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Effective factors on the number of decayed and filled teeth using the Conway-Maxwell-Poisson count model

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Original Article

Abstract

BACKGROUND AND AIM: Recognizing the factors affecting the number of decayed and filled teeth has a major role in oral health. Dental data usually suffer from over-dispersion and excess zero frequencies. The purpose of this study was to use the Conway-Maxwell-Poisson (COM-Poisson) model to determine some of the factors affecting the number of decayed and filled teeth.

METHODS: In this cross-sectional study, a sample of 1000 people from a cohort study in Shahrekord City, Iran, aged 35-70 years, was selected through systematic sampling. The data were analyzed using the Bayesian approach through Markov chain Monte Carlo (MCMC) simulation by OpenBUGS. Zero-inflated Poisson (ZIP), COM-Poisson model, and zero-inflated Com-Poisson (ZICMP) model were fitted on the data and compared using the deviance information criterion (DIC).

RESULTS: The mean numbers of decayed and filled teeth were 0.77 ± 1.63 and 4.37 ± 4.62, respectively. The Com-Poisson and ZICMP showed to be better fit for the number of decayed and filled teeth, respectively. Those people who were younger, male, smokers, diabetics, did not floss, and did not use mouthwash had significantly more number of decayed teeth ($P < 0.05$). Those people who were younger, female, non-diabetics, non-smokers, employed, literate, had less body mass index (BMI), flossed, and got higher score of quality of life had significantly more number of filled teeth ($P < 0.05$).

CONCLUSION: By controlling such factors as education, BMI, flossing, using mouthwash, smoking, diabetes, and quality of life, we could improve the oral health.

KEYWORDS: Bayes' Theorem; Conway-Maxwell-Poisson Distribution; Decayed, Missing, and Filled Teeth; Zero-inflated

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Dental caries in permanent teeth is a multifactorial disease and one of the most common chronic diseases worldwide.[1] Many factors affect the risk of dental caries, including environmental ones such as fluoride and fluoride exposure, behavioral factors including diet, lifestyle, and oral health, and demographic characteristics such as age, gender, race, ethnicity, socioeconomic status, education, occupation, and access to oral health care, which are among the most influential factors.[2] Tooth decay is a localized infectious disease that affects people at any age and in any region of the world. Oral health is part of general health and oral and dental illnesses affect all aspects of the life quality.[3,4] In addition, oral health has been shown to be a risk factor for cardiovascular diseases (CVDs), diabetes, and pneumonia (lung infection).[5,6] The prevalence of dental caries among 28 provinces of Iran was reported to be 37%, and there was a significant relationship between it and socioeconomic status and literacy.[7]

Some methods have been developed in recent years for analyzing dental count data,

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which include the number of decayed, missing, and filled teeth (DMFT). An important feature of these data is the existence of a large number of zero observations and that the distribution is positively skewed. These methods include Poisson model, negative binomial, generalized Poisson, zero-inflated Poisson (ZIP), zero-inflated negative binomial, and hurdle model.[8-10]

Due to the complexity of dental data, sometimes these models do not fit well the data. Recently, another model called the Conway-Maxwell-Poisson (COM-Poisson) model is used in the area of count models that has interesting features. The COM-Poisson distribution was first introduced by Conway and Maxwell in 1962 to model queues.[11] Although the COM-Poisson distribution is not specifically new, until obtaining the initial properties of the distribution in 2005, it has not been widely used.[12] The COM-Poisson distribution is a part of the exponential-family distribution and has two flexible parameters.[13] The distribution can be presented as generalization of Poisson, Bernoulli, and geometric distributions.[12] This distribution has capability to address the extra zero observations and over- or under-dispersion. The COM-Poisson model is expected to be better fit for dental data. The purpose of this study was to use this model to determine some of the factors affecting the number of decayed and filled teeth.

Methods

In this population-based cross-sectional study, a sample of 1000 individuals from Shahrekord Cohort Study (SCS),[14] including 476 men and 524 women aged 35-70 years, were selected through systematic sampling. This study was designed to supplement the centers of the Prospective Epidemiological Research Studies in Iran (PERSIAN) Cohort, which was conducted in Shahrekord, the capital of Chaharmahal and Bakhtiari Province, southwest of Iran.[15,16] The study protocol of SCS was checked and approved by the Ethics Committee of Shahrekord University of Medical Sciences (IR.SKUMS.REC 1394.286) at regional and national scale on PERSIAN Cohort. Details of the SCS protocol have been published elsewhere.[14] Inclusion criteria were eligibility to be included in the cohort study, consisting of both sexes aged 35-70 years, residing in the limited geographic of cohort, and having adequate physical and mental ability to participate in the evaluation program as well as signing the written informed consent. The exclusion criterion was unwillingness to participate in dental examination. The examination of dental health was performed by a trained expert. A dentist also supervised the examination and the demographic questionnaire was completed by the examiner.

