ORIGINAL ARTICLE

Correlation analysis of saliva volume and salivary pH on dental caries status in children aged 11-12 years using the HI BOGI application: a cross sectional study

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ABSTRACT

Introduction: Oral health is a key indicator of overall wellbeing, with dental caries remaining one of the most prevalent oral health problems in Indonesia. Saliva, particularly its volume and pH, is an important host factor influencing caries development. This study aims to analyze the association between saliva volume and salivary PH and dental caries among schoolchildren using the HI BOGI application. **Methods:** An analytic observational study with a cross-sectional design was conducted among 11–12-year-old students from six randomly selected primary schools in Cimahi City (n=285). Saliva volume and pH were measured, and dental caries experience was assessed using the HI BOGI application. Data were analyzed using the Spearman rho correlation test. **Results:** Children with lower saliva volume and more acidic saliva pH demonstrated higher DMF-T scores. Correlation tests indicated a relationship between low salivary volume and dental caries incidence (rs= –0.117; p≤0.05) and between salivary pH and caries (rs= –0.287; p≤0.05). **Conclusion:** saliva volume and acidic saliva pH are significant risk factors for dental caries incidence among 11–12-year-old children as identified through the HI BOGI application assessment.

KEYWORDS

Dental caries, saliva pH, saliva volume, age 11-12 years, application

INTRODUCTION

Dental caries is a multifactorial pathological condition resulting from the interaction between host factors, microorganisms, substrates, and time. Saliva plays a crucial role as a host factor by facilitating the self-cleansing process that removes food debris from tooth surfaces. [1–3]

The self-cleansing process can be hampered because there are physiological changes in the composition and characteristics of saliva, resulting in a decrease in salivary flow which can reduce the buffer ability so that there is a decrease in pH in the oral cavity.[4,5] Low salivary pH can also be caused by the metabolic activity of acidogenic bacteria. The metabolism of acidogenic bacteria produces lactic acid,

lowering the oral pH below the critical level of 5.5. In combination with reduced salivary flow, these acidic conditions promote ion loss from tooth enamel, marking the onset of dental caries.[6,7]

Dental caries can be assessed through saliva examination because it is easy and simple to collect which is a marker of dental caries incidence in line with the results of Buzalaf (2020) and De-Sausa (2021) studies; high concentrations of carbonic anhydrase VI, while low concentrations of flour, calcium and bicarbonate ions are markers of dental caries.[8,9] Dental caries has a relationship between low salivary volume and acidic salivary pH, which showed that children aged 7-9 years with low salivary volume had a high caries rate of 51.6%. With the acidic salivary pH category, the children had a high caries rate of 70%.

Dental caries can generally occur in all age groups, however, the risk increases in children.[10] The prevalence of dental caries based on the characteristics of age groups is similar to the results of the SKI in 2023 which showed that the prevalence of caries in the 5-9-year age group was 84.8% and the 10-14 age group was 63.8%. The high incidence of dental caries in children aged 7-12 years can be proven in a study conducted by Fadilah (2021), namely the prevalence of children who experience dental caries in the working area of Puskesmas Padasuka, Cimahi City was 80%. The high prevalence of dental caries at SDN Cimahi Mandiri 2 in children aged 12 years was proven in a study conducted by Ulum B (2024) of 60%.

However, despite these extensive reports on prevalence, no previous studies have examined the association between caries prevalence and specific host-related factors, such as salivary volume and pH, particularly in schoolchildren[11,12]. This gap underscores the need for further investigation to better understand the underlying risk determinants and inform targeted preventive strategies. [13]

Dental caries can be prevented through regular check-ups to dentists and dental health status screening by health workers such as community health centres. However, there is a big problem, namely the low attention of the community, especially children, in routine dental examinations. One of the causes is high anxiety during dental treatment including dental examinations. The risk of dental caries can increase due to low public awareness of dental examinations and dental care as early as possible. Based on this, the problem can be overcome by the use of dentistry 4.0 technology or digital dentistry.[12,14,15]

