# Validation of Cariogram as a Tool for Caries Risk Prediction Among 12-Year-Old Institutionalized Children - A Longitudinal Follow-up Study

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## Abstract

Aim: To evaluate cariogram as a tool for caries risk prediction among 12- year-old institutionalized children and to validate it against the new increment of caries lesions. Materials and Methods: A longitudinal follow-up study was conducted among 36 institutionalized children. Baseline data were collected in the month of January 2012. Children were individually interviewed to record the nonclinical information necessary to complete the cariogram. Clinical information for the assessment of visible plaque was recorded using the Silness and Löe plaque index and evidence of decalcification and caries was recorded using ICDAS criteria. The children underwent the follow-up examination in July 2013 to determine the new increment of dental caries. Results: 52.77% of the participants were classified as low risk and very low risk for future development of dental caries, remainder of the subjects were fairly equally distributed in the medium (19.44%) and high (19.44%) risk groups. Very few (8.33%) participants were classified under very high risk group. Highest odds ratio for disease indicators was 4.20 for past caries experience. Highest odds ratio for pathological factors was 7.15 and 5.54 for the association of M streptococci and visible heavy plaque respectively. Mean caries increment noted from the time of the initial examination to the follow-up was 0.55 ± 0.80 for the total sample. A trend could be noted in which caries increment increased with elevated risk classification, mean caries increment was 1.66 ± 0.57for very high risk, 0.85 ± 0.89 for high risk, 0.71 ± 0.75 for medium risk and 0.27 ± 0.64 for low risk. Sensitivity for CAMBRA was found to be 47.62% with a specificity of 80%, and the area under the ROC curve was found to be 0.638. Conclusion: Cariogram was valid and highly predictive in determining the caries risk among institutionalised children.

*Key Words: Cariogram, Caries risk assessment, Institutionalized children, Validity*

## Introduction

Historically, the management of dental caries was based on the notion that it was a progressive disease that eventually destroyed the tooth unless there was surgical/restorative intervention [1]. Modern management of dental caries is more conservative and is based on principals of evidence-based dentistry, with a more intense focus on prevention. Comprehensive caries control involves focusing on the whole patient to manage the individual risk factors of the patient to promote and maintain optimum oral health [2]. Because of multifactorial etiology of the disease, single factor studies were not very successful in predicting caries prone children [3].

Attempts to develop predictive tests began even before 1900. Since then, many investigators have studied a wide variety of demographic, dietary, physical, chemical, and microbiological factors in search of methods to predict caries occurrence but with only limited success [4].

Risk assessment tool estimate caries risk, identify the primary etiological factors, provide an inventory of the patient's current preventive practices, and serve as a guide for selecting specialized preventive care tailored to that individual's needs [5,6]. Several models and tests are available; the traditional caries prediction models have focused on individual factors associated with high caries activity [7]. Since caries is a multifactorial disease it is important to consider all the factors involved, the multifactorial etiology of caries, points in the direction of constructing a more promising risk assessment model that includes the various factors that contribute to the development of caries as no single test can simultaneously measure the principal components of dental caries [5,8,9].

CRA may be valuable in the clinical management of caries by helping dental clinicians to; Categorize the level of the patient's risk of developing caries to control the intensity of treatment rendered, pin point main etiological factors that contribute to the development of decay and thus determine appropriate form of therapy, assist in restorative treatment decisions (e.g. choice of restorative material), improve prognosis of planned therapeutic care, provide information on what additional diagnostic tests and screening are required, educate and motivate patients to improve and maintain optimum oral health and guide timing of subsequent recall appointments [10-14].

The most recent innovation in caries risk assessment has been the development of an algorithmic model the cariogram, by which the caries risk profile can be formed and graphically represented to the patients. This instrument supports both risk factors and risk predictors by giving predetermined algorithmic weightages to them. This was originally developed in 1996, as an educational model (Swedish version) aiming to demonstrate the multifactorial etiology of dental caries in a simple manner. It has gradually evolved over a long period of time until it became a reality on April 2, 2004 when the internet version (2.01) of cariogram was launched in English [8,15,16].

This multifactorial model, however, has never been evaluated to determine if it can accurately predict caries risk levels and if the overall risk score predicts future dental caries more accurately than any single factor measured. Hence this

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study aimed to evaluate cariogram as a tool for caries risk prediction among 12- year-old institutionalized children and to validate it against the new increment of caries lesions.

