]. Santchez-Perez *et al*. [28] reported that Snyder's test had the strongest association with caries increment. Furthermore, there is a paucity of studies analyzing the association of SCAT with ICDAS to confirm early caries. This study is based on the hypothesis that the ICDAS score of dental caries in children positively correlate with the SCAT score, which represents oral acidity. The aim of the present study was to confirm the correlation between ICDAS and SCAT to evaluate early childhood caries in preschool children.

2. Materials and methods

2.1 Study design

The present cross-sectional study was designed to evaluate primary dental caries of children and to confirm the association between ICDAS and SCAT.

2.2 Setting

The survey was conducted in an empty classroom provided by a kindergarten in July 2018, and all children were instructed to brush their teeth once before the survey, as the survey was conducted after their lunch break. A qualified dentist performed the oral examinations and assigned scores to teeth with enamel caries (decayed teeth (d)) and teeth with fillings (ft) as 1–6 (stage of enamel demineralization to the cavity-forming dentin caries stage) according to the ICDAS for each tooth surface of the primary teeth. ICDAS scoring criteria are presented in Table 1 [14, 28]. The oral examinations were performed in the classroom, with children sitting facing a window, and a portable blue-white color spectrum examination light was used. The diagnostic criteria were established as per the ICDAS protocol. Examinations were performed using following disposable instruments: plane mirrors, sharp explorers and ball-ended Community Periodontal Index probes. Radiographs were not used for diagnosis. The examiner utilized a photograph that could visually confirm the degree of dental caries according to the ICDAS criteria [14], which was used as a reference during oral examinations and for diagnosis.

2.3 Participants and study size

The sample size calculation for this study was based on ANOVA-test for mean differences among four ICDAS groups. The ICDAS mean differences of dmfs in 4–5 years old children was 3.0 [30]. A study with an effect size of 0.3 and a power of 80% will require a total sample of 128 to test the association at 5% levels using one-way analysis of variance (ANOVA) [30]. The power calculation was carried out using G*Power software, version 3.1.9.2. (Franz Faul, Christian-Albrechts-Universität Kiel, Kiel, Germany). Considering the probability of missing data/dropouts of the study participants, 150 people were investigated. In 2018, 153 children, including 75 boys and 78 girls, were enrolled from a kindergarten located in Yangsan-si city in South Korea (Table 1). Information regarding the study and participation was explained to the children and caregivers, and written informed consent was obtained from the caregivers. Children with systemic disease, trauma, or orthodontic treatment were excluded from the study to eliminate factors that could affect the outcome.

2.4 Variables

2.4.1 ICDAS code

ICDAS code was one of main dependent variables. The following were the ICDAS codes and criteria: (i) ICDAS code 0 (denoted as d (decayed tooth) 0), indicated sound teeth; (ii) codes 1 and 2 (d1 and d2), indicated distinct visual changes in enamel due to early caries and enamel degeneration; (iii) code 3 (d3), indicated partial enamel destruction without clinical visual signals of dentinal involvement due to dental caries; (iv) code 4 (d4), indicated underlying dark shadows from dentin; (v) code 5 (d5), indicated cavity formation, with clearly visible dentin; (vi) code 6 (d6), indicated extensive and distinct dentin cavities. The code d0 represented the total number of children with sound teeth. The code d1–2 indicated the total number of children (representing both numbers and %) assigned with ICDAS codes 1 and 2. The code d1–2t indicated the average number of ICDAS code 1 and 2 teeth. Lastly, the code d1–2s indicated the average number of ICDAS code 1 and 2 tooth surfaces. The code d3–6ft indicates the average number of filled teeth with ICDAS codes 3 to 6. The code d3–6fs indicates the average number of filled tooth surfaces with ICDAS codes 3 to 6 [31]. In this study, the cut-off point for enamel caries was set to an ICDAS score 3 [32], *i.e.*, the cut-off point was established as "clinically diagnosed dental caries requiring treatment". According to Laajala *et al*. [32], the cut-off point was judged to be caries which

TABLE 1. Classification of International Caries Detection and Assessment System (ICDAS).

