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Establishment and Validation of an Early Childhood Caries Prediction Model: a Multicentre Prospective Cohort Study

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Objective: *To establish a risk assessment model for early childhood caries and verify its credibility.*

Methods: *This 1-year multicentre cohort study comprised cohorts of 3-year-old children with and without caries recruited from kindergartens in Beijing, Shanghai, Sichuan, Hubei and Guangdong. Oral disease–related social and behavioural risk factors were collected from both children and their parents using questionnaires. Clinical examinations were performed according to World Health Organization standards, and the plaque's ability to produce acid, saliva pH value and saliva-buffering capacity were assessed. Logistic regression methods were employed to construct a risk-prediction model for caries incidence. Cross-validation methods were applied for the internal validation of the model, and the area under the curve (AUC) and calibration curves were used to evaluate the predictive performance of the constructed model.*

Results: *A total of 4,381 children were included in the study and randomly allocated 1:1 to the development and validation sets. Using the new occurrence of decayed, missing and filled surfaces as the dependent variable, the predictive model demonstrated AUCs of 0.83 (95% confidence interval [CI] 0.81 to 0.84) in the development model and 0.80 (95% CI 0.78 to 0.82) in the validation model at 1 year. The training and validation sets exhibited high sensitivity (0.69 to 0.72) and specificity (0.73 to 0.81).*

Conclusion: *The predictive models demonstrated good discriminability with both the training and validation sets and were suitable for primary oral care clinicians and stomatological hospitals.*

Keywords: *caries risk prediction model, early childhood caries, primary tooth, risk assessment*

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Dental caries is a biofilm-mediated, sugar-driven, multifactorial, dynamic disease that causes the phasic demineralisation of hard dental tissues.[1] Early childhood caries (ECC) is defined as the presence of one or more decayed (noncavitated or cavitated), missing (as a result of caries) or filled tooth surfaces in any primary tooth in a child aged 71 months or younger.[2] ECC can result in pain, infection, tooth loss and other complications that affect the oral health and quality of life of both children and parents.[3] According to the World Health Organization, dental caries is a chronic disease that ranks as the fourth most expensive to treat, affecting 60% to 90% of children and imposing a significant economic burden.[4-7] The Fourth National Oral Health Epidemiologic-

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al Survey of China indicated that the prevalence rate of caries among 5-year-olds was as high as 71.9%, with an uneven distribution; around three-quarters of the cases of caries observed in primary teeth were found in only one-third of the children.[8] ECC is one of the most prevalent oral diseases that affect children's health in China, and reducing the high prevalence of dental caries in young children is an urgent issue that must be addressed in oral public health.

ECC is one of the most easily preventable chronic diseases in children.[9] As such, early and accurate identification of children who are at high risk of caries through risk prediction models may be useful for more cost-effective caries control measures. Dental caries is a multifactorial disease caused by environmental, behavioural, microbial and other factors. Previous caries experience has been considered the best-isolated indicator of lesion development; however, given the complexity of dental caries, a standard system that combines multiple variables for prediction must be used.[10,11] At present, multiple dental caries risk assessment tools are available in some countries, such as the caries assessment tool (CAT),[12] Cariogram,[13] CAMBRAM,[14] CARE[15] and NUSCRA.[16] However, each system has its advantages and disadvantages and applicable scope, particularly with certain limitations for ECC. Moreover, most are not routinely utilised in practice, and the choice of some is not commonly based on high-quality evidence.[17]

Currently, very few risk prediction models have been developed for ECC in China, and these models were based on small study samples.[18] Thus, the present study aimed to establish a risk assessment model for ECC that is tailored to the national conditions of China and validate its reliability. The results of this prospective study could be used to offer personalised caries prevention plans, implement interventions for high-risk groups on a population level and utilise health care resources more effectively to decrease the incidence of ECC.

Materials and methods

This multicentre study was approved by the Ethics Committees of the Stomatological Hospital of Wuhan University, Stomatological Hospital of Peking University, Shanghai Ninth People's Hospital Shanghai Jiao Tong University, West China Hospital of Stomatology Sichuan University and the Hospital of Stomatology at Sun Yat-sen University. The clinical trial registration number is ChiCTR2100047211 and the medical research record number is MR-42-22-003822. Before the study commenced, the parents of the children who participated in the study were informed of the research content and signed an informed consent form.

Study design and sample size

This multicentre longitudinal study covered the period from November 2021 to April 2023, and two distinct cohort groups were created. Sample size calculations are detailed in Supplement S1 (provided on request). In the caries-free group, with model variables not exceeding 20 and an expected incidence rate of 25%, the sample sizes calculated by the two methods were 960 and 1,005, respectively. In the caries group, with model variables not exceeding 20 and an expected incidence rate of 50%, the sample sizes calculated by the two methods were 437 and 1,329, respectively. Consistent with the principle of constructing the predictive model using the largest possible sample size and considering the actual situation of data collection and potential parameters, the sample sizes for the two study cohorts were both set at 1,500 individuals, with an additional 1,000 for validation, totalling 2,500. Data surveys also considered both urban and rural areas, as well as sex ratios. Thus, each research centre maintained cohorts with and without caries, each comprising 500 participants. The initial 300 participants were utilised for modelling, whereas the subsequent 200 were reserved for validation. Through cluster sampling, cohorts of 3-year-olds without dental caries were randomly selected from urban and rural kindergartens in Beijing, Shanghai, Sichuan, Hubei and Guangdong, and cohorts of 3-year-olds with dental caries. The inclusion criteria were children aged 3 to < 4 years (born between 1 November 2017 and 31 January 2019) and having had an informed consent form signed by their guardians/parents. The exclusion criteria were children diagnosed with severe illness that would hinder follow-up completion and children unable to cooperate with the oral examinations. The caries-free group included children without caries (including filled teeth) for the entire mouth. The caries group included children with caries in at least one primary tooth.