The numbers of decayed and filled teeth for each individual were recorded and defined as response variables, and other factors like age, weight, sex, occupational status, educational level, diabetes, smoking, body mass index (BMI), quality of life, mouthwash use, using dental floss, and number of brushing during the day were considered as independent variables.

The frequency distributions of the number of decayed and filled teeth for each individual were positively skewed. The frequency charts showed a huge number of zeros in our data and the mean and standard deviation (SD) showed a very over-dispersion in the frequency distributions. This motivated us to use COM-Poisson distribution to analyze the data. The COM-Poisson distribution is a generalization of Poisson distribution with two parameters, which is flexible enough to handle different levels of dispersion especially over- or under-dispersion. The count variable Y has COM-Poisson distribution with parameters (λ, ν). The λ parameter is a close approximation of the mean and the ν parameter is the dispersion parameter.[17,18]

Analyses of COM-Poisson regression model and zero-inflated COM-Poisson (ZICMP) model were carried out based on Bayesian framework using Markov chain Monte Carlo (MCMC) simulation.

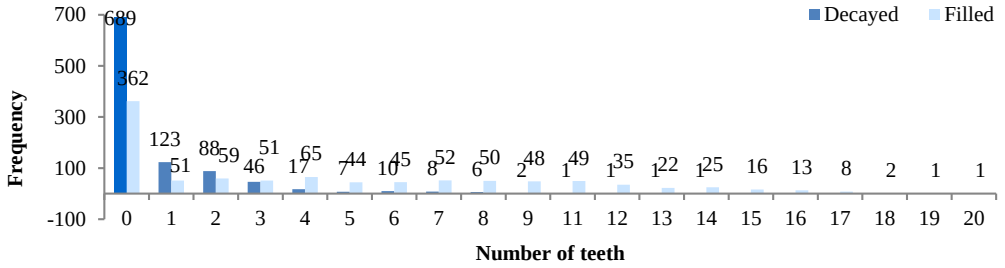

Figure 1. Frequency of the number of decayed and filled teeth per individual

In this method, posterior distribution of the model parameters was obtained based on previous information of the model parameters and available data. This was done with OpenBUGS software. To compare the models, deviance information criteria (DIC) were used.[19] Statistical summaries of the model parameters were obtained based on 20000 samples after the implementation of 5000 samples as burn-in period.

Results

In summary, out of the 1000 samples, 476 (47.6%) were men and 524 (52.4%) were women. The age range of participants was 36 to 72 years with the mean of 52.2 ± 9.4. The number of decayed teeth was from 0 to 14 with the mean of 0.77 ± 1.63, and the number of filled teeth was from 0 to 20 with the mean of 4.37 ± 4.62. Totally, 311 individuals (31.1%) had at least one decayed tooth and 638 individuals (63.8%) had at least one filled tooth. Figure 1 shows the frequency of the number of decayed and filled teeth per individual in the study. Some characteristics and the mean numbers of decayed and filled teeth of participants have been brought in table 1.

Table 1. Some characteristics of participants and mean number of decayed and filled teeth