ICDAS code	Status of tooth	Abbreviation
Code 0	No evidence of caries (sound)	d_0
Code 1	First visual change in enamel	d_1
Code 2	Distinct visual change in enamel	d_2
Code 3	Localized enamel breakdown (without clinical visual signs of dentinal involvement)	d_3
Code 4	Underlying dark shadow from dentin	d_4
Code 5	Distinct cavity with visible dentin	d_5
Code 6	Extensive distinct cavity with visible dentin	d_6

d, decayed teeth; d_0, sound; d_1, first visual change in enamel; d_2, distinct enamel opacity; d_3, Localized enamel breakdown caries; d_4, Underlying dark shadow from dentin caries; d_5, Distinct cavity with visible dentin caries; d_6, Extensive distinct cavity with visible dentine caries.

progressed to enamel carious lesions. In this study, teeth with ICDAS code 3 (d3)—partial enamel destruction, were determined as carious teeth; furthermore, caries experience index (d3–6ft index) and caries experience surface index (d3–6fs index) were calculated. In this study, the ICDAS was analyzed by dividing the scores into three or four groups, based on the degree of dental caries progression or on the data presented, respectively. The four ICDAS groups were as follows: sound enamel (d0), enamel opacity (d1–2), cavitated enamel caries (d3–4), and cavitated dentinal caries (d5–6). The three ICDAS groups were as follows: d0, d1–2, and d3–6. Caries were denoted as per ICDAS codes as follows: d_0t, sound teeth; d_{1-2}t, enamel opacity teeth; d_{1-2}s, enamel opacity tooth surfaces; d_{1-6}t, enamel opacity to cavitated dentinal caries of teeth ; d_{1-6}s, stages of enamel opacity to cavitated dentinal caries of tooth surfaces; d_{3-4}t, decayed teeth with uncavitated enamel caries; d_{5-6}t, decayed teeth with cavitated dentine caries; d_{3-6}t, decayed teeth with cavitated and uncavitated enamel caries; d_{3-6}s, decayed tooth surfaces with cavitated and uncavitated enamel caries; d_{3-6}ft, filled teeth with uncavitated and cavitated enamel caries; d_{3-6}fs, filled tooth surfaces with cavitated and uncavitated enamel caries.

2.4.2 SCAT

SCAT was the other main dependent variable. SCAT confirms the activity of acidogenic bacteria in the saliva and measures the acid production level in the oral cavity [33]. SCAT is based on the assumption that the number of acidogenic bacteria increase in a patient's oral cavity as the pH of the oral environment decreases. SCAT medium contains beef extract (3 g/L), dextrose (20 g/L), agar (8 g/L), bromocresol green (0.04 g/L), and 0.1 M Lactic acid adjusted to a pH of 5.5. To evaluate the change in color of the SCAT medium, the pH of the medium was adjusted to 5.5, with the initial color as "cyan blue".

Plaque samples were collected from the buccal surfaces of the maxillary first molars with a sterile cotton swab, immersed in 3-mL vials of modified SCAT media, and incubated at 37 °C for 72 hours; the extent of color change of the media was observed at 24-hour intervals. After incubation, Snyder's agar cultures that contain acid-producing bacteria from the plaque show glucose fermentation with the production of acid, which lowers the pH to 5.5, and this is the level of acidity at which dental caries form. At this pH the green medium turns yellow. A culture exhibiting a yellow colour within 24 to 72 hours is indicator of the host's susceptibility to the formation of dental caries. A culture that does not change colour is suggestive of lower susceptibility. If the color changed from cyan blue to green or yellow after 24 hours, oral condition was considered as highly active caries; color change after 48 hours indicated moderately active caries; color change after 72 hours indicated mildly active caries; and no color change after 72 hours indicated no caries activity [34, 35]. The scores were assigned as follows: 4, high activity; 3, moderate activity; 2, mild activity; and 1, no activity. The colour of the culture medium was compared with the standard colour chart provided by the manufacturer under natural light and the scores ranging from 1 to 4 were evaluated by reference (Fig. 1).

