**Research Article**

# Zero Inflated Binomial Model for Prognosis of the Risk Factors Associated with dmft Index in Children Aged 5 - 6 Years in Tehran

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**Abstract**

**Background and Objective:** The most common index in dental studies is the decayed, missing or filled teeth (dmft)/DMFT. Risk factor evaluation in order to investigate the significant factors that affected this dmft in children has an important role in dental epidemiological studies. This study aims to use a zero inflated binomial model for investigating the risk factors that affected the dmft in children aged 5 - 6 years in Tehran, Iran.

**Methods:** This cross - sectional study was a part of a national survey for assessing the oral health status of Iranian citizens in 2012. The target population was children aged 5 - 6 years. The information and oral examination were collected by the WHO recommended clinical examination form and a trained calibrated dental team (dentists and hygienists). A binomial zero inflated model (ZIB) with random effect was used for evaluating the effect of all variables on dmft.

**Results:** In general, 593 subjects were studied. From the entire subject in this study the frequency of zero was 1071 (45%). The result of ZIB model with random effect in zero part showed that brushing the teeth (OR = 3.5; P value = 0.012) and mothers with university education (OR = 11.24; P value = 0.016) had significant relation with zero dmft. The variance component of random intercept in zero part was significant too ($\sigma^2$ =4.68, P < 0.001).

**Conclusions:** Zero inflated binomial model with random effect in zero part fitted better to this data. Brushing the teeth and high education of mothers had protective effect for dmft in children aged 5 - 6 years in Tehran.

*Keywords:* ZIB Model, Dental Caries, dmft

## 1. Background

Oral health has an important role in general health. Various oral health diseases have affected the well - being of population, but among them dental caries is the most common and widely spread disease. Dental caries is well known as a progressive disease, which can cause pain, infection, and possible disfigurement, particularly in children (1).

There are some diseases, such as asthma, diabetes, obesity and dental caries that are very common in children but dental caries as the most common disease, is up to eight times more prevalent than asthma (2). Also it has been ranked as number three among all non - communicable chronic diseases which require worldwide attention for prevention and treatment by the World Health Organization (WHO) (3). Different studies from all over the world

examined the situation of dental caries among children; A study from USA has shown that almost 20% of 2-4 - year - old children have clinically detectable caries and the percent of having at least one or more teeth with caries raised to 80% by age 17 (4). Another study, conducted in Iran has reported that only 48.3% of 3-5 - year - old children were caries - free (5).

The most common index in dental epidemiological studies is the decayed, missing or filled surface dmft/DMFT index. This index has been used for more than 70 years and is the key measure of caries experience in dental epidemiology (6). This index is applied to the permanent or primary dentition. In the case of primary dentition, it is written in lowercase letters, the dmft index, and accounted for a child as the total number of teeth that are decayed (d), missing (m), or filled (f) and scores ranging from 0 to 20 (7). The most important characteristic of this

index is its count and often has a huge proportion of zeros due to its nature. This high proportion which is called zero inflated, can make misleading results if it is not taken into account during analyzing. This high proportion of zero makes the dmft index tend to exhibit overdispersion. The phenomenon of overdispersion is denoted to the case where excessive variation in data set exists, relative to Poisson distribution as a most common distribution for the count data (8-13). Therefore, Poisson modeling is unable for analyzing this data. Recently, special statistical models were developed for analyzing this zero inflated data (14-16) including; Zero Inflated Poisson (ZIP) regression, Zero Inflated Negative Binomial (ZINB) regression and Zero Inflated Binomial (ZIB), which tried to overcome the problem of zero inflated count data. In the context of dmft index, this modeling assumes that there are two latent or unobserved groups which could contribute to the excess zeros, a most common subpopulation of this kind are children who come from the zero state (they have no decayed teeth due to their personal characteristics) and the subpopulation of children, who are susceptible to caries development, or zero for chance or misclassification (17).

The aim of this study was fitting a Bayesian ZIB model to assess the risk factors associated with dental caries among 5 - 6 years old children in Tehran.