## Materials and Methods

### Study design

A longitudinal follow-up study was designed to examine the disease activity, risk factors for dental caries at baseline, subsequent dental caries experience at follow-up after 18 months and to validate the cariogram model with caries increment at follow-up.

### Ethical clearance and informed consent

The ethical clearance was obtained from the Institutional Review Board of Narayana Dental College & Hospital and permission to conduct the study was obtained from principal of Vatsalaya vidhayasharam, Nellore. The purpose of the study was explained to the principal, participating children and their guardians and informed consent was obtained prior to start of the study. The subjects were also informed that they could with draw at any point during the study.

### Sampling procedure

To estimate the sample sizes, a power analysis was performed based on the data obtained by a previous study conducted by Almosa NA et al. [17] with a significance level of 5%, standard deviations within groups of 30 units, a least detectable difference of 20 units between groups on the Cariogram, and a power for that detection of 80%.

The sample size arrived at was 28, to compensate for the loss of sample due to attrition over a period of 18 months 25% of the sample was added, so the final sample consisted of 36 subjects.

### Study subjects

This study was conducted among 12 year old children which is a key risk group according to WHO [18,19]. A total of 36 children who gave informed consent and satisfied the inclusion criteria were selected from a social welfare institute randomly using table of random numbers.

### Eligibility criteria

Children aged 12 years with full complement of permanent dentition who were residing in social welfare schools from past 2 years and who agreed to participate in the study by signing the informed consent, dually signed by both the child and the guardian were included. Children with any systemic diseases, taking any antibiotics during the time of examination and children with special needs were excluded.

### Pilot study

Pilot study was conducted prior to the main study among 6 subjects who were included in the final sample to standardize the proforma, methodology and feasibility of the study. The examiner was trained and calibrated to diagnose caries using ICDAS [20] and for recording Silness and Loe [21] plaque index in the department of Public Health Dentistry by rechecking the scores of the 6 subjects. The related kappa value of the investigator was found to be adequate 0.71 and 0.86 for Silness and Loe plaque index and ICDAS.

### Study procedure

**Data collection instrument**: The data was collected using a custom designed proforma having three parts at two time intervals baseline and follow up. Part-1 recorded demographic details, oral hygiene practices and diet frequency of the participants by an interview. Part-2 clinical examination for recording the amount of plaque and dental caries experience of the participants. Part-3 consisted of saliva collection and analysis.

**At baseline**: The base line data for the study was collected in the month of January 2012. The risk assessment consisted of four steps: an interview, clinical examination (estimation of oral hygiene, dental caries status), saliva sampling/ analysis and creation of risk profile for each child using cariogram which is based on 10 parameters.

Two parameters (“Related diseases” and “Clinical judgment”) were kept constant at score “0 and 1” respectively, while information on the other 8 parameters was gathered from the study.

**Interview**: The children were individually interviewed to record any illness, oral hygiene practices and fluoride exposure. As children may not reveal easily about any illness and may not know whether the toothpaste was fluoridated their guardian assistance was taken to complete the interview.

### Clinical examination

Children were examined for plaque and dental caries. Silness and Loe plaque index (1961) was used to assess the amount of plaque. Dental caries was assessed using the International Caries Assessment and Detection System – II (ICDAS-II) 46 ICDAS classifies the severity of dental lesions from the earliest stages of visual demineralization to frank cavitations. An ICDAS score 0 is used for a sound surface, whereas a score 1 describes the first visual changes in enamel (seen only after prolonged air drying or restricted to within the confines of a pit or fissure), and a score 2 is used for distinct visual changes in enamel. Scores 3–6 describe different degrees of cavitation; with score 3 describing localized enamel breakdown (without clinical visual signs of dentinal involvement), score 4 being lesions with an underlying dark shadow from dentin and score 5 describing distinct cavitation with visible dentin. Score 6 is used for the most severe lesions with extensive distinct cavitation with visible dentin. The examiner observed the buccal, lingual, mesial, distal, and occlusal aspects of each tooth. Changes on tooth surfaces related to dental caries were given scores and recorded based on ICDAS criteria for lesion severity, lesion activity, and filling status.