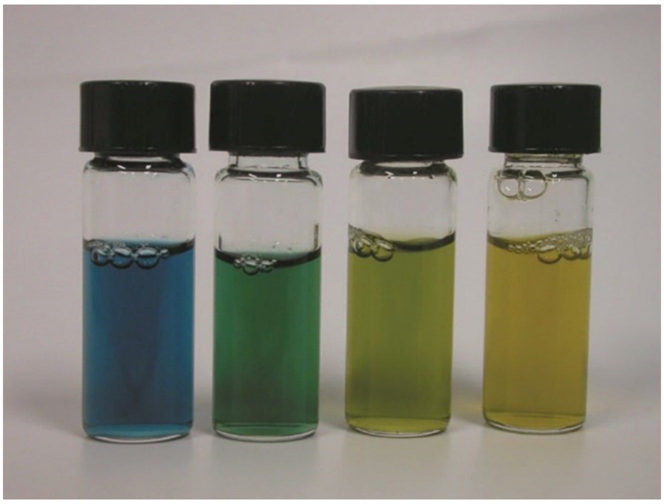

FIGURE 1. Assessment of Snyder's caries activity test. After incubating saliva in a culture medium for 24 to 72 hours, color change of the medium was assessed (blue or green to yellow).

2.5 Statistical method

Using IBM SPSS Statistics 23.0® (IBM Corp. Chicago, IL, USA), the normality of data (ICDAS and SCAT scores) were confirmed with the Shapiro-Wilk test (p = 0.176). To conduct one-way analysis of variance (ANOVA), the test of homogeneity of variances was confirmed with Levene's test ($p = 0.649$). ANOVA was performed to analyze the dental caries experience index (d3–6ft index), the caries experience surface index (d3–6fs index), caries index (d3–6t index), and caries surface index (d3–6s index). Pearson correlation analysis was performed to analyze the correlation between the ICDAS (carious teeth and caries-experienced teeth) and SCAT. One-way analysis of variance (ANOVA) was performed for both the 3 ICDAS groups (d0t, d1–2t, d3–6t) and the 4 ICDAS groups (d0t, d1–2t, d3–4t, d5–6t) to confirm the score difference for SCAT (the capacity of acid production) according to the ICDAS while considering the degree of dental caries progression. The ANOVA test and least significant difference (LSD) *post-hoc* test were conducted to investigate the difference in the 3 groups and 4 groups to confirm the score difference for SCAT. The significance level was determined as a type I error of 0.05.

3. Results

3.1 ICDAS code and SCAT

A total of 153 children, aged 3 years (n = 27), 4 years (n = 68), and 5 years (n = 58), were included in the study (Table 2). The proportion of total children with d0, d1–2, d3–4 and d5–6 scores at 3, 4 and 5 years of age have been presented in Table 3.

TABLE 2. Distribution of participants.

		n	%
Total		153	100.0
Sex			
	Boy	75	49.0
	Girl	78	51.0
Age (yr)			
	3	27	17.6
	4	68	44.4
	5	58	37.9

SCAT evaluation showed 30.7% of children with no caries activity, 30.1% with mild caries activity, 26.8% with moderate caries activity, and 12.4% with high caries activity. Based on SCAT, the percentages of children for no, mild, moderate, and high caries activity at 3, 4 and 5 years of age have been presented in Table 3.

3.2 Comparisons of d3–6ft index, d3–6fs index, d3–6t index, d3–6s index

The distribution of the scores of the dental caries according to age is presented in Table 4. As age increased, d3–6t index, and d3–6s index, d3–6ft index, and d3–6fs index increased. The difference between different ages was statistically significant only for the d3–6fs index ($p < 0.05$), and not for the d3–6t, d3–6ft, and d3–6s indices ($p > 0.05$). It was confirmed that d3–6fs of 5-year-old children was significantly higher compared to that of 3- and 4-year-old children.