Questionnaire

The questionnaire utilised in this study was adapted from the validated instrument employed for preschool-aged children (aged 3 to 5 years) in the Fourth National Oral Health Epidemiological Survey. Social and behavioural risk factors were collected from children and their parents via face-to-face questionnaires that covered demographic information, socioeconomic background, dietary behaviour, oral hygiene behaviour and

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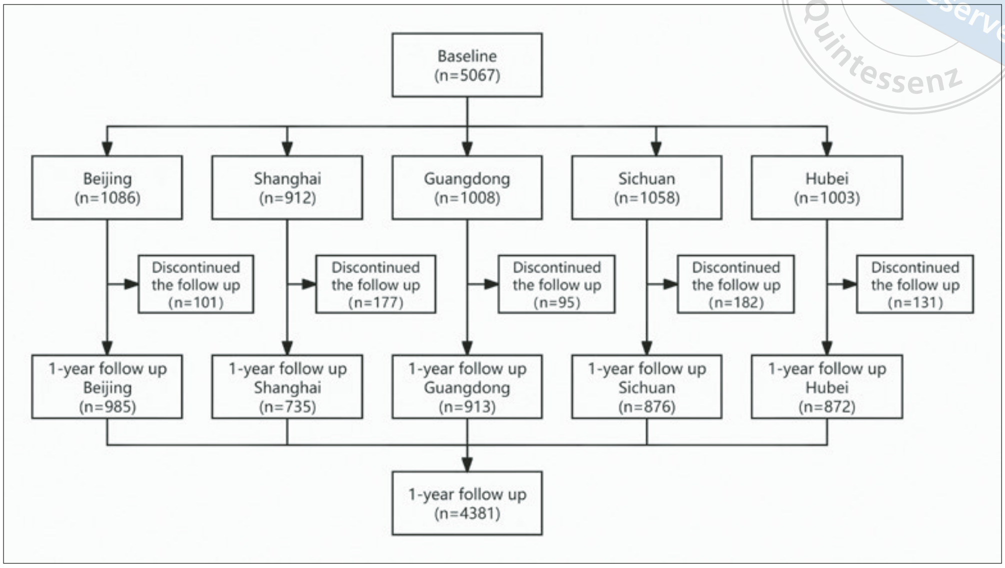

Fig 1 Flow diagram of the subject enrolment process.

medical-seeking behaviour. The questionnaires were completed by the child's mother or father at baseline and 1 year later.

Clinical examination

Clinical examinations were performed by trained dental practitioners. All examiners received theoretical and unified training in oral clinical examinations and underwent standardisation consistency testing. Each examiner, paired with the same professional reference examiner, performed dental caries assessments on the same cohort of 10 children. The inter-rater reliability was quantified using a Cohen kappa statistic, yielding values ranging from 0.80 to 0.91. The examinations were performed under artificial light using the World Health Organization criteria[19] for dental caries examination and community periodontal index probes to examine the entire dentition. A tooth was recorded as decayed (dt) when a lesion had an unmistakable cavity, undermined enamel or a detectably softened floor or wall; teeth that were sealed but also decayed were included as well. A tooth was recorded as missing (mt) when it was extracted due to caries. For missing primary teeth, this score should be used only if the subject is at an age where normal exfoliation would not be a sufficient explanation for absence. A tooth was recorded as filled (ft) when it was permanently filled without caries. The visible plaque index[20] was used to assess the plaque status of the entire dentition. The plaque conditions of the buccal (mesial, central and distal) and lingual (central) surfaces of each tooth were observed at four sites and awarded a score of 0 for absent or 1 for present. Laboratory examinations encompass the evaluation of plaque acidogenicity, saliva pH levels and saliva-buffering capacity, which was examined at 2 hours postprandial. To assess plaque acidogenicity, a specialised sterile sampling swab was used to rub the buccal surfaces of maxillary molars and the labial cervical areas of mandibular anterior teeth bilaterally for five strokes each. Subsequently, the swab should be agitated vertically five times in a culture medium tube. After securing the cap tightly, the tube should be placed in a constant-temperature incubator for 48 hours at 37°C and then quantified using a CarioScreen 1000 photometer Ruigu Biotechnology, Chuzhou, China Children held pH indicator strips for caries risk assessment in the mouth until fully saturated with saliva. After colour stabilisation (typically within 10 seconds), calibrated assessors compared the strips against the standardised calibration card affixed to the product bottle. The saliva pH levels (scored ≤ 5, 5~7, > 7.5) and saliva buffering capacity (< 500 ppm, 500~750 ppm, > 1000 ppm) were determined according to the chromatic demarcations on the card.