## 2. Methods

### 2.1. Participants

This study was designed as a cross - sectional study. The data belonged to a national survey for assessing the oral health status of Iranian citizens in 2012 (18). According to world health organization (WHO), the 5-6 - year old life period is one of the recommended age groups for evaluation of oral health status at the national level. At this age group, the primary dentition is evaluated.

Sample size selection was according to a published book of WHO which claimes that 300 samples in each age group are needed for dmft studies (19). In current study, we used data of Tehran province and due to the large population of Tehran compared to other provinces, the sample size of this Province was chosen twice that of other provinces. Totally 593 samples were selected (7 samples did not respond).

For Selecting the samples one - stage stratified cluster sampling was used. Cities in Tehran Province were considered as the clusters. Clusters were selected by systematic random sampling. The 10 - digit zip codes were used for choosing the cluster heads within each stratum.

Each cluster included one or more blocks or part of a block in cities. In addition, a cluster encompassed one or more villages or part of villages until sufficient samples were recruited in each county. Oral examinations and the WHO recommended clinical examination form was filled out by a trained calibrated dental team (dentists and hygienists). Other information regarding demographics, health attitude, and health behaviors was filled out by parents using the second WHO questionnaire. The information that was collected in this study included sex, place of residence (rural or urban), family size, brushing (yes or no), visiting by dentist in last year (yes or no), consuming fresh fruit (several times in a day or rarely) and education of mother (illiterate, primary or high school, university).

The dmft index regarded as a dependent variable, including the total number of teeth that are decayed (d), missing (m), or filled (f) was evaluated in all subjects. In this age group (5-6 years old) the total count is 20 teeth so this index can be varying from 0 to 20 in each subject. In this study, the jaw for each subject was divided into 4 parts: side 1, side 2, side 3 and side 4, which corresponded to mandible right, mandible left, maxilla right and maxilla left respectively. In each quadrant, 5 primary teeth were examined. Therefore, the dmft varied from 0 to 5 in every quadrant. Informed consent was obtained from all study participants before the project began.

### 2.2. Statistical Methods

The dmft variables are not generally approximated by a normal distribution (20) and tend to exhibit overdispersion due to the large proportion of zeros (17). A zero inflated binomial model was used for accounting this overdispersion. For accounting the correlation structure between subjects, a random effect with normal distribution was added to the model. The model had 2 distinguished parts (zero inflated part and binomial part), so first a normal random effect was added to zero inflated part. In second step, this random effect was entered to binomial part of the model. Akaike Information Criterion (AIC) was used for comparison between two models (random effect in zero part and random effect in binomial part). All P values less than 0.05 were considered as significant. SAS 9.4 software was employed to fit models.

## 3. Results

In general, 593 subjects aged 5-6 years were enrolled in this study, among them 328 (44.7%) were girls. Table 1 shows the distribution of variables included in this study. Family size with mean = 3.91 and Standard Deviation (SD) = 1.02 was the only continued variable. The jaw was divided into four parts. The frequency of dmft index in these four parts for all subject of this study ranged from 0 to 5. The

mean (SD) of dmft in side 1, side 2, side 3 and side 4 were 1.18 (1.37), 1.2 (1.38), 0.93 (1.06) and 0.92 (1.05) respectively. Table 2 shows distribution of the count of dmft in each quartile.

**Table 1.** The Distribution of Variables

| Categorical variables | N | % |
|---|---|---|
| **Sex** | | |
| Boys | 265 | 44.7 |
| Girls | 328 | 55.3 |
| **Place of residence** | | |
| Rural | 50 | 8.4 |
| Urban | 543 | 91.6 |
| **Brushing** | | |
| Yes | 327 | 94.4 |
| No | 22 | 5.6 |
| **Using fresh fruit** | | |
| Several times in a day | 281 | 71 |
| Rarely | 115 | 29 |
| **Education of mother** | | |
| Illiterate | 55 | 18.2 |
| Primary or high school | 164 | 54.3 |
| University | 83 | 27.5 |
| **Visiting by dentist in last year** | | |
| Yes | 189 | 71.1 |
| No | 77 | 28.9 |