One of the uses of Digital Dentistry is in the form of dental examinations, treatment plans, treatment, remote health education in the field of dentistry.[14] Utilisation in Indonesia can be done using various platforms, such as surbochat, dashboard, Dentalk, Gigi.ID, and HI BOGI. However, studies investigating salivary parameters using digital platforms remain limited. This gap highlights the need for further exploration of saliva-based assessments in digital oral health monitoring and caries prevention.[16]

HI BOGI, which stands for 'Halo Indonesia with dentist, is a digital dentistry application for oral health education, self-assessment of dental health, toothbrush and flossing alarms, and real-time consultation with dentists. The HI BOGI application was registered with the issuance of HAKI (copyright) in 2021 with application number EC00202149488. The HI BOGI application is the only application that can be used to assess dental health according to the DMF-T index for communities in Indonesia which can be done independently (self-assessment) through taking intra oral photos and then an assessment will be carried out by a dentist which can simplify calculations and shorten examination time.[14,16]

The use and utilisation of the HI BOGI application is for assessing the picture of permanent dental caries status.[15,17] Compared to other teledentistry platforms such as Surbochat, Dentalk, or Gigi.ID, HI BOGI offers a unique advantage in its ability to perform self-assessment of dental caries status based on the DMF-T index through intraoral photo uploads, followed by dentist evaluation. This feature enables standardized, time-efficient, and community-accessible caries assessment, particularly for large-scale oral health screening. Therefore, HI BOGI

was chosen for this study because it allows objective and practical evaluation of salivary parameters and caries status within a digital framework suited to Indonesia's public health context.

The novelty of this research lies in the integration of salivary parameter assessment with digital dental health evaluation using the HI BOGI application, which has not been previously explored in Indonesia or globally. This innovative approach bridges the gap between teledentistry and biological indicators of oral health, offering a more comprehensive understanding of caries risk assessment in children. Therefore, this study aims to analyze the correlation between salivary parameters (volume and pH) and the incidence of dental caries among 11–12-year-old children using the HI BOGI application.

METHODS

This was an analytical observational study with a cross-sectional research design approach. The population in this study was all students aged 11-12 years in 2023/2024 from 91 public primary schools in Cimahi City. The sample in this study represented the entire population, which was determined by fulfilling the inclusion and exclusion criteria.

The participants of this study met the following inclusion criteria: primary school students registered as active students in 2023/2024; public primary school students aged 11-12 years old in Cimahi City; and willing to complete the research until the end of the study. The participants of this study met the following exclusion criteria: Students were absent from school activities on the day the study was conducted; Students at the time undergoing orthodontic treatment; Students who were not cooperative; Students who had difficulty opening their mouth maximally.; Students who had physical and mental limitations. The sample size in this study was calculated using the single sample size formula for correlation analytic tests.

The sample size was calculated using the correlation formula with the parameters of significance level ($\alpha = 1.64$) and statistical power ($\beta = 0.84$). The minimum correlation coefficient considered meaningful was set at $r = 0.285$ based on Fadilah (2019). By substituting these values into the formula, the calculation yielded a sample size of 74.585, which was rounded up to 75 participants.[18] Based on the results of the formula, the minimum sample size was 75.

The sampling technique used a random sampling technique with a cluster random sampling approach, namely, by randomly selecting several groups from the population and then dividing the population into several groups/clusters. The cluster random sampling procedure began with the stratification of all primary schools in Cimahi City based on geographical location into three sub-districts (North, Central, and South). Schools were randomly selected from each sub-district to ensure proportional representation. Specifically, two schools were chosen from each sub-district to balance the sample across regions while maintaining data collection feasibility.

This approach allowed for the inclusion of schools from all subdistricts, thereby representing the overall distribution of the target population. The final sample therefore consisted of six schools, with an approximately equal proportion of students from each sub-district, which was considered adequate to reflect the geographic diversity of the study population.

The clusters in this study included 91 primary schools in Cimahi City from three sub-districts, namely South Cimahi, Central Cimahi, and North Cimahi, and two schools/clusters in each sub-district to obtain a total of six schools. A cluster random sampling technique was applied, with schools serving as primary sampling units. To address potential intra-cluster correlation, the design effect was considered during sample size calculation.