3.3 Correlation analysis of carious teeth, caries-experienced teeth, and SCAT scores based on ICDAS standards

The correlation between ICDAS and SCAT scores is presented in Table 5; the d3–6t, d1–6t, d1–6s and d5–6s indices had a positive but low correlation with the SCAT score ($p < 0.05$). In addition, the correlation coefficient of SCAT was low but increased with an increase in scores of d3–6t, d1–6t, d1–6s, and d5–6s ($p < 0.05$). The caries experience (d3–4s) did not show a significant correlation with the SCAT score.

3.4 Caries activity test according to ICDAS

Among the children with d0t, d1–2t, and d3–4t, the children with d3–4t had higher SCAT scores of 2.33 ± 0.98 than those with d0t and d1–2t. Moreover, children with d5–6t had the highest SCAT score of 2.92 ± 0.88 ($p < 0.001$) (Table 6). Comparing the result classified by ICDAS tooth surface index stage into 3 groups (d0t, d1–2t, d3–6t), children with d3–6t had the highest SCAT score of 2.69 ± 0.95 (Table 6). Therefore, it was confirmed that there was a significant difference in SCAT at d3–4t, d3–6t and d5–6t.

4. Discussion

This study confirmed the hypothesis that the ICDAS score of dental caries in children positively correlate with the SCAT score. Dental caries is one of the most common chronic diseases of the oral cavity. If the balance between demineralization and remineralization, which continuously occur on the tooth surface, is disrupted, dental caries form [35]. Early carious lesions, which are not severely demineralized, can be remineralized, if oral hygiene management and appropriate preventive measures are taken [36]. Especially, the incidence of dental caries increases in preschool years. Consequently, prevention of early childhood caries is important in children. As it occurs owing to several interrelated factors, prompt diagnosis and treatment are needed when teeth are demineralized early [36]. The ICDAS classification can be used to investigate the degree of caries over the WHO standard method (DMFT index). The ICDAS classification system is widely used for dental caries examination and allows early detection of carious lesions [37].

The National Oral Health survey of Korea in 2018 showed that the prevalence of deciduous caries was 33.9% [38]. According to the ICDAS classification, the proportion of children with d3–6 was 25.5% in this study, which was lower than those of the National Oral Health survey results in 2018. Unlike this study, which classified dental caries as codes 3–6 per ICDAS criteria, Park *et al.* [39] classified code 0 as sound tooth, codes 1–3 as enamel caries, and codes 4–6 as dentinal caries also according to the ICDAS criteria. There was a difference in the areas judged as dental caries from code 4 onwards. Codes 1–2 represent a stage wherein the degree of demineralization is not severe and remineralization is possible; however, localized enamel breakdown starts from ICDAS code 3, and later, codes 4–6 represent a stage in which dental caries is more likely to progress.

In children's caries activity tests, clinical tests, saliva and

TABLE 3. ICDAS and SCAT of the children according to age.

Categorized	Total		Age (yr)					
			3		4		5	
	n	%	n	%	n	%	n	%
	153	100.0	27	100.0	68	100.0	58	100.0
ICDAS								
d_0	71	46.4	16	59.3	28	41.2	27	46.6
d_{1-2}	43	28.1	7	25.9	21	30.9	15	25.9
d_{3-4}	15	9.8	2	7.4	10	14.7	3	5.2
d_{5-6}	24	15.7	2	7.4	9	13.2	13	22.4
SCAT								
Non-actived	47	30.7	11	40.7	15	22.1	21	36.2
Mild	46	30.1	8	29.6	21	30.9	17	29.3
Moderate	41	26.8	7	25.9	20	29.4	14	24.1
High activity	19	12.4	1	3.7	12	17.6	6	10.3

SCAT, Snyder's caries activity test; d_0, sound; d_{1-2}, enamel opacity; d_{3-4}, uncavitated enamel caries; d_{5-6}, cavitated dentine caries.