Variable	Level	n (%)	Number of decayed teeth	Number of filled teeth
			Mean ± SD	Mean ± SD
Gender	Male	476 (47.6)	0.880 ± 1.793	3.470 ± 4.104
	Female	524 (52.4)	0.670 ± 1.470	5.190 ± 4.190
Age (year)	< 40	115 (11.5)	1.050 ± 1.973	6.130 ± 4.749
	40-60	664 (66.4)	0.810 ± 1.674	4.990 ± 4.606
	> 60	221 (22.1)	0.500 ± 1.242	1.600 ± 3.301
Education	Literate	793 (79.3)	0.830 ± 1.708	5.150 ± 4.687
	Illiterate	207 (20.7)	0.550 ± 1.297	1.400 ± 2.826
BMI (kg/m^2)	< 25	260 (26.0)	0.880 ± 1.858	4.380 ± 4.637
	25-35	675 (67.5)	0.700 ± 1.538	4.600 ± 4.666
	> 35	65 (6.5)	1.060 ± 1.619	1.920 ± 3.251
Having job (employee)	Yes	481 (48.1)	0.860 ± 1.753	4.750 ± 4.595
	No	519 (51.9)	0.690 ± 1.513	4.020 ± 4.624
Smoking	Yes	156 (15.6)	1.040 ± 2.063	2.030 ± 3.421
	No	844 (84.4)	0.720 ± 1.538	4.800 ± 4.687
Diabetes	Yes	95 (9.5)	0.910 ± 1.902	2.340 ± 3.913
	No	905 (90.5)	0.760 ± 1.634	4.580 ± 4.641
Brushing (day)	No brushing	398 (39.8)	0.600 ± 1.498	2.340 ± 3.774
	Once	423 (42.3)	0.870 ± 1.756	5.930 ± 4.506
	Twice	151 (15.1)	0.880 ± 1.604	5.520 ± 4.466
	More	28 (2.8)	1.070 ± 1.609	6.750 ± 5.118
Flossing	Yes	358 (35.8)	0.720 ± 1.591	7.721 ± 4.561
	No	642 (64.2)	0.800 ± 1.658	2.790 ± 3.830
Using mouthwash	Yes	79 (7.9)	0.490 ± 1.036	3.720 ± 4.698
	No	921 (92.1)	0.800 ± 1.674	4.430 ± 4.614
Quality of life	< 50	119 (11.9)	0.670 ± 1.513	3.700 ± 3.941
	50-80	797 (79.7)	0.790 ± 1.684	4.170 ± 4.770
	> 80	84 (8.4)	0.790 ± 1.299	2.100 ± 3.020

BMI: Body mass index; SD: Standard deviation

Table 2. Results of deviance information criterion (DIC)

Response variable	Model	$\overline{Dbar}$	P_D	DIC
Number of decayed teeth	ZIP	998400	14.24	998400
	CMP	997400	13.57	997400
	ZICMP	997400	13.69	997400
Number of filled teeth	ZIP	100500	14.69	100500
	CMP	100300	14.98	100300
	ZICMP	100300	14.90	100300

ZIP: Zero-inflated Poisson; CMP: COM-Poisson; ZICMP: Zero-inflated COM-Poisson; DIC: Deviance information criterion

We use the COM-Poisson model and ZICMP to analyze our dental data. The results of DIC were presented in table 2, which show a better fit of the COM-Poisson model for decayed teeth data as well as a better fit of ZICMP for filled teeth data.

Statistical summaries of models' parameters of fitting the COM-Poisson model and ZICMP, including mean, median, SD, and 95% credible intervals, based on 20000 simulated values after considering 5000 samples as burn-in period, were shown in tables 3 and 4, respectively.

Based on the estimate of regression coefficients and their 95% credible intervals that do not contain zero, the independent variables of age, gender, frequency of brushing, diabetes, flossing, using mouthwash, and smoking are significant factors for the number of decayed teeth. In the presence of the above-mentioned variables in the model, other variables including BMI, job, education, and quality of life did not have a significant effect on the number of decayed teeth. Also, the variables of age, sex, BMI, frequency of brushing, diabetes, flossing, job, quality of life, smoking, and education were significant factors for the number of filled teeth. Using mouthwash did not affect the number of filled teeth.

Discussion

Oral health plays a major role in quality of life,[20] so recognizing the factors affecting the number of decayed and filled teeth is very important. In this paper, we used the COM-Poisson and ZICMP for analyzing the number of decayed and filled teeth, respectively.

Based on the results of the COM regression model on the number of decayed teeth, we can conclude that the number of decayed teeth has a negative association with age, so that it was higher in younger subjects.

Table 3. Posterior summaries for the parameters of COM-Poisson regression model for decayed teeth

Parameter	Mean	SD	Median	2.5 percentile	97.5 percentile
Constant	4.879	0.592	4.877	3.656	6.111
Age*	-0.117	0.010	-0.117	-0.137	-0.096
Gender (Female vs. male)*	-1.571	0.214	-1.570	-1.992	-1.152
BMI	0.032	0.018	0.032	-0.002	0.068
Brushing 2 times vs. Once a day*	0.574	0.229	0.576	0.119	1.011
Brushing more than 2 times vs. once*	2.257	0.408	2.279	1.398	2.993
No brushing vs. once a day*	-1.782	0.191	-1.782	-2.162	-1.412
Diabetes*	1.862	0.222	1.860	1.413	2.301
Flossing*	-1.469	0.187	-1.470	-1.838	-1.097
Having job	-0.347	0.193	-0.351	-0.726	0.035
Quality of life	0.006	0.006	0.007	-0.006	0.019
Using mouthwash*	-1.602	0.282	-1.601	-2.162	-1.053
Smoking*	1.555	0.232	1.556	1.104	2.024
Education (illiterate vs. literate)	-0.054	0.228	-0.055	-0.496	0.401
ν	1.09×10^{-4}	6.47×10^{-4}	7.695×10^{-7}	4.420×10^{-21}	0.001