The caries experience was calculated by adding decayed, missing and filled permanent tooth which gives the past caries experience parameter as it is required for entering in the cariogram model to create caries risk. To establish the decayed component as per the cariogram WHO 1997 [22] criteria was recommended, so scores 0–2 from the ICDAS-II were considered as sound surfaces and scores 3–6 were graded as decayed surfaces for the purpose of entering in to the cariogram computer model [23,24].

**Saliva collection**

Saliva collection was done in the morning at least an hour after their breakfast and tooth brushing. Patients were made to be seated in an upright, relaxed position, a paraffin pellet was given to the children to chew for 30 seconds, then they were asked to spit out the accumulated saliva, then the child was asked to continue to chew for five minutes, and the accumulated saliva was collected continuously in to a measuring sterile test tube with the help of a sterile funnel. After 5 minutes the amount of saliva collected was calculated by volumetric analysis [25].

**Salivary flow rate**

Salivary flow rate was assessed by measuring the amount of saliva secreted per minute using volumetric analysis [25].

**Salivary buffering capacity**

The buffer capacity of the stimulated whole saliva was determined using Saliva check buffer strip (GC Corporation, Japan). An indicator system incorporated in the test strip changes color, clearly showing the buffer capacity of the saliva [26]. By placing a test strip facing up on an absorbent paper without touching the test strip, the enclosed pipette was used to apply a drop of stimulated saliva to the test strip, enough to cover the entire strip. When a drop of collected saliva was added to the test pad of the strip, the saliva starts to dissolve acids which have been dried into the test strip, which contains pH sensitive dyes. After exactly 2-minute reaction time three colours were obtained: green, blue, and red which were analyzed by the colour combinations and buffering capacity of saliva was obtained according to the provided model chart.

**Salivary microbial analysis**

The fresh saliva sample which was collected in a sterile test tube was then used for culturing on selective media and for microbial analysis. Chair-side tests CRT Bacteria (SM Strip Mutans and LB strips, Ivoclair Vivadent, Shawn, Europe) was used to evaluate both *Mutans streptococcus* (MS) and *Lactobacillus* (LB). The agar carrier was removed from the test vial; $NaHCO_3$-tablet was placed at the bottom of the vial for creating anaerobic medium. Then the protective foils from the two agar surfaces are removed carefully without disturbing and touching them for preventing of contamination. Both the agar surfaces were thoroughly wetted with saliva, using a pipette without scratching the agar surface and by holding the agar carrier slightly oblique which will allow the excess saliva to drip off. Then the agar carrier is slide back into the vial and the vial is closed tightly. A waterproof pen was used to note the name of the child and the date on the vial. The test vial was placed upright in the incubator and incubated at 37°C/99°F for 48 hours. The vial from the incubator was taken out after 48 hours to compare the density of the *mutans streptococci* and *lactobacilli* colonies with the corresponding evaluation pictures in the enclosed model chart [27].

**Creation of cariogram**

When all the information was available they were scored according to the predetermined scale (*Table 1*). The scores were entered into the cariogram computer programme to calculate the 'caries risk' and conversely 'chance of avoidance of caries' for each child.

*Table 1. Distribution of children according to various cariogram parameters at baseline.*

| Cariogram parameters | Variables | Baseline n=36 | (%) |
|---|---|---|---|
| DMFT | DMFT-0 | 17 | -47.22 |
| | DMFT>0 | 19 | -52.78 |
| Lactobacillus | <$10^4$ CFU/ml | 15 | -41.66 |
| | $10^4$-$10^5$ CFU/ml | 13 | -36.11 |
| | >$10^5$ CFU/ml | 8 | -22.22 |
| Plaque amount | 0.1 to 0.9 (Good) | 25 | -69.44 |
| | 1.0 to 1.9 (Fair) | 11 | -30.56 |
| | 2.0 to 3.0 (Poor) | 0 | 0 |
| *M Streptococci* | <$10^4$ CFU/ml | 15 | -41.66 |
| | $10^4$-$10^5$ CFU/ml | 14 | -38.88 |
| | >$10^5$ CFU/ml | 7 | -19.44 |
| Fluoride program | Fluoridated dentifrice once daily | 36 | -100 |
| Saliva Flow | 0: >0.7 ml/min | 24 | -66.66 |
| | 0.3–0.7 ml/min | 12 | -33.33 |
| | <0.3 ml/min | 0 | 0 |
| Buffering capacity | pH >6.0 | 18 | -50 |
| | pH 4.5 – 5.5 | 17 | -47.22 |
| | pH <4.0 | 1 | -2.77 |