**Table 2.** The Distribution of dmft in Each Quadrant

| Quadrant | dmft | N | % |
|---|---|---|---|
| Side 1 | 0 | 262 | 44.2 |
| | 1 | 129 | 21.8 |
| | 2 | 102 | 17.2 |
| | 3 | 50 | 8.4 |
| | 4 | 31 | 5.2 |
| | 5 | 19 | 3.2 |
| Side 2 | 0 | 254 | 42.8 |
| | 1 | 132 | 22.3 |
| | 2 | 113 | 19.1 |
| | 3 | 41 | 6.9 |
| | 4 | 31 | 5.2 |
| | 5 | 22 | 3.2 |
| Side 3 | 0 | 278 | 46.9 |
| | 1 | 130 | 21.9 |
| | 2 | 151 | 25.5 |
| | 3 | 19 | 3.2 |
| | 4 | 10 | 1.7 |
| | 5 | 5 | 0.8 |
| Side 4 | 0 | 277 | 46.7 |
| | 1 | 141 | 23.8 |
| | 2 | 136 | 22.9 |
| | 3 | 27 | 4.6 |
| | 4 | 7 | 1.2 |
| | 5 | 5 | 0.8 |

The results of univariate analyzing showed that relation between dmft and all independent variables was significant (except for visiting by dentist in last year). Male subjects, living in urban area, subjects that brushed the teeth, subjects who used fruit several times a day and subjects who had mothers with university education had significantly higher frequency of zero dmft (Table 3).

In the next step, with controlling the effects of sex, a ZIB model with random effect in zero inflated part was used for assessing the impact of all other independent factors on dmft. In the last step, a ZIB model with random effect in binomial part was fitted to data. According to the amount of Akaike information criterion (AIC), (3460.9 vs 3570.6) a model with random effect in binomial part fits better to data than model with random effect in zero part.

Table 4 shows the results of this model. Odds ratio (OR) (not in table) and confidence interval (CI) and estimation are reported. This results indicate that brushing (estimate = 1.28 OR = 3.5; 95% CI (0.38, 2.07)) and university education of mothers (estimate = 2.42; OR = 11.24; 95%CI (0.44, 4.40)) had significant relation with dmft. The chance of zero dmft for subjects who have brushed their teeth is 3.5 times higher than for those who have not brushed. This chance for subjects who have mothers with university education is 11.24 times of subjects who have mothers with no education.

In addition to regression parameter in this model, one variance component of random intercept model was estimated and it was statistically differing with zero ($\sigma^2 = 4.68$, P < 0.001).

## 4. Discussion

The ZIB model with a normal random effect in binomial part was according to AIC index the best model for analyzing dmft data in this study.

A real effect on caries distribution caused a number of extra zeros and it is a special case that so called overdispersion [21, 22]. This overdispersion leads to violate the basic assumptions implicit in the utilization of the standard distributions [23]. In the case of dmft, emerging a large number of zeros is particularly true since a large proportion of children are caries-free (zero counts) according to this index while a small number of children typically account for an extreme amount of caries [24].