Statistical analysis

A chi-square test was utilised for univariate analysis, with the presence of new decayed, missing and filled teeth/decayed, missing and filled surfaces (dmft/dmfs) as the dependent variable. For the group of children without caries and the group with caries, a development set and a validation set were used in a ratio of 3:2 to build and verify the model, At the same time, all subjects were randomised to development and validation sets using a 1:1 allocation ratio. Subsequently, the logistic regression

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Table 1 Dental caries status in children.

Time point	Number of participants	dmft	dmfs	Δdmft[a]	Δdmft incidence rate (%)	Δdmfs[b]	Δdmfs incidence rate (%)
Baseline	5,067	2.04	4.32	NA	NA	NA	NA
1 year	4,381	3.39	7.50	1.35	49.58	3.18	55.22

[a]Incident dmft in 1 year. [b]Incident dmfs in 1 year.

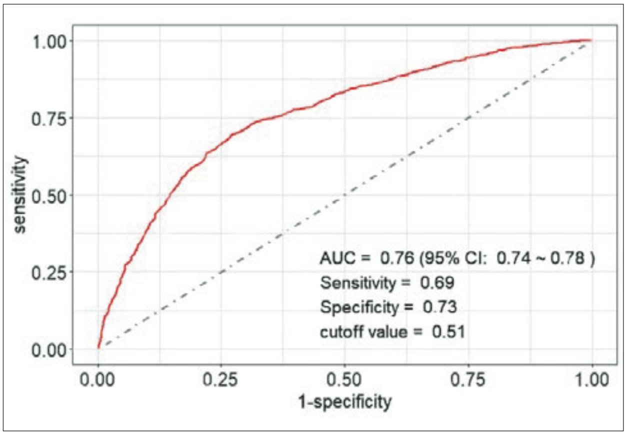

Fig 2 Receiver operating characteristic (ROC) curve constructed using univariate and stepwise regression methods (Δdmft).

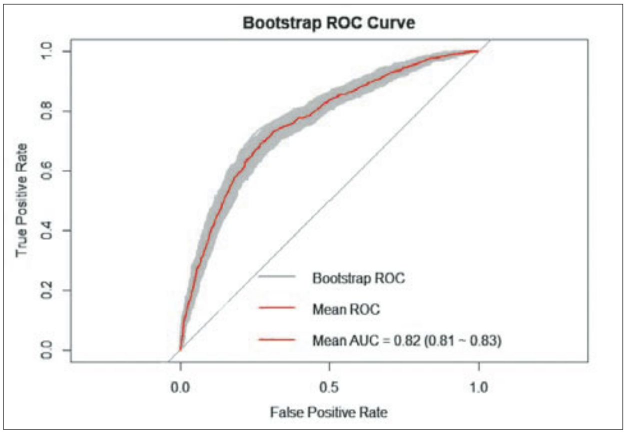

Fig 3 Bootstrap internal validation of the model ROC curve (Δdmft).

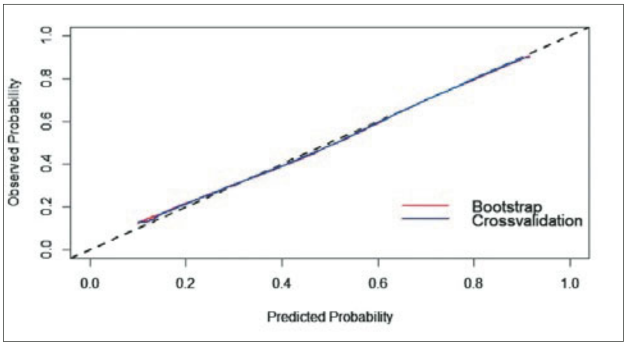

Fig 4 Calibration plot for caries risk prediction model in 3-year-old children (Δdmft).

stepwise method was employed to construct a caries risk prediction model. Bootstrap cross-validation was applied for internal validation of the model, and metrics such as the area under the curve (AUC) and calibration curves were used to assess the predictive performance of the constructed model. Finally, independent external validation samples were utilised to confirm the accuracy and reliability of the constructed model, and a nomogram was used to present the constructed risk prediction model.

Results

This study included a total of 5,067 children at baseline, with 4,381 individuals followed up after 1 year, resulting in a loss-to-follow-up rate of 14%, as shown in Fig 1. At baseline, the mean dmft and dmfs scores in children were 2.04 and 4.32, respectively. After 1 year of follow-up, the corresponding mean scores were 3.39 and 7.50, respectively (Table 1).

In the overall cohort, univariate analysis was conducted using the annual new Δdmft as the dependent variable. The results indicated that sociodemographic factors, including urban or rural residence, family size, family income, parents' educational level, only child status, parents' occupation, parents' oral health status and behaviours (e.g., caries history, frequency of tooth brushing and use of dental floss), parents' oral health knowledge and attitudes, children's oral health behaviours (current bottle-feeding status; habit of consuming milk, beverages or sweets after bedtime brushing; nighttime feeding or falling asleep with a bottle; consumption of sugary foods or beverages; initiation of oral hygiene before the eruption of primary teeth; initiation of tooth brushing after the eruption of the first primary tooth; daily tooth brushing frequency; use of fluoride-containing toothpastes; age at the first dental checkup; professional fluoride varnish application; and pit and fissure sealant) and clinical examination results (salivary pH value, salivary buffering capacity, plaque acidogenicity and presence of dental caries at baseline) were closely associated with Δdmft (Table 2).