**At follow-up**

After 18 months, all the children from the original sample were re-examined. Children were contacted, new increment of decayed and filled permanent tooth surfaces was measured for each child from the date of the baseline checkup (in January 2012) to the date of the 18 month follow-up (July 2013). All the tooth surfaces were evaluated for newer increment of dental caries using ICDAS-II. For follow up examination to assess Dental caries incidence ICDAS - II score ≥ 1 were considered as decayed.

Caries risk was reevaluated at follow up examination by reassessing all the parameters required for creation of cariogram model to assess caries risk and to evaluate any change that may have occur between baseline and follow-up examination.

**Data analysis**

All data were analyzed using the software STATA (Stata Corporation, College Station, Tex., USA, version 12). Descriptive statistics including the means and standard deviations of all cariogram risk related factors were calculated for all five caries related groups. Differences between baseline and follow up DMFT between different cariogram groups were assessed using Kruaskal Wallis ANOVA. A stepwise logistic regression analysis was performed to assess the impact of independent factors on DMFT. Statistical significance was set at 5% level. The performances of Cariogram in predicting caries increment were evaluated by receiver operating characteristic (ROC) analysis. The gain of certainty was calculated as the sum of sensitivity and specificity based on ROC analysis, sensitivity (Se), specificity (Sp), positive predictive value (PPV) and negative predictive value (NPV) of the caries risk assessment tool were calculated using the "Total Risk Score" as the predictor variable for the development of caries.

## Results

Mean age of the study subjects was 12.86 ± 0.67 years with an age ranging from 12 to 14 years. Majority of the participants (52.78%) were 13 years old and there was a higher representation of males (66.67%). Analysis of sociodemographic characteristics revealed that the children were from socially deprived families and their families were from lower socioeconomic class and there was a slightly higher representation from urban areas (63.99%). 36.11% of children had a previous or past visit to dentist. Since the children were staying in a boarding school their diet frequency and oral hygiene practices were same.

Distribution of children according to various cariogram parameters revealed that, 52.78% experienced one or more carious lesions at the time of the baseline examination, with a mean DMFT of 1.91 ± 2.32, 69.44% had good oral hygiene, stimulated salivary rates were normal for 66.66% and 50% of the children had adequate salivary buffering capacity. The bacterial challenge for *mutans Streptococci* and *Lactobacilli* was low for 41.66% and moderate or high for 58.44% of children as depicted in *Table 1*.

The frequencies of subjects within the five caries risk categories, at baseline are presented in *Table 2*. Approximately one-half (52.77%) of the participants were classified as low risk and very low risk for future development of dental caries. The remainder of the subjects were fairly equally distributed in the medium (19.44%) and high (19.44%) risk groups. Very few (8.33%) participants were classified under very high risk group.

***Table 2.*** *Distribution of children in five cariogram risk groups at baseline and caries prevalence at baseline.*

| Cariogram risk groups | Baseline (%) |
|---|---|
| High risk (0-20%) | 3 (8.33) |
| High medium (20-40%) | 7 (19.44) |
| Moderate (40-60%) | 7 (19.44) |
| Low medium (60-80%) | 11 (30.55) |
| Low risk (80-100%) | 8 (22.22) |

Logistic regression analysis was carried out to determine the variables which were the strongest predictors of caries activity when all the individual factors were considered simultaneously. *Table 3* presents Odds Ratio with 95% confidence intervals (CIs) of the disease indicators, the pathological and protective factors of the cariogram logarithm. The highest odds ratio for disease indicators was 4.20 for the past caries experience. The highest odds ratio for pathological factors was 7.15 and 5.54 for the association of M streptococci and visible heavy plaque respectively. When caries prevalence was regressed over independent variables at baseline, past caries experience, *M. streptococci* colonies and the amount of plaque were the factors which were found to be strongly associated with caries activity which was statistically significant (*Tables 4 and 5*).