Representative sampling from the selected schools was conducted using a random process using the SPSS programme. The locations of this study were SDN

Cibeber 1, SDN Melong Mandiri 4, SDN Cimahi Mandiri 2, SDN Cimahi Mandiri 4, SDN Cibabat Mandiri 2, and SDN Cipageran Mandiri 2

The variable of this study was salivary volume, which means that the saliva collected for 60 seconds in an unstimulated condition was then collected and measured by looking at the scale in the collection cup measuring cup.13,14,66 The results of measuring salivary volume in the form of Ordinal consisting of Very Low (<0.5 mL); Low (0.5-1.4 mL), and normal (>1.5 mL). Salivary pH in this study was collected using the spitting method and measured with a pH strip.13,53,68,72 Research instruments were used to determine salivary volume and pH using a collection cup and digital stopwatch.

Researchers collected data on salivary volume and pH using the following steps: a. pH strips and a calibrated collection cup (or measuring cylinder) were prepared for saliva collection. b. Each respondent was instructed to expectorate unstimulated saliva continuously for 60 seconds into the collection cup provided, as illustrated in Figure 1. c. Salivary volume was measured by reading the scale on the collection cup or measuring cylinder and recorded using Google Form. d. Salivary pH was assessed by immersing a pH strip into the collection cup containing the participant's saliva and allowing it to react for 10 s, as shown in

Figure 2. e. The color change on the pH strip was compared with the manufacturer's reference scale to determine the salivary pH value, as illustrated in Figure 3. f. The obtained pH values were subsequently recorded in Google Forms. g. After the measurement, the collection cup, used pH strips, and disposable gloves were discarded in a medical waste container.

Figure 1. Saliva examination

Figure 2. Saliva pH was assessed by immersing a pH strip

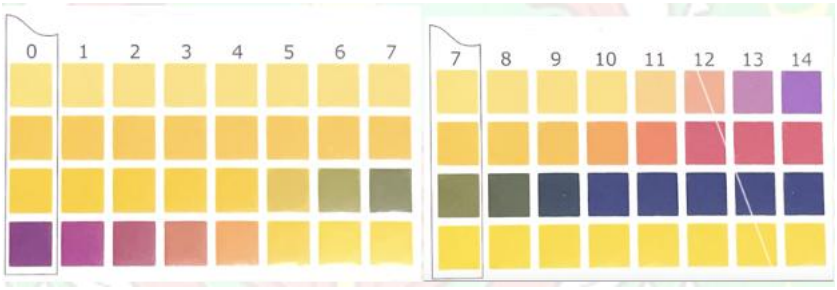

Figure 3. pH Strip Scale

The dental caries status in this study was observed using the HI BOGI application based on DMF-T index scoring. Dental caries status was assessed using the HI BOGI application, which integrates clinical input with a standardized scoring system. The HI BOGI application was used as a structured data-capture tool during the clinical examination. For each permanent tooth, the examiner selected one code describing the tooth's status (e.g., sound, decayed, filled, missing due to caries).

The application was configured to apply standard DMFT rules: each tooth contributes at most once to the DMFT total (D, M, or F). The app automatically summed the tooth-level codes into an individual DMFT score (DMFT = number of decayed teeth + number of missing teeth due to caries + number of filled teeth). If a tooth showed both a restoration and an active carious lesion (restored with recurrent decay), the tooth was classified as decayed (D should take precedence over F) following standard DMFT coding conventions. Missing teeth were counted as M only if extraction was due to caries (not due to trauma, orthodontic extraction, congenital absence, or other causes). These DMFT rules follow the WHO and standard epidemiological guidelines in the application

Clinical examinations were performed by trained examiners who received calibration sessions before data collection. Inter-examiner reliability was tested using Cohen's kappa, with a value of ≥0.80, considered acceptable for consistency. The data were then recorded in the application for analysis.