The results of constructing a diagnostic model using the logistic regression stepwise method are shown in Fig 2, using the 1:1 allocation ratio. The caries risk prediction model utilising 1-year incident dmfts as the

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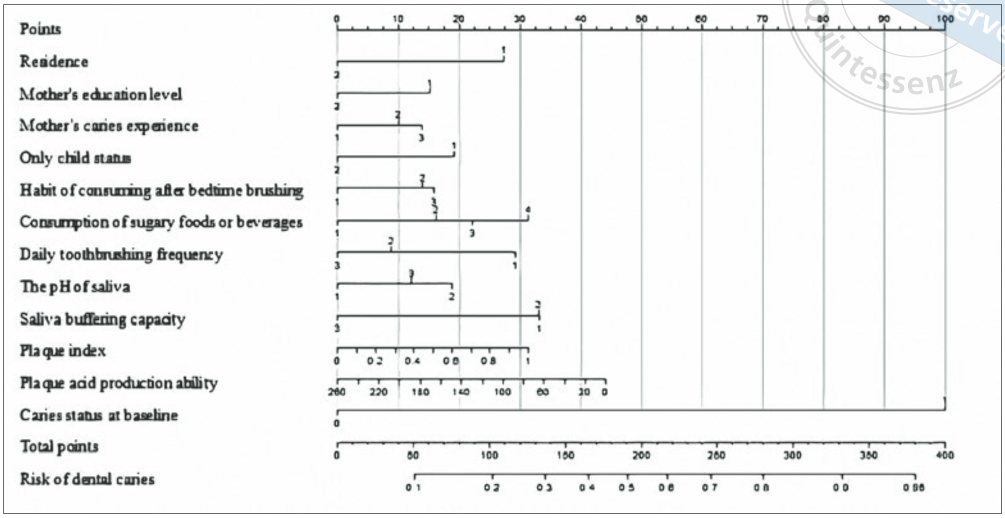

Fig 5 Nomogram model for caries risk prediction in children with Δdmft as the dependent variable.

outcome variable demonstrated acceptable discriminatory power, with an AUC of 0.76 (95% confidence interval [CI] 0.74 to 0.78), sensitivity of 0.69 and specificity of 0.73. Bootstrap internal validation revealed exceptional discriminative performance (AUC 0.82, Fig 3). Calibration analyses through internal and cross-validation demonstrated the close approximation of the calibration curve to the 45-degree reference line (Fig 4), indicating strong agreement between the predicted and observed caries risk probabilities in 3-year-olds. The final nomogram for 1-year dmft risk prediction is presented in Fig 5.

In the univariate analysis with 1-year new dmfs (Δdmfs) as the dependent variable in the whole cohort, the results were similar to those in the univariate analysis of Δdmft (Table 2). The results of constructing a diagnostic model using the logistic regression stepwise method are illustrated in Fig 6. The caries risk prediction model utilising 1-year incident dmfs as the outcome variable demonstrated acceptable discriminatory power, with an AUC of 0.82 (95% CI 0.80 to 0.83), sensitivity of 0.72 and specificity of 0.81. Bootstrap internal validation revealed exceptional discriminative performance (AUC 0.82, Fig 7). Calibration analysis through internal and cross-validation demonstrated the close approximation of the calibration curve to the 45-degree reference line (Fig 8), indicating strong agreement between the predicted and observed caries risk probabilities in 3-year-olds. The final nomogram for 1-year dmfs risk prediction is presented in Fig 9.

Discussion

This multicentre study analysed data from 4,381 children recruited from urban and rural preschools across five geographically diverse regions in China to develop a caries risk prediction model suitable for Chinese children. Although numerous caries prediction models exist globally, their direct applicability to the Chinese paediatric population is limited by substantial disparities with regard to socioeconomic factors, diet and access to health care, and most studies of caries risk-prediction models predominantly target permanent dentition in adults or adolescents; thus, preschool cohorts remain critically underrepresented in the development of current caries detection algorithms.[21-24] The present study directly addresses this gap by establishing the first multicentre ECC prediction model derived from a geographically diverse Chinese cohort (Beijing, Shanghai, Sichuan, Hubei and Guangdong), explicitly accounting for urban-rural dichotomies. This design ensures enhanced generalisability across heterogenous Chinese settings, a critical advancement over prior province-specific models.[25,26] This geographic selection bias substantially compromises the external validity of current models for the general Chinese population. In the present study, two simple and easily usable prediction models were constructed, using 1-year incident dmft and dmfs as the basis for judging whether children have caries. These models did not only consider different rural and urban characteristics; two different caries risk prediction models suitable for primary medical institutions and professional dental hospitals were

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Table 2 Univariate analysis of incident dmft and dmfs in 1 year