TABLE 4. Comparison with d_{3-6}t, d_{3-6}s, d_{3-6}ft and d_{3-6}fs indices by age.

ICDAS level	Total	Age		
		3 (n = 27)	4 (n = 68)	5 (n = 58)
d_{3-6}t	0.56 ± 1.48	0.59 ± 1.16	0.74 ± 1.49	0.64 ± 1.35
d_{3-6}s	0.82 ± 1.88	0.81 ± 2.22	0.69 ± 1.47	0.98 ± 2.14
d_{3-6}ft	2.03 ± 3.01	1.52 ± 2.79	1.68 ± 2.69	2.69 ± 3.36
d_{3-6}fs	5.05 ± 8.50	4.22 ± 7.76^a	3.66 ± 6.71^a	7.07 ± 10.27^b

ICDAS, International Caries Detection and Assessment System; d_{3-6}t, decayed teeth with uncavitated and cavitated enamel caries; d_{3-6}s, decayed tooth surfaces with uncavitated and cavitated enamel caries; d_{3-6}ft, filled teeth with cavitated and uncavitated enamel caries; d_{3-6}fs, filled tooth surfaces with cavitated and uncavitated enamel caries.
Mean ± SD calculated using one way analysis of variance (ANOVA).
^{a,b} are different superscript letters and indicate significantly different values. $p < 0.05$, post-hoc test used least significant difference (LSD).

TABLE 5. Correlation between ICDAS level and Snyder caries activity test.

	d_{3-6}t	d_{3-6}ft	d_{1-6}t	d_{1-6}s	d_{1-2}s	d_{3-4}s	d_{5-6}s
SCAT	0.22**	0.14	0.28**	0.22**	0.13	0.11	0.20*
p-value	$p < 0.001$	0.04	$p < 0.001$	$p < 0.001$	0.006	0.08	0.01

*ICDAS, International Caries Detection and Assessment System; SACT, Snyder's caries activity test; d_{3-6}t, decayed teeth with uncavitated and cavitated dentine caries; d_{3-6}ft, filled teeth with uncavitated and cavitated enamel caries; d_{1-6}t, teeth including enamel opacity or cavitated dentine caries; d_{1-6}s, tooth surfaces including enamel opacity or cavitated dentine caries; d_{1-2}s, Enamel opacity tooth surfaces; d_{3-4}s, decayed tooth surfaces with uncavitated enamel caries; d_{5-6}s, decayed tooth surfaces with cavitated enamel caries. *$p < 0.05$; **$p < 0.001$.*

TABLE 6. Comparison of SCAT with ICDAS scores.

ICDAS	N	SCAT Mean ± SD	*p*	ICDAS	n	SCAT Mean ± SD	*p*
Total	153	2.21 ± 1.02	<0.001	Total	153	2.21 ± 1.02	<0.001
d_0t	71	1.92 ± 0.95^a		d_0t	71	1.92 ± 0.95^a	
d_{1-2}t	43	2.26 ± 1.03^a		d_{1-2}t	43	2.26 ± 1.03^a	
d_{3-4}t	15	2.33 ± 0.98^{ab}		d_{3-6}t	39	2.69 ± 0.95^b	
d_{5-6}t	24	2.92 ± 0.88^b					

SD, Standard differences; ICDAS, International Caries Detection and Assessment System; SCAT, Snyder's caries activity test; d_0t, Sound teeth; d_{1-2}t, Enamel opacity teeth; d_{3-4}t, decayed teeth with uncavitated enamel caries; d_{5-6}t, decayed teeth with cavitated dentine caries.
^{a,b} are different superscript letters indicate significantly different values; post-hoc test used least significant difference (LSD).

bacterial markers can be used to evaluate the risk of dental caries. According to a 4-year cohort follow-up study of 6-year-old children in Mexico [28], dental caries experience, SCAT results and the fissure morphology significantly affected the increase in dental caries. Moreover, according to a study by Ali *et al*. [40], in caries-free, average caries and rampant caries groups, 40%, 60% and 80% samples showed color change for SCAT at 72 hours, respectively. In other words, similar previous studies used SCAT to evaluate or predict dental caries in children.