Several measures were implemented to minimize the bias. Selection bias was reduced by using random sampling of schools and including all eligible children within the selected clusters. Information bias was limited through the use of standardized saliva collection protocols and examiner calibration. Observer bias was minimized by ensuring that the examiners were blinded to the salivary test results during caries assessment.

The tools used in this study consisted of an android-based device with the HI BOGI application, cheek retractor, flashlight (head lamp), pH strip, and a digital stopwatch. The materials used in this study consisted of cotton, alcohol, disinfectant, hand sanitizer, mask, gloves (handscoon), collection or measuring cup, and tissue. The research period was from September to December 2024.

Written informed consent was obtained from the parents or legal guardians of all the participating children prior to their enrollment in the study. In addition, verbal assent was obtained from the children to ensure their willingness to participate in the study. All participants were informed of the purpose, procedures, potential risks, and benefits of the study before data collection.

Data analysis was performed using the statistical test using univariate and bivariate data analyses. Univariate analysis was used to determine the frequency distribution of independent variables, namely salivary volume and pH, and dependent variables, namely dental caries status (DMF-T scoring).

Normality tests were performed before bivariate analysis using the Kolmogorov-Smirnov test (n>50). Data that were not normally distributed ($p \leq 0.05$) were analyzed using Spearman's rho correlation test. Bivariate analysis aimed to analyze the correlation between independent variables, namely, volume and pH of saliva, and dependent variables, namely, dental caries status (DMF-T

index). This test used a 95% confidence degree and an error degree of 5% or a = 0.05.

RESULTS

This study obtained data on saliva volume and pH from 285 respondents and examined caries status using the DMF-T index with the HI BOGI software application in children aged 11–12 years in December, 2024.

Table 1. Respondent characteristic

Respondent Characteristic	Number	Percentage
Gender		
Male	137	48.1
Female	148	51.9
Age		
11 years old	130	45.6
12 years old	155	54.5
District Region		
South Cimahi	114	22.8
North Cimahi	106	40
Central Cimahi	65	37.2

The results showed that the majority of respondents were female (51.9%) and 12 years old (54.4%). The majority of respondents were from North Cimahi (40%) (Table 1).

Table 2. Categories of Saliva Volume

Categories of Saliva Volume	Number	Percentage
Low	168	58.9
Normal	107	37.5
High	10	3.5

Table 3. Saliva pH

Saliva pH	Number	Percentage
Acids	107	65.6
Neutral	85	29.8
Bases	10	4.6

The pH levels of saliva in the respondents of this study, which included children aged 11–12 years, were categorized as acidic (pH < 6.7), normal (pH 6.7–7.4), and alkaline (pH > 7.4). The results of this study showed that 187 children had low saliva volume (58.9%), but 65.6% had an acidic pH (Tables 2 and 3).

Table 4. Dental Caries Status

DMFT Index	Number
Decayed teeth	249
Missing teeth	46
Filling teeth	12

Table 5. DMFT Index

Variabel	Mean ± SD
DMFT Index	2.61 ± 1.77

Tables 4 and 5 show the dental caries status analysis of children aged 11 to 12 years, based on the DMF-T index computation. According to these findings, the majority of pupils had mild dental caries, with an average of 2.61 teeth impacted.

Table 6. Children's oral caries condition and saliva volume

Variabel	Saliva Volume		
	Low	Normal	High
DMFT Index	2.77(168)	2.44(107)	2(10)

Table 7. Children's oral caries condition and pH saliva

Variabel	Saliva Volume		
	Acids	Neutral	Bases
DMFT Index	3.55(85)	2.33(187)	1.92(13)

Table 8. Related Saliva Volume dan pH with Dental Caries

Variabel	R	P Value
Saliva Volume and Dental Caries	-0.0117	0.048
Saliva pH and Dental Caries	-0.287	0.000

According to the findings, most children had dental cavities and little saliva (Table 6). Most pupils had dental cavities and acidic saliva. According to the subdistrict-based description of dental caries, children in the Central Cimahi subdistrict had moderate dental caries, with an average DMFT index of 2.75. According to the study's findings, dental caries in youngsters between the ages of 11 and 12 years were significantly correlated with little saliva and an acidic pH (Tables 7 and 8).