*Significant, $P < 0.05$

BMI: Body mass index; SD: Standard deviation

Table 4. Posterior summaries for the parameters of zero-inflated COM-Poisson (ZICMP) regression model for filled teeth

Parameter	Mean	SD	Median	2.5 percentile	97.5 percentile
Constant	-1.281	0.236	-1.278	-1.759	-0.819
Age*	-0.021	0.002	-0.021	-0.026	-0.015
Gender (Female vs. male)*	0.335	0.053	0.336	0.229	0.437
BMI*	-0.010	0.005	-0.010	-0.020	-0.090
Brushing twice vs. once a day*	-0.127	0.052	-0.126	-0.228	-0.024
Brushing more than twice vs. once a day**	0.444	0.122	0.441	0.212	0.695
No brushing vs. once a day*	-0.415	0.048	-0.415	-0.511	-0.321
Diabetes*	0.256	0.086	0.252	0.088	0.436
Flossing*	0.599	0.041	0.599	0.519	0.680
Having job*	0.194	0.051	0.194	0.092	0.295
Quality of life*	-0.003	0.001	-0.003	-0.007	-0.000
Using mouthwash	-0.069	0.081	-0.069	-0.227	0.093
Smoking*	-0.490	0.073	-0.490	-0.635	-0.347
Education* (illiterate vs. literate)	-0.976	0.092	-0.972	-1.170	-0.802
ν	1.903×10^{-4}	3.403×10^{-4}	6.749×10^{-7}	2.124×10^{-19}	0.001
p	0.034	0.008	0.034	0.020	0.052

*Significant, P < 0.05
BMI: Body mass index; SD: Standard deviation

This number was also associated with gender, so that the mean number of decayed teeth was higher in men than in women. This similarity has been seen in other studies too; it seems that its reason is more attention of women to their health and referring to the dentist for the prevention of oral and dental diseases.[21] Besides, women had greater knowledge, a more positive attitude, and a higher level of oral health behaviors than men.[22] Daily brushing has a complicated effect on decayed and filled teeth. The mean number of decayed teeth was less for those who brush twice or more a day versus those brushing once a day. In addition, the number of decayed teeth was less for those who did not brush a day versus those brushing once a day. The mean number of decayed teeth was less for those who flossed and those who used mouthwash. Diabetes has adverse effects on decayed teeth, so that diabetic people are exp (1.86) = 6.4 times more at risk for increasing dental decay than non-diabetic people.

The results of the zero- inflated COM-Poisson regression model on the number of filled teeth showed that those people who were younger, female, non-diabetic, employed, literate, had less BMI, flossed, and got less score of quality of life had significantly more number of filled teeth. Literate and employed individuals had more filled teeth than others. The mean number of filled teeth in the literate people was exp (1/-0.976) = 2.6 times higher than that in the illiterate ones. Oral health status in retired elderly people in Iran had a direct relationship with literacy levels.[23] Employed and literate people may pay more attention to their oral health because of their more knowledge and financial ability to refer for dental services. This was consistent with Gao et al.'s study too.[24] The younger people had significantly more decayed and filled teeth. In the study of Ahmadi et al.,[23] aging had inverse effects on oral health. Flossing had a direct relationship with the number of filled teeth and inversely with the number of decayed teeth.

Diabetic individuals had more decayed teeth and less filled teeth than non-diabetic ones. In the study of Yonekura et al.,[25] participants with poorly controlled diabetes had more decayed and less filled teeth than the control group.

Smoking has a direct significant relationship with the number of decayed teeth and a

negative significant relationship with the number of filled teeth. The direct relationship between smoking and dental disease has been confirmed in other studies too.[26,27]

Oral health is a major part of the quality of life[24] and good quality of life is a protective factor for dental caries. In this study, participants with higher level of quality of life had less number of filled teeth; showing that the high level of quality of life influences one's oral health.

Conclusion

Many controllable factors such as education, BMI, flossing, using mouthwash, smoking, diabetes, and quality of life affect the number of decayed and filled teeth. Therefore, by planning educational and cultural programs to prevent diabetes and smoking as well as by encouraging people to floss and use mouthwash, we could improve oral health.

Conflict of Interests

Authors have no conflict of interest.

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