***Table 3.*** *Stepwise univariate logistic regression analysis of caries prevalence at baseline with different cariogram related independent variables at baseline.*

| Independent variables | S.E. | Z-value | P-value | Odds ratio |
|---|---|---|---|---|
| DMFT | 0.75 | 3.64 | 0.05* | 4.2 |
| Saliva Flow | 0.99 | 1.33 | 0.18 | 1.95 |
| Buffer | 0.9 | 0.53 | 0.46 | 0.52 |
| *M. Streptococci* | 4.4 | 3.17 | 0.00* | 7.15 |
| *Lactobacillus* | 0.89 | 1.06 | 0.29 | 1.73 |
| Plaque | 3 | 3.1 | 0.00* | 5.54 |
| Cariogram risk | 1.14 | 1.59 | 0.2 | 0.24 |

***Table 4.*** *Cross tabulation of caries incidence at 18 month follow up with overall caries risk level predicted by cariogram at baseline.*

| Cariogram risk groups | No of children n (%) | Baseline DMFT (Mean, SD) | Children with caries increment n (%) | Follow-up DMFT (Mean, SD) | Mean caries increment | % | |
|---|---|---|---|---|---|---|---|
| Very high | 3 (8.33) | 5.67 ± 1.15 | 3 (100) | 7.33 ± 0.58 | 1.66 ± 0.57 | 8.33 | |
| High medium | 7 (19.44) | 3.86 ± 2.41 | 4 (57.14) | 4.86 ± 3.24 | 0.85 ± 0.89 | 11.1 | |
| Moderate | 7 (19.44) | 1.71 ± 1.60 | 4 (57.14) | 2.43 ± 1.99 | 0.71 ± 0.75 | 11.1 | |
| Low medium | 11 (30.55) | 1.09 ± 1.81 | 2 (18.18) | 1.36 ± 2.34 | 0.27 ± 0.64 | 5.56 | 5.2018 |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| Very low | 8 (22.22) | 0.13 ± 0.35 | 0 | 0.13 ± 0.35 | 0 | 0 | p-value (0.02*) |
| Total | 36 (100) | 1.92 ± 2.32 | 13 (36.11) | 2.47 ± 2.98 | 0.55 ± 0.80 | 36.1 | |
| Kruaskal Wallis ANOVA | | | | | | | |

***Table 5.*** *Sensitivity, specificity and predictive values of individual cariogram elements, cariogram cutoff 1 and cariogram cutoff 2 with caries incidence.*

| Tests | Sensitivity | Specificity | PPV | NPV | Diagnostic accuracy |
|---|---|---|---|---|---|
| Salivary Flow | 53.85% | 78.26% | 58.33% | 75.00% | 69.44% |
| Buffering capacity | 72.22% | 44.44% | 56.52% | 61.54% | 58.33% |
| *Mutans streptococci* | 53.85% | 86.96% | 70.00% | 76.92% | 75.00% |
| *Lactobacillus* | 30.77% | 86.96% | 57.14% | 68.97% | 66.67% |
| Plaque | 53.85% | 82.61% | 63.64% | 76.00% | 72.22% |
| Past caries experience | 63.16% | 94.12% | 92.31% | 69.57% | 77.78% |
| Cariogram Cut-off 1 | 53.85% | 86.96% | 70.00% | 76.92% | 75.00% |
| Cariogram Cut-off 2 | 84.62% | 73.91% | 64.71% | 89.47% | 77.78% |

*Table 4* showing the caries incidence at 18 months follow up with overall caries risk level predicted by Cariogram at baseline. Participants' caries increment, expressed as caries incidence from the initial examination to subsequent follow-up examination at 18 months was 36.11%. The mean caries increment noted from the time of the initial examination to the follow-up was 0.55 ± 0.80 for the total sample. A trend could be noted in which caries increment increased with elevated risk classification, mean caries increment was 1.66 ± 0.57 for very high risk, 0.85 ± 0.89 for high risk, 0.71 ± 0.75 for medium risk and 0.27 ± 0.64 for low risk. The trend of increased caries experience with elevated risk classification was statistically significant ($p<0.02$). Nearly one third of the sample (36.11%) had developed new carious lesions, of the individuals deemed at a very low risk for future caries activity by the risk assessment model, none of them developed new carious lesions, only 18.18% had new caries for those who belong to low risk group. Caries experience increased significantly in the moderate risk and high risk categories with 57.14% and 100% of high and very high risk participants respectively presenting with new caries at their recall examination at 18 months.