The distribution of dental caries status among children aged 11–12 years varied across the three districts of Cimahi City. As shown in Figure 4, the mean DMFT index was highest in Central Cimahi (2.75), followed by North Cimahi (2.58), and lowest in South Cimahi (2.42). Although the differences in the DMFT index across districts were relatively small, the findings suggest a slightly higher caries burden in the central urban area than in the northern and southern regions. This geographical variation may be influenced by differences in environmental factors, dietary habits or access to oral health care services.

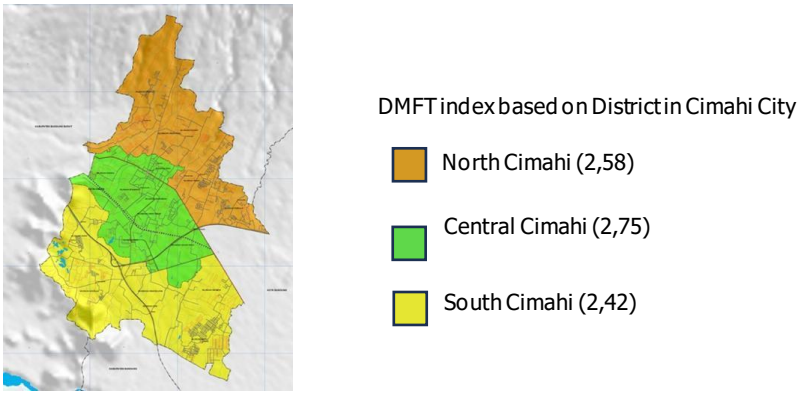

Figure 4. Dental Caries Status among children 11-12 years old

DISCUSSION

According to the study's findings, samples with the lowest saliva volume had the highest DMF-T index value (2.77) in table 6, suggesting that among children at Cimahi City primary schools who were 11–12 years old, the lower the saliva volume, the higher the DMF-T index. These results are consistent with a 2021 study by Paramanandana on 7–9-year-olds in Denpasar, who discovered that children with reduced saliva volume had high DMF-T scores, and that children between the ages of 11 and 12 years, who have low saliva volumes, are more susceptible to dental cavities. The reason for this is that children's high levels of activity and anxiety during salivary examination might lower saliva secretion rates, which results in thicker saliva and less efficacy in carrying out its activities.[4,5]

According to Wani[18], saliva helps retain germs and substrates because saliva reduces its antibacterial components and composition, which helps protect teeth from cavities.[19]These antimicrobial ingredients aid in the natural defense of the mouth cavity against germs and debris. Reduced self-cleaning capacity can make it easier for acidogenic bacteria, which cause dental caries, to adhere to teeth,

and to produce lactic acid. The findings of this study are different from those of a 2021 study on children with Down syndrome in Jember by Rafika, who discovered that the incidence of dental caries decreased with increasing saliva volume.

The study's findings showed (Table 7) that samples with the highest DMF-T scores (3.35) were those with acidic saliva pH, suggesting that children at SDN Kota Cimahi who were 11 to 12 years old had higher DMF-T scores, the more acidic their saliva pH. These results are consistent with those of a 2021 study by Paramanandana on 7–9-year-olds in Denpasar, who discovered that children with high DMF-T scores had acidic saliva pH values.The use of cariogenic foods and beverages, which provide an acidic environment in the oral cavity and lead to higher demineralisation compared to remineralisation, may have an impact on the acidic saliva pH in children at Cimahi City primary schools who were 11 to 12 years old.

This demineralization process supports Ritter's[20] hypothesis that the acidic pH of the oral cavity encourages calcium and phosphate ions from teeth to dissolve into the biofilm. Demineralization is the process by which the pH changes from neutral to acidic, resulting in greater quantities of dissolved calcium and phosphate ions in the teeth than in the oral cavity. Zahara [20] claims that damage to the enamel, dentin, and pulp, which is typified by dental caries lesions, might result from repetitive demineralisation that is not counterbalanced by remineralisation. The findings of this study are different from those of a 2021 study on children with Down syndrome in Jember by Rafika, who discovered that the incidence of dental caries decreased with alkaline saliva pH.