Variable		Δdmft		Δdmfs	
		OR (95% CI)	*P* value	OR (95% CI)	*P* value
Residence	Rural	1 (ref.)		1 (ref.)	
	Urban	0.56 (0.50–0.63)	< 0.01	0.55 (0.49–0.62)	< 0.01
Sex	Male	1 (ref.)		1 (ref.)	
	Female	1.00 (0.89–1.13)	0.97	1.02 (0.91–1.15)	0.71
Father's education level	Primary/junior/senior high/vocational school	1 (ref.)		1 (ref.)	
	College/university and above	0.64 (0.55–0.74)	< 0.01	0.59 (0.51–0.69)	< 0.01
Father's occupation	Farmer/individual/company/administrator/technical	1 (ref.)		1 (ref.)	
	Other/unemployed	1.31 (1.12–1.54)	< 0.01	1.27 (1.09–1.49)	< 0.01
	Medical/educational staff	0.86 (0.65–1.12)	0.26	0.84 (0.64–1.10)	0.20
Father having caries	No	1 (ref.)		1(ref.)	
	Yes	1.15 (1.00–1.31)	0.05	1.15 (1.01–1.32)	0.04
	Not sure	1.23 (1.05–1.44)	0.01	1.13 (0.97–1.33)	0.12
Mother's education level	Primary/junior/senior high/vocational school	1 (ref.)		1 (ref.)	
	College/university and above	0.55 (0.47–0.64)	< 0.01	0.53 (0.46–0.62)	< 0.01
Mother's occupation	Farmer/individual/company/administrator/technical	1 (ref.)		1 (ref.)	
	Other/unemployed	1.33 (1.16–1.53)	< 0.01	1.29 (1.12–1.49)	< 0.01
	Medical/educational staff	0.96 (0.80–1.16)	0.71	0.95 (0.79–1.15)	0.60
Mother's daily tooth brushing frequency	Once or less	1 (ref.)		1 (ref.)	
	Twice or more	0.79 (0.68–0.91)	< 0.01	0.83 (0.71–0.96)	0.01
Mother uses dental floss	No	1 (ref.)		1 (ref.)	
	Yes	0.89 (0.79–1.01)	0.07	0.88 (0.78–1.00)	0.04
Mother's caries experience	No	1 (ref.)		1 (ref.)	
	Yes	1.30 (1.15–1.47)	< 0.01	1.37 (1.21–1.55)	< 0.01
	Not sure	1.19 (0.94–1.52)	0.15	1.12 (0.88–1.43)	0.35
Is the child an only child?	No	1 (ref.)		1 (ref.)	
	Yes	0.59 (0.52–0.67)	< 0.01	0.57 (0.51–0.64)	< 0.01
Weeks of pregnancy at childbirth	Full-term	1 (ref.)		1 (ref.)	
	Pre-term	1.11 (0.87–1.40)	0.41	1.02 (0.80–1.30)	0.85
Birth weight of the child	Normal	1 (ref.)		1 (ref.)	
	Low	0.82 (0.61–1.11)	0.20	0.80 (0.60–1.07)	0.14
	Overweight	1.09 (0.83–1.43)	0.54	1.14 (0.87–1.50)	0.34
Feeding method within 6 months	Breastfeeding	1 (ref.)		1 (ref.)	
	Artificial feeding	0.90 (0.71–1.14)	0.38	0.88 (0.69–1.12)	0.31
	Mixed feeding	0.93 (0.82–1.06)	0.30	0.91 (0.80–1.03)	0.15
Current bottle-feeding status	Only before age 2 (including 2 years)	1 (ref.)		1 (ref.)	
	After age 2	1.18 (1.04–1.33)	0.01	1.21 (1.06–1.37)	< 0.01
Main caregiver of the child	Parents	1 (ref.)		1 (ref.)	
	Grandparents/others	0.97 (0.85–1.10)	0.62	0.95 (0.84–1.08)	0.43
Habit of consuming milk, beverages, or sweets after bedtime brushing	Never	1 (ref.)		1 (ref.)	
	Occasionally	1.80 (1.58–2.05)	< 0.01	1.79 (1.57–2.04)	< 0.01
	Frequently	1.97 (1.65–2.35)	< 0.01	1.91 (1.59–2.28)	< 0.01
Nighttime feeding or falling asleep with a bottle	Never	1 (ref.)		1 (ref.)	
	Occasionally	1.47 (1.22–1.77)	< 0.01	1.50 (1.24–1.81)	< 0.01
	Frequently	2.10 (1.66–2.67)	< 0.01	2.66 (2.05–3.44)	< 0.01
Consumption of sugary foods or beverages	Occasionally/never	1 (ref.)		1 (ref.)	
	1–3 times per month	1.38 (1.14–1.66)	< 0.01	1.35 (1.12–1.63)	< 0.01
	1–6 times per week	1.37 (1.15–1.63)	< 0.01	1.35 (1.14–1.61)	< 0.01
	Once or more per day	1.83 (1.50–2.22)	< 0.01	1.97 (1.62–2.40)	< 0.01
Initiation of oral hygiene before eruption of primary teeth	No	1 (ref.)		1 (ref.)	
	Yes	0.75 (0.66–0.85)	< 0.01	0.70 (0.62–0.80)	< 0.01
	Not sure	0.92 (0.77–1.10)	0.37	0.89 (0.74–1.06)	0.19

