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Original Article

# Caries experience between primary teeth at 3–5 years of age and future caries in the permanent first molars



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## KEYWORDS

Caries prediction;  
Dmf;  
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experience

**Background/purpose:** Past caries experience remains the most powerful predictor of future caries. This study was aimed at exploring the possible relationship between the caries statuses at 3–5 and 8–10 years of age and examining the predictive power of caries experience at 3–5 years of age for the caries pattern at 8–10 years of age.

**Materials and methods:** A total of 76 children (43 boys and 33 girls) were included in this study from 2012 to 2018. The first caries examination, performed in 2012, was completed when participants underwent dental rehabilitation under general anesthesia at 3–5 years of age. Tooth decay was recorded based on the International Caries Detection and Assessment System criteria. The caries examination was repeated in the clinic in 2018 when the participants were 8–10 years old. Associations between the permanent and primary teeth were analyzed using the Mann–Whitney *U* test. The receiver operating characteristic curve analysis was performed to determine the predictive accuracy of the primary dentition.

**Results:** A significant dmfs score of the primary second molar was found between groups of free dentin caries and dentin caries of the permanent first molars ( $p = 0.002$ ). The calculated areas under the receiver operating characteristic curve for the dmfs score of the primary second molar was 0.74.

**Conclusion:** Caries in the primary second molars is a clinically useful predictor at 3–5 years of age for future dentin caries development on surfaces of the first permanent molars in the following 5 years.

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## Introduction

The studies of global incidence and distribution of dental caries are complicated by different diagnostic criteria, and the results are also different.<sup>1,2</sup> However, in recent decades, the prevalence and severity of caries in permanent teeth have declined indeed in many developed countries.<sup>3</sup> The prevalence of dental caries slows with increasing age.<sup>4</sup> Although the caries prevalence has generally declined in developed countries over the past few decades, many children develop caries because of special situations, such as a nursing bottle habit.<sup>5</sup> Furthermore, caries is usually found in certain teeth and tooth types, such as the primary second molar and permanent first molar.<sup>6</sup>

The evaluation of caries prediction is difficult because of multifactorial etiologies.<sup>7</sup> No single variable has been proved to be a successful predictor for future dental caries.<sup>8</sup> Past caries experience in caries risk assessment models is still the most powerful predictor of future caries in the young permanent dentition.<sup>11</sup> Although the caries development of young permanent dentition is related to the corresponding caries status of deciduous dentition.<sup>9</sup> This relationship has not been fully understood so that the new caries prediction for permanent teeth by measuring the caries experience of deciduous teeth needs more researches to prove.<sup>8–10</sup>

To our knowledge, no previous Taiwanese studies have investigated the prediction of dental caries. This study was aimed at investigating the caries experience in the primary teeth as a predictor of future caries in the permanent teeth in the same individuals. Such a predictor would be helpful in planning dental preventive programs for children. Therefore, the purposes of this longitudinal study were (1) to investigate the relationship between the caries prevalence and types in the primary dentition of 3–5 years old and permanent dentition of 8–10 years old, and (2) to explore the predictive power of caries experience of 3–5 years old children for the permanent dentition of 8–10 years old.

## Materials and methods

The study was conducted in a longitudinal design and was based on two caries examinations for the same children aged 3–5 and 8–10 years. A total of 76 children with early childhood caries requiring full mouth dental rehabilitation under general anesthesia were recruited from the Children's Dental Clinic of the Kaohsiung Chang Gung Memorial Hospital. The first dental examination in this study took place in 2012, when they were 3–5 years old. The number of subjects dropped from 117 to 76 during the second examination in 2018, when they were 8–10 years old. No differences were noted between the study subjects and those lost to follow-up ( $p > 0.05$ ). "Moving out of town" and "loss of contact" were the main reasons for dropouts. The study protocol was approved by the Institutional Review Board of the Chang Gung Memorial Hospital (IRB no: 202000607B0). The parents of the children were invited to participate in the study and were requested to provide informed consent.