With a p-value of 0.048 ($p \leq 0.05$) and a negative reliability value ($r=-0.117$) (Table 8), the study's findings show that data on the low saliva volume variable among children aged 11 to 12 years at Cimahi City primary schools are linked to the occurrence of caries. We might deduce that the incidence of dental caries increases with a decrease in salivary volume. These results are consistent with those of the 2024 Brazilian study by Muñoz [21] that found that a higher incidence of dental caries is linked to lower saliva volume.

According to Newman's[3] theory, a low saliva volume can hinder the self-cleaning process that removes food particles from the tooth surface. This can lead to bacterial adhesion and substrate retention, which can increase the bacterial metabolism and lactic acid production, ultimately lowering the pH of the mouth. As shown in Subekti's 2020 study on the analysis of cariogenic foods, an acidic environment lowers the pH to a threshold (< 5.5), which can decrease the buffering capacity of saliva. Dental caries is specifically caused by the attachment of cariogenic bacterial colonies on tooth surfaces, which produce organic acids like lactic acid, as a result of decreased saliva's buffering capacity and compromised self-cleaning ability.[21,22]

With a p-value of 0.000 ($p \leq 0.05$) and a negative reliability value ($r=-0.287$) (Table 8), the study's findings show a correlation between the acidic saliva pH variable and the frequency of dental cavities in children aged 11 to 12 years at Cimahi City primary schools. We can deduce that the incidence of dental caries increases with the acidity of the saliva. These results are consistent with those of a 2023 study by Zahara[20] in Aceh Besar, which found that acidogenic bacteria, the main cause of dental cavities, may more easily colonize saliva at acidic pH. Paramanandana supported this notion by stating that acidogenic bacteria that create lactic acid, which dissolves hydroxyapatite through a process called demineralization, are a source of acidic salivary pH. Nanci's[25] theory states that a decrease in bicarbonate ions ($HCO3-$), which neutralize the oral cavity from an acidic condition to a normal pH, is the physiological cause of acidic salivary pH, which in turn causes dental caries.

Dental caries are influenced by both saliva volume and pH. A decline in the ability of saliva to buffer the oral cavity and its self-cleaning function occur simultaneously when saliva volume is low, which promotes bacterial adherence and may result in dental caries. Higher amounts of dissolved calcium and

phosphate ions are found in the teeth than in the oral cavity because acidic saliva pH lowers the buffering ability of saliva. Bicarbonate ions help neutralize the oral cavity from an acidic state to normal pH. The findings of a study by Paramanandana, which discovered a correlation between pH and saliva volume in kids ages 7-9 at SDN 5 Sumerta Denpasar, support this notion. The findings of a study by Rafika, which discovered a correlation between saliva volume and pH and dental caries in children with Down syndrome at SLB Jember, provide evidence of the relationship between these variables and the incidence of dental caries.

The HI BOGI program, a teledentistry technology, was used in this investigation to detect the occurrence of dental caries in place of more conventional diagnostic methods.[17,23,24] The self-assessment option for dental health is one of the characteristics of the HI BOGI program, chosen in this study because it provides an alternative to traditional basic instrumentation. To identify the DMF-T index, this entails taking intraoral pictures, recording them in the system, and then moving on to the scoring stage of the respondents' teeth.

Studies by Fadilah on children aged 6–12 years at Cimahi City primary schools and by Ulum on children aged 11–12 years at SDN Cimahi Mandiri 2 Cimahi City demonstrated the use of the HI BOGI application as a fundamental tool for dental caries evaluation.[12,17] According to a study on dental caries detection using quantitative light compared to conventional examinations conducted by Oh S[22], the self-assessment feature of the HI BOGI application can improve efficiency in terms of time, effort, and cost when compared to conventional examinations. This is because conventional examinations have limitations, such as limited visual access, inadequate lighting, and incomplete examination of dental conditions, which can result in diagnostic errors.