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Variable		Δdmft		Δdmfs	
		OR (95% CI)	*P* value	OR (95% CI)	*P* value
Initiation of tooth brushing after eruption of the first primary tooth	No	1 (ref.)		1 (ref.)	
	Yes	0.62 (0.54–0.70)	< 0.01	0.60 (0.52–0.68)	< 0.01
	Not sure	0.86 (0.69–1.06)	0.15	0.84 (0.68–1.04)	0.12
Child's daily tooth brushing frequency	Occasionally/Not at all	1 (ref.)		1 (ref.)	
	Once a day	0.67 (0.54–0.84)	< 0.01	0.69 (0.55–0.87)	< 0.01
	Twice or more a day	0.50 (0.40–0.63)	< 0.01	0.54 (0.43–0.68)	< 0.01
Do parents help child to brush teeth?	Never	1 (ref.)		1 (ref.)	
	Occasionally	1.11 (0.77–1.61)	0.57	1.12 (0.77–1.62)	0.55
	Frequently	0.82 (0.57–1.18)	0.28	0.81 (0.56–1.17)	0.26
Use of fluoride-containing toothpaste	No	1 (ref.)		1 (ref.)	
	Yes	0.83 (0.72–0.96)	0.01	0.87 (0.75–1.00)	0.05
	Not sure	1.11 (0.94–1.31)	0.20	1.18 (1.00–1.39)	0.05
Do parents help child to use dental floss?	Never	1 (ref.)		1 (ref.)	
	Occasionally	0.94 (0.81–1.08)	0.39	0.89 (0.77–1.03)	0.11
	Every day	0.78 (0.52–1.17)	0.23	0.66 (0.44–0.99)	0.05
Age at first dental check-up	Never checked	1 (ref.)		1 (ref.)	
	0–1 years	0.87 (0.72–1.04)	0.13	0.83 (0.68–1.00)	0.05
	1–2 years	0.93 (0.78–1.11)	0.43	0.90 (0.75–1.08)	0.25
	2–3 years	1.24 (1.08–1.43)	< 0.01	1.38 (1.19–1.59)	< 0.01
Has the child received professional fluoride varnish application?	Never	1 (ref.)		1 (ref.)	
	Occasionally	1.16 (1.01–1.33)	0.04	1.16 (1.01–1.33)	0.04
	Regularly	0.80 (0.67–0.95)	< 0.01	0.80 (0.67–0.94)	< 0.01
Has the child received pits and fissure sealants?	No	1 (ref.)		1 (ref.)	
	Yes	1.54 (1.21–1.96)	< 0.01	1.52 (1.19–1.95)	< 0.01
If the child has caries, does he/she need treatment?	No/depends on the child	1 (ref.)		1 (ref.)	
	Yes	0.65 (0.57–0.73)	< 0.01	0.60 (0.53–0.68)	< 0.01
How do you evaluate the child's general health?	Average/poor	1 (ref.)		1 (ref.)	
	Good	0.87 (0.73–1.05)	0.15	0.84 (0.69–1.01)	0.06
	Very good	0.86 (0.72–1.04)	0.12	0.83 (0.69–1.00)	0.06
Family size	≤ 3	1 (ref.)		1 (ref.)	
	> 3	1.67 (1.45–1.93)	< 0.01	1.63 (1.41–1.87)	< 0.01
Family monthly income	≤ 10,000 yuan	1 (ref.)		1 (ref.)	
	> 10,000 yuan	0.72 (0.64–0.82)	< 0.01	0.73 (0.64–0.83)	< 0.01
pH of saliva	6.5~7	1 (ref.)		1 (ref.)	
	≤ 6	1.42 (1.25–1.61)	< 0.01	1.44 (1.27–1.63)	< 0.01
	> 7.5	0.94 (0.77–1.16)	0.58	1.00 (0.81–1.22)	0.97
Saliva buffering capacity	< 250 ppm	1 (ref.)		1 (ref.)	
	500–750 ppm	0.80 (0.71–0.91)	< 0.01	0.80 (0.71–0.91)	< 0.01
	> 1000 ppm	0.65 (0.48–0.88)	< 0.01	0.74 (0.55–1.00)	0.05
Caries status at baseline	No	1 (ref.)		1 (ref.)	
	Yes	5.65 (4.96–6.44)	< 0.01	10.90 (9.44–12.60)	< 0.01
Mother's age at childbirth		1.00 (0.99–1.01)	0.93	1.00 (0.99–1.01)	0.99
Father's age at childbirth		1.00 (0.99–1.01)	0.69	1.00 (0.99–1.01)	0.99
Plaque Index		2.91 (2.32–3.65)	< 0.01	3.63 (2.88–4.58)	< 0.01
Plaque acid production ability		0.99 (0.99–0.99)	< 0.01	0.99 (0.99–0.99)	< 0.01