## Caries examination

The first dental examinations were performed under general anesthesia in 2012. Immediately after the participant had been anesthetized, dental checkups were performed by two pediatric dentists (Lin JYT and Lin YT). Caries were evaluated using decayed, extracted, or missing, and filled teeth/surfaces (dmft/dmfs) index for the primary teeth and DMFT/DMFS index for the permanent teeth. Decayed teeth were recorded based on the International Caries Detection and Assessment System ICDAS criteria.<sup>11,12</sup> Digit ICDAS codes were determined for each tooth surface; caries codes of ICDAS 1, 2, and 3 were counted as enamel caries (D1–3), and codes 4, 5, and 6 were counted as dentin caries (D4–6). The caries experience (D4–6MFT and D4–6MFS) for the permanent teeth was calculated using dentin caries, missing, and filled teeth/surfaces. The caries examination was repeated in the pediatric dental clinic in 2018.

## Statistical analysis

Two senior pediatric dentists (Lin JYT and Lin YT) participated in a pilot study involving 10 cases. The kappa score of the inter-examiner reliability test was 0.83. The prevalence of caries in the permanent first molars and each deciduous tooth were used for further analysis of caries prediction. In this analysis, children were divided into two groups. One group developed dentin caries of the first permanent molar at the age of 8–10 years and the other group had not. The Mann–Whitney U tests were then used to compare the caries status of each primary tooth at 3–5 years of age between free dentin caries and dentin caries of the permanent first molars at 8–10 years of age. The receiver operating characteristic curve analysis was performed to determine the predictive accuracy of the primary dentition. The calculated areas under the curve (AUC) for the primary first molars and second primary second molars were assessed. Statistical software was used to analyze the data (Statistical Package for Social Sciences 19 for Windows, Chicago, IL, USA). A  $p$ -value  $< 0.05$  was considered significant.

## Results

A total of 76 children (43 boys and 33 girls) were included in the study from 2012 to 2018. At 8–10 years of age, all permanent first molars and 96% of the incisors of the subjects had erupted with  $D_{1-6}MFT$  of  $3.33 \pm 2.37$  and  $D_{1-6}MFS$  of  $3.36 \pm 2.27$ . Tables 1 and 2 provide details information on the distribution and severity of caries. The caries free rate ( $D_{1-6}MFS = 0$ ) was 18.4%, and 26.3% of the children had dentin caries and/or filling surface ( $D_{4-6}MFS > 0$ ). Fifty-four children (71.1%) had carious lesions involving the permanent first molars. Eight children (10.53%) had carious lesions involving the permanent incisors, and three children (3.95%) had dentin caries and/or filled surfaces ( $D_{4-6}MFS$ ). No significant  $d_{1-6}mfs$  scores of the primary anterior teeth at 3–5 years of age were noted between groups of free dentin caries and dentin caries of the permanent first molars at 8–10 years of age (Table 3). However, a significant  $d_{1-6}mfs$  score of the primary second molar was found

**Table 1** The caries prevalence at tooth level  $d_{1-6}mft$  in the primary teeth at 3–5 years of age and  $D_{1-6}MFT$  in the permanent teeth at 8–10 years of age.

	Mean (SD)		Mean (SD)
$d_{1-3}t$	4.24 (3.10)	$D_{1-3}T$	1.68 (1.43)
$d_{4-6}t$	9.39 (4.35)	$D_{4-6}T$	0.59 (1.06)
ft	0.58 (1.17)	FT	1.05 (1.30)
mt	0.16 (0.54)	MT	0.00 (0.00)
$d_{1-6}mft$	14.37 (3.72)	$D_{1-6}MFT$	3.33 (2.37)

SD: standard deviation;  $d_{1-3}$ ,  $D_{1-3}$ : enamel caries;  $d_{4-6}$ ,  $D_{4-6}$ : dentin caries; f, F: filled; m, M: missing; t, T: teeth.

between groups of free dentin caries and dentin caries of the permanent first molars (Table 3). The ROC analysis showed that the screening versions of dmfs of the primary second molars generated better prediction (higher AUC) than the other primary teeth (Fig. 1). The calculated areas under the curve (AUC) for the primary first molars and second primary second molars were 0.58 and 0.74, respectively (Fig. 1 and Table 4).