Sensitivity (Se) and specificity (Sp) of the cariogram were compared at two cut-off points with individual cariogram elements. The accuracy varied among the two cariogram cut-off approaches, when the moderate risk group was combined with the low risk groups it was taken as cut off 1 and when moderate risk group was combined with the high risk groups it was taken as cut off 2. Sensitivity and NPV both increased for cariogram cut off point-2 (Se 53.85 to 84.62% and NPV 76.92 to 89.47%). Conversely, Specificity and PPV both decreased, 86.96% to 73.91% and 70 to 64.71%, respectively, cariogram with cut -off point-2 had the highest diagnostic accuracy of 77.78% (*Table 5*).

ROC analysis was done, while the area under the ROC curve was plotted for the cariogram and compared for two cut-off points, and individual cariogram elements in plot. The area under ROC curve for cariogram cut off -1 and cut off 2 was 0.735 and 0.771 respectively, for the individual elements assessed past caries experience had the highest area under the ROC curve 0.786 which was highly significant (0.00*).

## Discussion

The management of caries needs to be based on the patient's risk of developing caries in order to prevent caries and to be cost effective [5]. In this context, the caries risk assessment could be of great benefit in daily clinical practice when it comes to evaluating the patient's caries profile [28]. So this study was planned to evaluate the cariogram model by predicting caries risk and help allocate patients to the right caries risk category and to identify the caries-related factors over a period of 18 months.

There was no significant difference observed among the study participants regarding their oral hygiene practices and dietary practices. Since all the children were residing in a social welfare institute they had common practices of using tooth brush, fluoridated tooth paste, used to clean their tooth once daily and were under the same diet and all the children were from low socioeconomic background.

Clinical examination for detecting dental caries at base line and follow up was done using ICDAS-II criteria. ICDAS-II has certain advantages as it allows evaluation of both non-cavitated (incipient lesions) and cavitated caries lesions it help in detecting caries incidence and its associations more sensitively during a shorter follow-up period, this system provides data comparable with WHO criteria [23,24].

Collection of stimulated saliva for analysis of flow rate, buffering capacity and microbial assessment in the present study was done using spitting method by using a softened paraffin wax. This method was found to be most reliable method for collecting stimulated saliva in children. Since softened paraffin wax (Ivoclair Vivadent, Shawn, Europe) is more attractive which could be due its chewing gum consistency and it is pleasing for the children [18,25]. Hence this method of saliva collection was employed and stimulated flow rate was assessed by volumetric analysis.

Salivary check buffer strip (GC Corporation, Japan) was used to estimate the buffer capacity of the stimulated whole saliva. This has an indicator system incorporated in to the test strip which changes colour, at different acid concentrations. Since this method is a new and simplified method, as it readily estimates the buffering capacity then electrolyte method at chair side this method was adopted [26].

Chair-side tests kits CRT Bacteria, (SM Strip Mutans and LB strips, Ivoclair Vivadent, Shawn, Europe) was used for microbial assessment in the present study rather than microbial lab investigations as it requires a trained laboratory personnel and equipment's and need coordination with microbial department. CRT Bacteria was reliable and simplified procedure suitable for quick chair side assessment [27] so it was adapted for the present study.

Multifactorial caries risk assessment models like cariogram are becoming more popular and their use more prevalent as they present an overall picture of the interaction of the multitude of caries risk factors [9,28,29]. The dated method of relying on a single factor to dictate the development of a multifactorial disease often would lead to inaccurate predictions [30]. When all independent variables of cariogram were considered in the logistic regression analysis, M streptococci, plaque amount and past caries experience were significantly associated with caries activity. These findings were similar to the findings of studies reported by Scheinin A et al. [31], Hebbal M et al. [32,33], Basha S et al. [34].

Bacterial counts (i.e., *Streptococcus mutans* and *Lactobacillus*) were found to be significantly associated with caries activity in the study population. This finding was quite expected since a systematic review of literature has concluded that increased salivary *mutans streptococci* counts are associated with higher caries outcomes in childhood [35]. Historically, when studied in groups, caries experience has been found to be related to *Streptococcus mutans* counts; however, bacterial counts by themselves are poor predictors of caries activity at the individual level [30]. In the present study, 41.66% of children had low levels of *Streptococcus mutans* and *Lactobacillus* at baseline but still presented with caries risk. This indicates that bacterial counts alone cannot predict future caries experience for an individual very accurately and thus we must rely on the overall risk score (i.e., the interaction of multiple factors) to assess risk level.