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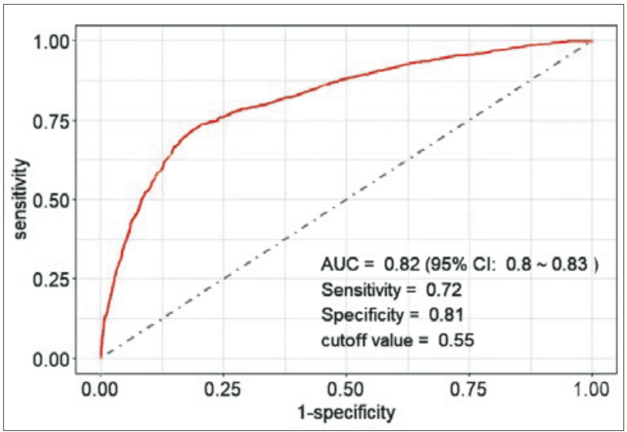

Fig 6 ROC curve constructed using univariate and stepwise regression methods (Δdmfs).

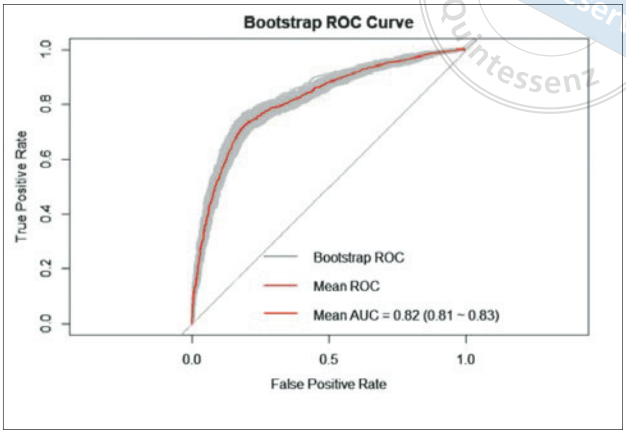

Fig 7 Bootstrap internal validation of the model ROC curve (Δdmfs).

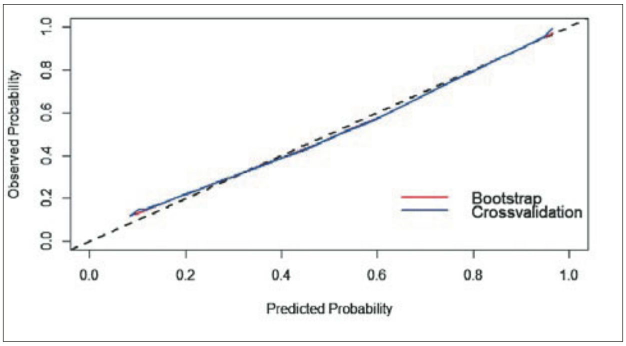

Fig 8 Calibration plot for caries risk prediction model in 3-year-old children (Δ dmfs).

also constructed to meet the need for risk assessment of primary teeth on different occasions.

Beyond geographic representativeness, the present authors' model integrates novel clinical biomarkers (salivary buffering capacity, plaque acidogenicity) with culturally contextualised behavioural factors (such as parental oral health literacy and pre-sleep feeding practices). In the present study, both prediction models incorporated 11 multidimensional predictors, namely living area (urban/rural), maternal educational attainment, maternal caries history, only child status, pre-sleep dietary behaviours, frequency of consumption of sugary foods/beverages, tooth brushing adherence, salivary pH, salivary buffering capacity, Plaque Index and chromaticity values of plaque deposits. Previous studies have identified relationships between caries progression and some determinants, including socioeconomic factors, age, eating habits, tooth brushing frequency and caries experience.[27-30] The present study revealed significant associations between parental determinants (educational attainment gradient and oral health–related behavioural patterns) and caries burden indices (dmft and dmfs). Dietary habits are an important aetiology of caries. A study found that the dietary and feeding habits of parents significantly affect their children's dietary habits.[31] This dose-response relationship underscores the pivotal mediator role of parental factors in shaping children's oral ecosystem through dual pathways, such as intergenerational transmission.[32] This study did not find a correlation between sex and dental caries (P = 0.710). Other studies did not show significant sex differences among children,[17] aligning with the findings of the present study. This is likely because unlike adults, who have developed the ability to think and act independently, the maintenance and establishment of children's oral health behaviours rely mainly on their parents; thus, sex has a limited effect on their behaviour. Consequently, before children develop independent health awareness, the awareness and behaviour habits of parents must be improved to promote children's oral health.

In this study, the present authors found that compared with those who had never undergone oral examinations, children who had their first checkup between the ages of 2 and 3 had higher dmft and dmfs scores. The first primary molar erupts between 12 and 18 months and the second primary molar between 20 and 30 months.[33] After the eruption of primary teeth, oral microbial diversity increases significantly, with cariogenic bacteria (such as *Streptococcus mutans* and *Lactobacillus*) being strongly associated with the eruption stage.[34] The age of 2 to 3 years is a high incidence period for ECC. At this age, higher dmft and dmfs scores at the initial examination may be attributed to seeking medical attention after discovering caries ra-