**Table 3.** The Results of Univariate Analysis

| Variable Categories | dmft, N (%) | | | | | | P Value |
|---|---|---|---|---|---|---|---|
| | **0** | **1** | **2** | **3** | **4** | **5** | |
| **Sex** | | | | | | | 0.012 |
| Boys | 518 (48.9) | 219 (20.7) | 199 (18.8) | 63 (5.9) | 39 (3.7) | 22 (2.1) | |
| Girls | 553 (42.1) | 313 (23.9) | 303 (23.1) | 74 (5.6) | 40 (3) | 29 (2.2) | |
| **Place of residence** | | | | | | | < 0.001 |
| Rural | 48 (24.0) | 37 (18.5) | 67 (33.5) | 27 (13.5) | 13 (6.5) | 8 (4) | |
| Urban | 1023 (47.1) | 495 (22.8) | 435 (20) | 110 (5.1) | 66 (3) | 43 (2) | |
| **Brushing** | | | | | | | < 0.001 |
| Yes | 671 (45.1) | 321 (21.6) | 308 (20.7) | 103 (6.9) | 49 (3.3) | 36 (2.4) | |
| No | 27 (30.7) | 15 (17) | 21 (23.9) | 6 (6.8) | 12 (13.6) | 7 (8) | |
| **Cleaning the teeth** | | | | | | | < 0.001 |
| At least once in a day | 510 (47.4) | 233 (20.7) | 226 (21.0) | 68 (6.3) | 30 (2.8) | 19 (1.8) | |
| Never | 188 (37.6) | 113 (22.6) | 103 (20.6) | 41 (8.2) | 31 (6.2) | 24 (4.8) | |
| **Using fresh fruit** | | | | | | | < 0.001 |
| Several times in a day | 541 (48.1) | 229 (20.4) | 215 (19.1) | 71 (6.3) | 38 (3.4) | 30 (2.7) | |
| Rarely | 154 (33.5) | 115 (25) | 115 (25) | 40 (8.7) | 23 (5.0) | 13 (2.8) | |
| **Education of mother** | | | | | | | < 0.001 |
| Illiterate | 71 (32.3) | 52 (23.6) | 58 (26.4) | 15 (6.8) | 12 (5.5) | 12 (5.5) | |
| Primary or high school | 285 (43.4) | 144 (22) | 138 (21) | 48 (7.3) | 29 (4.4) | 12 (1.8) | |
| University | 203 (61.1) | 67 (20.2) | 43 (13) | 9 (2.7) | 5 (1.5) | 5 (1.5) | |
| **Visiting by dentist in last year** | | | | | | | 0.190 |
| Yes | 334 (44.2) | 164 (21.7) | 166 (22) | 50 (6.6) | 28 (3.7) | 14 (1.9) | |
| No | 135 (43.8) | 73 (23.7) | 52 (16.9) | 27 (8.8) | 10 (3.2) | 11 (3.6) | |

This study aimed to find important risk factors associated with dental caries free children aged 5-6 years. Assessing the risk factors associated with different diseases has an important role in health care examination. Among various common diseases in childhood, dental caries is the most common. Finding related factors with this problem can help to reduce the burden of these diseases. In fact, statistical modeling and selecting appropriate model is crucial in this kind of studies.

The nature of dmft index has tendency to an excess zero, and this phenomenon does not perfectly fit to the some standard distributions and is referred to as zero - inflated (25, 26). For the first time in 1954, Grainger and Reid considered that caries counts are not generally approximated by a normal distribution. They recommended negative binomial distribution (20). Later, other researchers used this distribution for analyzing dental cries data (8-13). With growing health care attention in population over time, oral health has improved too (27), and epidemiological researches showed that the traditional count data models provide poor fits to caries data. So the zero inflation models were proposed for modeling the decayed, missing, and filled teeth index (28). Zero - inflated Poisson (ZIP) regression and zero - inflated negative binomial (ZINB) regression models were used by several researches recently and the authors used these models to examine the effect of different exposures and risk factors on dental caries situation (29).

Zero inflated binomial model (ZIB) used in this paper for analyzing dmft data, has been proposed by Hall in 2000 (30). In contrast to ZIP and ZINB models, this model can be an alternative for the case that there is a boundary limit for the count of data. In this study, each subject has 20 teeth (primary teeth), so it makes a boundary limit in data and leads to using ZIB instead of ZIP model. In addition, this ZIB model is a mixture model with two separated parts, which let us investigate the effect of variables on caries free or on high caries.

On the other hand, the jaw of every subject was divided into 4 parts and dmft was examined in each part. There-