## Discussion

Past caries experience in the deciduous dentition is a good single predictor of future caries in the permanent dentition. However, very few studies with strong evidence bases have been conducted. This is the first Taiwanese study to establish past caries experience in the primary dentition with clinically satisfactory predictive accuracy to identify high-risk children's future caries in the permanent teeth among pediatric patients who need general anesthesia intervention.

The parents of the children in this study showed similar educational and sociodemographic backgrounds. The present study used a longitudinal cohort design limiting the age of our study subjects to 3–5 and 8–10 years to obtain meaningful results. Another significant improvement was the use of the ICDAS method<sup>13–15</sup> compared to the WHO criteria, which were previously used in detecting carious lesions in Taiwan. ICDAS was developed to include early enamel caries lesions and categorize obvious dentin caries

**Table 3** Mann–Whitney U tests for comparisons of caries status of each primary tooth at 3–5 years of age between free dentin caries ( $D_{4-6}MF = 0$ ) and dentin caries ( $D_{4-6}MFS > 0$ ) of the permanent first molars at 8–10 years of age.

Primary tooth	$D_{4-6}MFS(6) = 0$ Mean (SD) N = 56	$D_{4-6}MFS(6) > 0$ Mean (SD) N = 20	P value
$d_{1-6}mfs$ of 52–62	10.77 (4.87)	11.05 (4.59)	0.858
$d_{1-6}mfs$ of 72–82	2.57 (4.44)	2.00 (4.04)	0.783
$d_{1-6}mfs$ of 53 & 63	3.11 (2.56)	3.30 (2.45)	0.694
$d_{1-6}mfs$ of 73 & 83	1.39 (2.09)	1.80 (2.42)	0.573
$d_{1-6}mfs$ of D	9.55 (5.41)	11.05 (5.58)	0.290
$d_{1-6}mfs$ of E	8.32 (4.78)	12.35 (4.58)	0.002*

$d_{1-6}mfs$ : decayed, missing and filled surfaces for the primary teeth;  $D_{4-6}MFS$ : dentin caries, missing and filled surfaces for the permanent teeth; 6: permanent first molar; D: primary first molar; E: primary second molar.

\*Significant difference in  $d_{1-6}mfs$  of the primary second molars was found between free dentin caries ( $D_{4-6}MFS = 0$ ) and dentin caries ( $D_{4-6}MFS > 0$ ) of the permanent first molars.

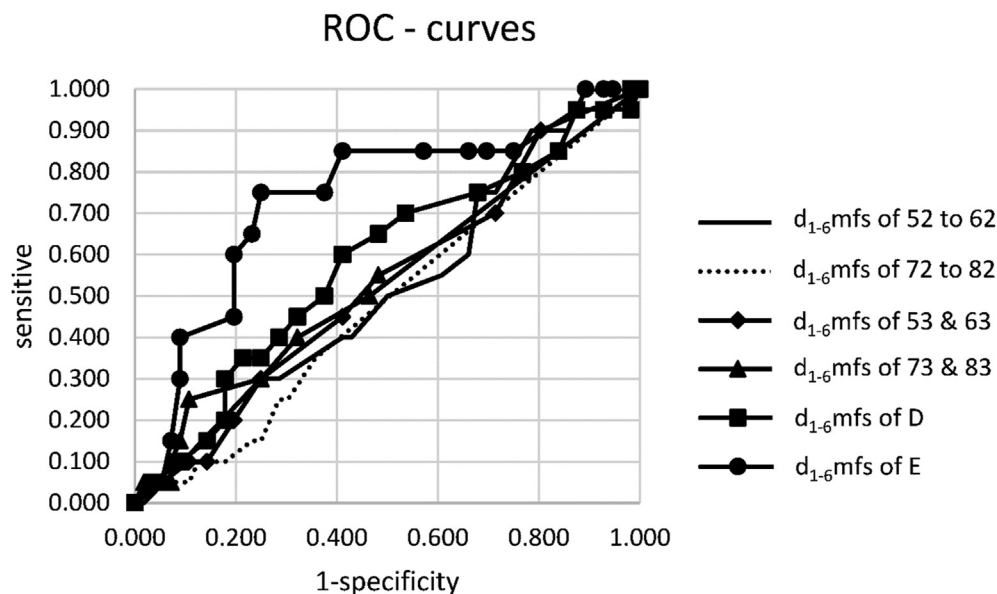
according to their progression.<sup>12</sup> The effectiveness and reproducibility of ICDAS have been verified in several *in vitro*<sup>16</sup> and clinical studies.<sup>17</sup>