Because dental caries is a microbiological disease, a prerequisite for caries development is the presence of dental plaque on the teeth, and unless this biofilm is present caries will not develop, regardless of any other risk factors [14]. So the amount of plaque was found to be significantly associated with caries activity in the study population, this was in line with prospective studies conducted by Mattila ML et al. [36] and Basha S et al. [34] who have showed significant association between plaque score level and caries experience and increment. Researchers have failed to demonstrate a consistent relationship between dental plaque scores and caries. Not all patients with poor plaque control inevitably develop caries; however, those who clean their teeth infrequently or ineffectively may be at higher risk for developing carious lesions [10,14]. Furthermore, conditions that hinder long-term maintenance of good oral hygiene, such as mental and physical disabilities and oral appliances, are positively associated with a higher caries risk [37].

According to the literature, past caries experience remains the most powerful single predictor of future caries development. It is the most common risk indicator used in clinical practice and in research due to its strong predictive ability [38-41]. Although caries experience is a powerful indicator of caries activity, it cannot specify the particular risk factors that are causing the dental caries and, therefore, it cannot be used alone to specify appropriate preventive strategies directed at eliminating or modifying the patient's risk for caries development [9,29,42]. DMFS has been documented as one of the strong predictor for future caries in the present study; this was same as reported by Reich et al. [5], Zero et al. [11], Fontana and Zero [10].

Caries incidence at 18 months follow up in the study population revealed that the number of carious teeth rose proportionately across the risk groups (1.66 ± 0.57 in very high risk group to 0 in very low risk group). Secondly, as the caries risk rose, the number of individuals displaying caries at the follow-up exam also increased. Approximately 18.18% of the low risk subjects presented with new caries lesion at the recall examination, while nearly 57.14% of the high risk group exhibited new carious lesions. Predicting caries in the moderate risk group proved to be more challenging; just over half of the moderate risk group presented with dental decay at the follow-up appointment. The caries incidence was increased as the risk increases this was in accordance to the studies conducted by Hänsel PG and Bratthall D [8], Hänsel Petersson G et al. [8,9], Bratthall D and Hänsel PG [29]. A clinical reflection based on these findings would be that it is more important to identify individuals at increased caries risk than to unveil a diminished risk.

The calculation of sensitivity, specificity, positive and negative predictive values is the preferred method for evaluation of disease prediction. The combined sensitivity + specificity of the present study was 141% similar to the findings of study conducted by Gao X et al. [43] 143%, Peterson et al. [44] 136%, Holgerson et al. [45] 134% and Utrej et al. [46] 127%.

For many people, pictures are easier to look at than tables with extensive numbers of numerals. Receiver Operating Characteristic (ROC) curves provides an alternative way of summarizing the predictive power of a multiple-level risk marker. The area under the ROC was 0.735 for cariogram in the present study which was similar when compared to Gao X et al. [43] (0.781), Petersson [44] (0.750) in their studies and it was much higher in a study conducted by Campus [47] (0.929) which showed that cariogram was highly valid predictor model.

The variables with missing data (fluoridated community, fluoride mouthwash, xylitol gum, chlorhexidine prescription, appliances, saliva reducing factors and $CaPO_4$ paste) were not taken into account in the statistical analysis, as the history of these factors was not available in the records.

The total proportion of children classified as having caries risk was approximately 72.22%. There was no preventive intervention as such given to the study participants during the course of the study by the investigators, but all children involved in the study were motivated towards preventive interventions and specific home care recommendations. The data have not been analysed to determine whether those who were provided with specific recommendations had less tooth decay or not. Further research is needed to determine if those who received treatment, preventive intervention and specific home care recommendations had a lower caries increment at the follow-up examination.

## Conclusion

Cariogram was valid and highly predictive in determining the caries risk among institutionalized children. Children who were categorized into moderate and high risk groups at baseline developed a significantly higher new increment of caries at follow-up, which confirmed the validity of the tool.

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