In present study, based on ICDAS scores, dental caries examination showed that deciduous caries experience increased with age: the number of children with d3–6ft, d3–6fs, d3–6t, d3–6s, d1–6t and d1–6s indices increased. In a similar age-related study, Diamanti *et al*. [41]. reported that d3–6ft of 5-year-old children was 1.48, which was 0.55 less than the result of this study. Moreover, although the target age was different, it was confirmed that the number of dental caries (d3–6ft) of permanent teeth increased with age to 1.61 at 12 years old and 2.46 cases at 15 years [41].

A significant difference was found in the results of the SCAT and ICDAS code 3. In addition, the indices that did not show a significant correlation with the SCAT score were those that had not yet reached the cavitated enamel caries stage (d1–2s, d3–4s) or were the index for a tooth that had been treated (d3–6ft). The significance level of the association was confirmed (Table 5), however, the quantitative correlation values were low (ranging from 11% to 33%).

Table 5 demonstrates that the SCAT scores were not significant for d3–6ft (tooth with dental caries that have been filled), however, a significant correlation was confirmed with the SCAT color change value in the case of current dental caries (d3 or higher scoring dental caries). Specifically, in case of current dental caries, the SCAT color change can be confirmed, which can suggest the possibility that dental caries will continue to occur. ICDAS confirms the stage before the formation of the cavity, which is the initial caries (d0, d1, d2), however, it also evaluates the stage after the onset of caries.

SCAT can be helpful in more frequent and objective evaluation of the patients' dental caries risk through plaque or saliva examination. Li *et al*. [42] reported that dental caries is caused by various microorganisms rather than a specific bacterium. In the early stage of research on dental caries, lactic acid bacteria such as *Streptococcus mutans* were known as the main causative bacteria of dental caries, and *Lactobacilli* were representatively included. Recently, the direction of research on dental caries is evolving to assess the total number of bacteria in the oral cavity or the acidity in the oral cavity due to acidic substances produced by bacteria; therefore, the bacterial activity is indirectly checked, rather than an investigation of the presence or absence of specific bacteria. As a result, the Dentocult SM Strip mutans® test has not been used recently. The SCAT was used in this study to confirm the level of acid production in the oral cavity, not to indirectly measure the number of specific bacteria, *i.e.*, *Lactobacillus*. However, in the early days of the development of the SCAT, research was conducted to confirm the level of acid production in the oral cavity according to the number of *Lactobacillus*. Dental caries activity testing *via* the improved SCAT in clinical practice allows a clinician to check the acid production level in the oral cavity before the development of caries and to undertake active preventive measures. In addition, it can be very useful in oral health education of patients by allowing them to visualize the acid production rate of their oral cavity. For partial enamel destruction, without clinical visual signals of dentinal involvement due to dental caries (d3), as the acidity in the oral cavity increases, the SCAT varies. No cavity formation was associated with a lower SCAT. An SCAT value between 2 and 2.6 indicates the absence of cavity formation, however, early caries can be suspected. A lower SCAT value indicates a lower chance of cavity formation. Consequently, the stages before and after cavity formation can be distinguished by the SCAT average value. A significant correlation between the occurrence of primary caries and changes in oral acidity was confirmed in present study. In a study by Kunte *et al*. [34], the SCAT results showed a significant correlation to the severity of caries.