The caries index of children aged 3–5 years in the present study with  $d_{4-6}mft$  of 14.37 (Table 1) was higher than the corresponding mean dmft of 2.58 at 3 years of age and 4.41 at 4 years of age, as recorded in the national data registry in Taiwan.<sup>18</sup> This finding is mainly due to the fact that all subjects were at high risk of dental caries and required full mouth dental rehabilitation under general anesthesia. However, the caries index of permanent teeth at 8–10 years of age with  $D_{1-6}MFT$  of 3.33 and  $D_{1-6}MFS$  of 3.36 (Tables 1 and 2) in the present study was comparable to that in the Taiwan aboriginal data<sup>19</sup> and to a  $D_{1-5}MFT$  of 2.43 and  $D_{1-5}MFS$  of 3.53 in data from Norway in 2006.<sup>20</sup> After 5 years of follow-up, there were no significant  $d_{1-6}mfs$  scores of the primary anterior teeth at 3–5 years of age noted between free dentin caries and dentin caries of the permanent first molars at 8–10 years of age (Table 3), suggesting no association between the caries experience of

**Table 2** The caries prevalence and distribution at surface level  $D_{1-6}MFS$  in the permanent teeth at 8–10 years of age.

Surfaces	$D_{1-3}S$ Mean (SD)	$D_{4-6}S$ Mean (SD)	FS Mean (SD)	$D_{1-6}MFS$ Mean (SD)
Incisor				
Proximal	0.00 (0.00)	0.01 (0.12)	0.01 (0.12)	0.03 (0.16)
Buccal/Lingual	0.12 (0.40)	0.00 (0.00)	0.05 (0.28)	0.17 (0.47)
1 <sup>st</sup> permanent molar				
Proximal	0.01 (0.12)	0.03 (0.16)	0.54 (1.03)	0.08(0.40)
Buccal/Lingual	0.37 (0.78)	0.00 (0.00)	0.34 (0.68)	0.71(0.96)
Occlusal	1.79 (1.39)	0.54 (1.03)	0.04 (0.26)	2.37 (1.61)
Total				3.36 (2.27)

SD: standard deviation;  $D_{1-3}$ : enamel caries;  $D_{4-6}$ : dentin caries. F: filled; M: missing; S: surface.



**Figure 1** Receiver operating characteristic curves of the true-positive rate (sensitivity) against the false-positive rate (1-specificity) for 3–5 years old children at cut-off points of increasing  $d_{1-6}mfs$  of 52–62,  $d_{1-6}mfs$  of 72–82,  $d_{1-6}mfs$  of 53–63,  $d_{1-6}mfs$  of 73–83,  $d_{1-6}mfs$  of D, and  $d_{1-6}mfs$  of E used to predict dentin caries ( $D_{4-6}MFS > 0$ ) on the permanent first molars at 8–10 years of age.

**Table 4** Decision matrices and resulting ratios based on the screening criteria  $dmfs$  on primary second molars = 10.5 and primary first molars = 9.5 at 3–5 years of age and the absence/presence of dentin caries ( $D_{4-6}MFS$ ) in permanent first molars at 8–10 years of age.