**Table 4.** The Results of Binomial Zero Inflated Model with Random Effect in Binomial - part Analysis

| Variables | Binomial Part | | | | Zero - inflation Part | |
|---|---|---|---|---|---|---|
| | Estimate | P Value | 95% Cl | Estimate | P Value | 95% Cl |
| **Sex** | | | | | | |
| Girls (ref) | | | | | | |
| Boys | -0.08 | 0.307 | (-0.24, 0.07) | -0.79 | 0.083 | (-1.70, 0.10) |
| **Family size** | 0.13 | 0.213 | (-0.07, 0.34) | 0.95 | 0.078 | (-0.11, 2.02) |
| **Place of residence** | | | | | | |
| Rural (ref) | | | | | | |
| Urban | 0.11 | 0.330 | (-0.11, 0.35) | -0.86 | 0.175 | (-2.11, 0.38) |
| **Brushing** | | | | | | |
| No (ref) | | | | | | |
| Yes | 0.02 | 0.800 | (-0.14, 0.18) | 1.28 | 0.0123 | (0.38, 2.07) |
| **Side of jaw** | | | | | | |
| Side 1 (ref) | | | | | | |
| Side 2 | -0.02 | 0.799 | (-0.23, 0.18) | -0.38 | 0.199 | (-0.96, 0.20) |
| Side 3 | -0.07 | 0.497 | (-0.29, 0.14) | 0.11 | 0.699 | (-0.46, 0.69) |
| Side 4 | -0.08 | 0.427 | (-0.30, 0.12) | 0.10 | 0.721 | (-0.47, 0.68) |
| **Using fresh fruit** | | | | | | |
| Several times in a day (ref) | | | | | | |
| Rarely | 0.05 | 0.557 | (-0.219, 0.118) | -0.04 | 0.918 | (-0.85, 0.77) |
| **Education of mother** | | | | | | |
| Illiterate (ref) | | | | | | |
| Primary or high school | 0.02 | 0.765 | (-0.21, 0.16) | 0.92 | 0.329 | (-0.94, 2.79) |
| University | -0.08 | 0.487 | (-0.32, 0.15) | 2.42 | 0.016 | (0.44, 4.40) |
| **Visiting by dentist in last year** | | | | | | |
| Yes (ref) | | | | | | |
| No | 0.06 | 0.474 | (-0.11, 0.24) | -0.30 | 0.532 | (-1.28, 0.66) |
| **Random effect** | | | | 4.68 | < 0.001 | (2.20, 7.17) |

Abbreviation: Ref, Reference category.

fore, we had a repeated measures structure that led to dependence between responses and we fit a ZIB model with normal random effect to data for adjusting the effect of zero inflation and dependency structure of data simultaneously.

In this study, two types of ZIB model with random effect were fitted to data. In the first model, a normal random effect was entered in zero stat part and in the next model, normal random effect was added to binomial part. We wanted to find a flexible and better model between these two models for analyzing the data set. As mentioned before, a ZIB model with random effect in zero part was the best model. In this model brushing at least once a day and education of mothers had a significant effect on zero dmf

or being caries free. Significant Effect of some socioeconomic factors on dental caries situation has been proved in recent studies (31). In our study also some of these factors were examined but among them only education of mother as a social or a kind of economical factor, had a significant effect. there are several studies from all over the world that prove the role of parent's education, specially that of mother's as a protective factor in oral health of children (32-34). Therefore, this factor seems important for children's oral health. It is clear that people with high education are more concerned about health problems of their children. It is more highlighted in mothers. Mothers have more mutual connection with children especially in younger age.

Brushing the teeth is another important factor. A set of studies in current year (2016) were done around the world to prove the effect of brushing (35-38).

The results of our study can be compared with a study, performed in 2003 on dental situation in 3-5 years old kindergarten children in Tehran, indicating that washing the teeth and higher socioeconomic status were associated to lower dmft (39).

As a limitation of this study, can be mentioned that despite using calibration trained dental team for gathering the information, some deviation from the calibration goal might have happened.

In conclusion, using the zero inflated models in dmft studies due to overdispersion characteristics of this data is needed. Moreover, in the case of being an upper boundary in data such as dmft in our study (20 for each subject) a ZIB model will be appropriate for analyzing instead of ZIP model. Considering our results, we can say that regular and early starting of tooth brushing can fight the agents that can cause caries in primary teeth of children. Also due to target population's age of this study, parental supervision is crucial. Certainly, preschool children cannot maintain and pay attention to their oral health by themselves. So the regular attention of parents specially mothers can decrease the risk of dental caries in children (40). On the other hand, maybe with high - educated parents we can expect high level of health care in children and this will have its beneficial effect on dental situation of children.

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