Because patient data are recorded and stored in a cloud database system, the HI BOGI program employed in this study represents a substantial development in the process of diagnosing caries status. This guarantees more secure respondent data storage, enables effective patient data retrieval, and permits the validation or review of patient data reports to prevent errors in determining dental caries status and paperless data storage, which are accessible via the HI BOGI website (Figure 2). More precise and accurate dental examination findings can be obtained using HI BOGI application features in this study to aid in the detection of dental caries. This is consistent with Fadilah's[24] research, which demonstrated the precision and accuracy of HI BOGI application in caries evaluation.[25–27]

This study provides evidence that both salivary volume and pH are key host-related factors influencing the development of dental caries in children.[28] Specifically, reduced salivary volume and acidic salivary pH were strongly associated with higher DMF-T scores, supporting the role of saliva as a critical protective factor for maintaining oral health. These findings strengthen previous reports and highlight the importance of considering salivary parameters in preventive dental strategies.[29,30]

Nevertheless, the results must be interpreted with caution due to methodological limitations, including reliance on children's cooperation during saliva collection, technical challenges in intraoral imaging, and the absence of adjustments for dietary, behavioral, and socioeconomic variables. Furthermore, because the study was limited to a single age group in an urban setting, its generalizability remains restricted. Future multicenter and longitudinal studies across diverse populations are warranted to validate these findings and guide more effective, evidence-based interventions for caries prevention.

The limitations of this study include the absence of interventions to control salivary factors that may influence the salivary volume and pH. Another limitation lies in the data collection process, as saliva examination and photographic documentation were highly dependent on the children's cooperation and compliance, which prolonged the research duration. In addition, adequate lighting is required to obtain high-quality photographs; therefore, the use of additional

lighting devices is recommended for future studies. Furthermore, limitations of the HI BOGI application were also noted, as the process of uploading intraoral photographs required additional time because the system processed previous images and depended on the internet connection of the device being used, which consequently extended the research duration.

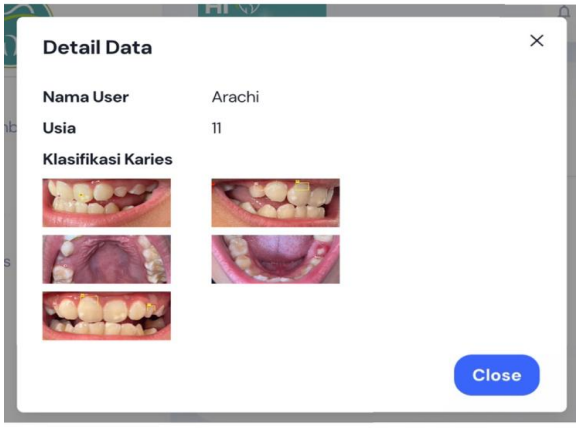

Figure 5. Data Report from HI BOGI Application

CONCLUSION

Using the HI BOGI application, dental caries status was found to be significantly correlated with low salivary volume and acidic salivary pH among children in this age group. Beyond these findings, the study highlights the potential practical utility of the HI BOGI application as a school-based dental health screening tool. The application enables a simple, rapid, and standardized assessment of caries experience and salivary factors, which may facilitate the early detection of at-risk children. Incorporating HI BOGI into routine school health programs can support preventive strategies, promote oral health education, and assist policymakers in targeting interventions more effectively. Future studies with larger and more diverse populations are recommended to further validate the role of this application in community-based oral health surveillance. The implication of this study is that integrating digital applications such as HI BOGI into school-based oral health programs can enhance early detection, prevention, and monitoring of dental caries, thereby contributing to more efficient and equitable community oral health management.

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Informed Consent Statement: Informed consent was obtained from all subjects involved in the study Written informed consent has been obtained from the patient(s) to publish this paper".
Data Availability Statement: Data supporting reported results can be found in the results section of the article manuscript
Conflicts of Interest: The authors declare no conflict of interest

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