	Screening criteria at 3–5 years			
	Cut point of $d_{1-6}mfs$ on primary second molars = 10.5		Cut point of $d_{1-6}mfs$ on primary first molars = 9.5	
Validation criterion	–	+	–	+
Caries in permanent 1st molars				
–	42	14	33	8
+	5	15	23	12
AUC(95% CI)	0.74 (0.60–0.87)		0.58 (0.43–0.73)	
Sensitivity	0.75		0.60	
Specificity	0.75		0.59	
Positive predictive value	0.52		0.34	
Negative predictive value	0.89		0.80	

$d_{1-6}mfs$ : decayed, missing and filled surfaces for the primary teeth;  $D_{4-6}MFS$ : dentin caries, missing and filled surfaces for the permanent first molar; AUC: areas under the curve; CI: confidence interval.

the deciduous anterior teeth and caries development in the permanent first molars, which may be attributed to the characteristic result of nursing bottle decay in these special groups of patients. However, a significant  $d_{1-6}mfs$  score of the primary second molar was found between free dentin caries and dentin caries of the permanent first molars, indicating that the primary second molar may be a reliable predictor for future caries development in the permanent first molar.

The area under the ROC curve represents the prediction ability of different prediction factors, which can be regarded as a measure of potential prediction accuracy.<sup>21</sup> In our study, the  $dmfs$  score of primary second molars resulted in a 74% area under the curve, which indicates that the primary second molar is a better caries predictor than the

other primary teeth. The calculated area under the ROC curve is consistent with the 73% reported in the Chinese children aged 6–7 years.<sup>22</sup> It might be practical to focus on the primary second molars based on Mejare and Stenlund's findings that the distal surface caries of the second primary molar from 6 to 12 years of age affects the mesial surface of the first permanent molar.<sup>23</sup>

The present study included children with a high caries risk who were prone to caries relapse after oral rehabilitation under general anesthesia and would provide promising clinical accuracy. After comprehensive dental care under general anesthesia, the oral environment of children improved significantly in the first six months. This was because parents were enthusiastic to improve their children's oral hygiene immediately after the impact of dental

care under general anesthesia.<sup>24</sup> However, it gradually returned to its original status. The caries activity persists possibly because a person's behavior for caries development has not changed, suggesting that the past caries experience is a potentially powerful predictor for dental caries, especially in the early permanent dentition.

In our study, recording incipient caries using ICDAS II criteria offers a new perspective for detecting carious lesions from the initial and precavitation stages. We explored all surfaces of the first permanent molars rather than only the mesial surface and distinguished enamel and dentin caries using ICDAS II criteria.<sup>2</sup> Compared to previous reports, these findings were consistent with the results of many analyses.<sup>9</sup> The caries status of recently exposed teeth is the most successful measure of past caries experience.<sup>9</sup> This study further demonstrated that the caries status in the primary teeth, particularly the primary second molars, can be a risk indicator for predicting caries in the permanent first molar.

Mejare et al. in his review concluded that multivariate caries prediction model had moderate to good accuracy in preschool children and limited accuracy in school-age children and adolescents.<sup>25</sup> Among those risk factors, past dental caries experience was the best predictor for preschool children and school-age children/adolescents.<sup>25</sup> The assessment of past caries experience may reflect the past caries activity and show the current metabolic activity in the biofilm.<sup>26</sup> The present study strengthened that caries in the primary second molar was a reliable predictor for the dentin caries of the first permanent molar after general anesthesia intervention.

Dental staff should therefore be aware of past caries experience in the primary dentition, as being a risk for future caries in the permanent teeth. Enhancing caries prevention programs, such as dental sealants and fluoride treatments, and advising parents on regular dental checkups is important so that high-risk children can be detected early and offered an effective caries prevention program for their primary teeth. The dental decay in the primary second molars is a useful predictor of the development of dentin caries on the surface of the first permanent molar in the next five years at 3–5 years of age. A practitioner can use these results and tell child and parents that the surfaces of deciduous second molars need special attention at an early age.

## Declaration of competing interest

The authors declare that they have no conflicts of interest relevant to this article.

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