Despite the many advantages of this study, there are some limitations. First, while obtaining institutional review board (IRB) approval to check children's oral health status, the survey items regarding the socioeconomic factors of the household could not be included and investigated owing to recent privacy policies and strengthened IRB approval procedures. In a study by Diamanti *et al*. [41], more educated parents and 15-year-old children living in cities had significantly fewer experiences with dental caries (DMFT). The authors agree that socioeconomic factors have an impact. In the present study, the sample population was retrieved from a kindergarten in the same area, and the authors attempted to highlight the current caries situation among kindergarten children to the best of their abilities. Second, it is recommended that two or more examiners conduct an oral examination after confirming the degree of agreement between the examiners. However, at the time the study was conducted, only one dentist was eligible to participate in the research. This dentist is an oral examination agent of the National Health and Nutrition Examination Survey who has participated in numerous oral examinations for the diagnosis of dental caries and has attended related training every year to receive education on oral examination quality control. Third, dental caries and oral pH in children are closely related to diet, which was not evaluated in present study. Hwang *et al*. [43] evaluated the pH before and after intake, according to the beverage type, using the modified SCAT; they found a lower pH in lactic acidic beverages than in alkaline or carbonated beverages. In addition, there were studies on changes in the pH of saliva and tooth demineralization depending on the type of beverage [44–46]. No association between d1 and d2 with SCAT was observed. It is necessary to compare and analyze the SCAT scores in relation to individuals' dietary habits. It is thought that if enough study participants are secured, this study may be reanalyzed, and the association between early caries (ICDAS d1, d2) and SCAT can be reconsidered. Additionally, it was difficult to confirm association of SCAT with early caries because the results of SCAT were challenging to analyze in detail with the colorimetric method. However, since the association was confirmed at d3 or higher, it could be inferred that the risk of caries was high through the SCAT. SCAT scores are based on an ordinal scale, and this limitation was overcome by comparing the correlation of the two indices. However, there may be some errors in the correlation analysis owing to the use of the ordinal scale. In future studies, it is necessary to subdivide the SCAT results to confirm the correlation. Nevertheless, in this study, the dental caries status of children was evaluated using the ICDAS, which assesses dental carries based on the initial degree of caries. The correlation with SCAT was confirmed, and the degree of dental caries was categorically investigated.

5. Conclusions

This study found that the higher the ICDAS scores, the higher were the SCAT scores. It is necessary to manage dental caries early to prevent the enamel opacity stage of dental caries to proceed to cavitation. ICDAS with SCAT is an appropriate index for diagnosing caries progression level and highly active caries. Additionally, in the process of treating dental caries and implementing related preventive education, the acidity of the oral environment, evaluated using SCAT, can be presented as a feedback data to the patient after treatment or oral education.

ABBREVIATIONS

SCAT, Snyder's Caries Activity Test; ICDAS, International Caries Detection and Assessment System; DMFT, Decayed, Missing and Filled Teeth due to caries in the permanent teeth; ANOVE, one way analysis of variance; LSD, least significant difference.

AVAILABILITY OF DATA AND MATERIALS

Dental data generated or analyzed in this study cannot be made publicly available as consent to publish the data were not obtained. However, the corresponding author can make de-identified data available on reasonable request.

AUTHOR CONTRIBUTIONS

HNK and SYK—wrote the entire manuscript and designed the experiments; conceived the study, coordinated the research work, and helped to draft the manuscript. All authors contributed extensively to the work presented in this paper. All authors read and approved the final manuscript.

ETHICS APPROVAL AND CONSENT TO PARTICIPATE

This study was approved by the Bioethics Review Committee of Pusan National University Dental Hospital (PNU IRB/2018_49_HR). All procedures involving human participants were performed in accordance with the tenets of the Declaration of Helsinki. All the study activities, benefits/risks of voluntary participation, and withdrawal from the study were verbally communicated to parents/guardians or caregivers in Korean. Questions were asked to confirm whether they understood the study, and written informed consent of the parents/guardians was obtained before recruitment.

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CONFLICT OF INTEREST

The authors declare no conflict of interest.

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