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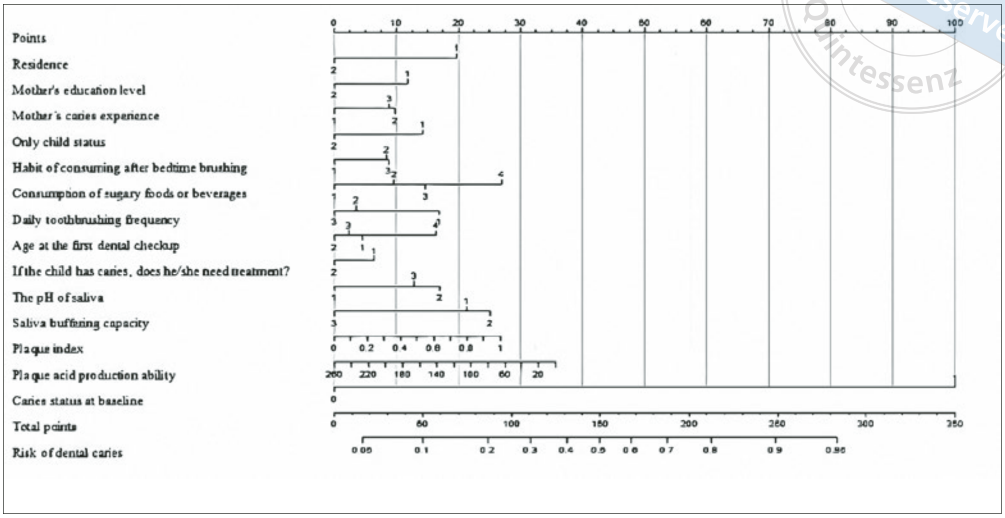

Fig 9 Nomogram model for caries risk prediction in children with Δdmfs as the dependent variable.

ther than to prevention. In this study, children who underwent pit and fissure sealant procedures had higher dmft and dmfs scores than those who did not. This result also reflects that the current primary focus is on treatment-orientated visits rather than preventive care. The regular application of fluoride varnish in children leads to lower dmft and dmfs scores, which indicates its preventive and protective effects against dental caries. Consequently, parental awareness regarding preventive visits must be improved to reduce ECC occurrence.

The predictive model, using incident dmfs as the primary outcome, demonstrated exceptional discriminative capacity over 12 months (AUC 0.82). Comparative analysis revealed superior performance to several international benchmarks, namely Fontana et al[35] (0.73), Kalhan et al[36] (0.71 to 0.75) and Hasan et al[37] (0.77). A recent domestic study reported an AUC of 0.75 to 0.91.[25] The differences in these results may stem from the varying factors included in each study, the different diagnostic criteria for dental caries and different analytical methods in different studies. Qu et al[25] indicated potential discrepancies caused by different analytical methods; however, these differences were not significant in another study.[38] More studies are needed to determine the most suitable analytical method for establishing the optimal ECC model.

Although the deployment of caries prediction tools faces implementation barriers including upskilling demands for the health care workforce, time constraints in primary care settings and referral pathway fragmentation,[39] the developed ECC risk prediction model was presented in the form of simple and intuitive charts and considered 1-year new dmft and dmfs scores as outcome measures that are intrinsically related to and predicted by a multitude of factors, which partially solve the above problems, rendering it more conducive to clinical practice. These models hold immediate translational value was integration into national ECC screening protocols, leveraging China's expanding primary health care network. The present findings will guide targeted resource allocation, identifying high-risk regions (e.g., rural areas with low maternal education) for focused public health campaigns and informing parental education programmes aimed at disrupting intergenerational caries cycles in a cost-effective strategy aligned with China's "Healthy China 2030" goals.

This study has several limitations. First, all dental-related behaviours were self-reported, which may have introduced some recall bias. Perhaps in the future, this limitation could be addressed by collecting real data from tooth-related intelligent technologies, such as smart toothbrushes. Second, the study did not include microbial indicators. However, in one study, given the high cost of measuring microbial markers, after attempting to exclude these, the model demonstrated good sensitivity and specificity in both the training and validation sets.[38] Third, this study did not employ more sophisticated statistical methods for analysis, such as machine learning methods. In addition, as a nationally representative ECC prediction model, the study prioritised population-level generalisability over quantifying province-specific heterogeneity. This design choice reflects the primary objective: to establish a unified risk assessment tool that is applicable across diverse Chinese health care settings. Although this approach enhances clinical utility for standardised implementation, it precludes analysis of potential interprovincial variation in caries determinants.

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Conclusion

The two ECC risk prediction models based on the incident dmft and dmfs counts within 1 year demonstrated good discriminability. The predictive model based on the number of new dmft within 1 year is suitable for use by primary oral care clinicians, and the predictive model based on the number of new dmfs within 1 year is more appropriate for specialised stomatological hospitals.

Conflicts of interest

The authors declare no conflicts of interest related to this study.

Author contribution

Dra Yan SI and Han JIANG contributed to the study design, project administration and drafting of the manuscript; Drs Bao Jun TAI, Xi Ping FENG, Huan Cai LIN and Tao HU provided academic supervision and played significant roles in reviewing and revising the manuscript; Drs Wen Hui WANG, Xi CHEN, Yan ZHOU, Li CHENG and Si Si WANG contributed to the clinical examinations, patient recruitment, data curation and collection; Dr Yi Zhen YU participated in on-site clinical examinations and contributed to the draft of the manuscript.

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