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Original Article

Application of zero-inflated Poisson model with heterogeneous random effects to evaluate the effect of oral health education on pregnant women's dental caries: A longitudinal experimental study

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ABSTRACT

Background: Pregnant women have poor knowledge of oral hygiene during pregnancy. One problem with the follow-up of dental caries in this group is zero accumulation in the decayed, missing, and filled teeth (DMFT) index, for which some models must be used to achieve valid results. The studied population may be heterogeneous in longitudinal studies, leading to biased estimates. We aimed to assess the impact of oral health education on dental caries in pregnant women using a suitable model in a longitudinal experimental study with heterogeneous random effects.

Materials and Methods: This longitudinal, experimental research was carried out on pregnant women who visited medical centers in Tehran. The educational group (236 cases) received education for three sessions. The control group (200 cases) received only standard training. The DMFT index assessed oral and dental health at baseline, 6 months, and 24 months after delivery. The Chi-square test was used for comparing nominal variables and the Mann–Whitney *U* test for ordinal variables. The zero-inflated Poisson (ZIP) model was applied under heterogeneous and homogeneous random effects using R 4.2.1, SPSS 26, and SAS 9.4. The level of significance was set at 0.05.

Results: Data from 436 women aged 15 years and older were analyzed. Zero accumulation in the DMFT was mainly related to the filled teeth (51%). The heterogeneous ZIP model fitted better to the data. On average, the intervention group exhibited a higher rate of change in filled teeth over time than the control group ($P = 0.021$).

Conclusion: The proposed ZIP model is a suitable model for predicting filled teeth in pregnant women. An educational intervention during pregnancy can improve oral health in the long-term follow-up.

Key Words: Dental caries, longitudinal studies, pregnancy, zero inflation

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INTRODUCTION

Oral and dental hygiene is vital for the public health of at-risk groups, such as mothers and children,

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who are particularly susceptible to dental diseases.[1] Although the factors contributing to tooth decay were identified over 50 years ago, their impact on the health-care systems of developing countries remains significant.[2] Clinical studies in dentistry have shown that mothers' oral hygiene is related to oral hygiene and tooth decay in their children.[3] Surveys conducted worldwide have shown that 58%–65% of pregnant women do not prioritize oral health care.[4,5] Studies indicate that pregnant women often do not maintain adequate oral hygiene practices and are unaware of the link between oral hygiene during pregnancy and its potential impact on their health.[6,7] Based on previous studies, dental hygiene was not being practiced in 45% of women during pregnancy[8] and about 60% of them were not aware of necessary visits to the dentist during pregnancy; as a result, most of them preferred to postpone dental care to after pregnancy.[9]

Considering the deterioration of children's caries index in Iran in the last decade, oral health promotion programs should focus on prevention. Therefore, it is essential to conduct interventions to enhance the awareness of pregnant mothers, thereby improving future generations' oral health. Research indicates that 80% of oral and dental diseases can be minimized through health education.[10] The World Health Organization has implemented a foundational oral health-care program that incorporates oral health education and highlights the importance of integrating health education with various oral health initiatives, including offering preventive, restorative, and emergency dental care. Recently, there has been a focus on evaluating the efficacy of oral health education programs.[11] Most studies concentrate on oral health education programs and interventions during pregnancy, including face-to-face and focus group discussions.[12,13] A recent study by Saffari *et al*. showed that oral health-related self-efficacy and behaviors among pregnant women may be improved using health education interventions, such as motivational interviewing (MI), which is a behavior-change technique.[14] The primary objective of the oral health education program is to enhance the availability of information by providing anticipatory guidance to pregnant women, with the ultimate aim of enhancing pregnancy outcomes.[15] Research has indicated that periodontal diseases affect overall health and contribute to negative pregnancy outcomes, including premature birth and low birth weight.[16-18]

There are many instruments to measure oral health conditions, such as the plaque index, Community Periodontal Index (CPI) for evaluating periodontal status, and the decayed, missing, and filled teeth (DMFT) index for evaluating dental caries.[19] The DMFT index is a count variable that assesses the frequency of DMFT.[20] Today, count data are used in a wide range of research, such as the number of deaths caused by an event, the number of cells or virus load in people with a certain disease, and the number of epileptic attacks. An accumulation of zero-in-count data can be problematic, resulting in poor fit and unreliable outcomes. In such instances, it is advisable to consider utilizing two-part models, including the hurdle model, zero-inflated Poisson (ZIP) model, and zero-inflated negative binomial model.[21]

The studied population may be heterogeneous due to the participants, interventions, or events that occur for various reasons such as sex, genetics, nutrition, and general internal or environmental factors, most of which cannot be controlled. In other words, heterogeneity occurs in random effects if the studied population does not have the same behavior toward an intervention. It is usually assumed that the random effects covariance matrix remains constant across subjects. Nevertheless, this matrix may vary depending on the measured covariates. Ignoring heterogeneity can result in a biased estimation of the random and fixed effects of the model.[22,23] Given that the assumption of homogeneity of variances is not met in many populations, this paper aimed to consider the heterogeneity of variance in the longitudinal dental caries data from pregnant women by modeling the variance-covariance matrix adequately. The objective was to examine whether oral health education could improve oral and dental hygiene in pregnant women and affect dental caries in mothers.

MATERIALS AND METHODS

Study design

This longitudinal experimental research was conducted on pregnant women (enrollment $n = 647$) during pregnancy in two medical centers of Pakdasht and Pishva in the Varamin region of Tehran Province. Pregnant women in the second and third trimesters (coverage of about 70%) visited the health-care centers associated with Shahid Beheshti University of Medical Sciences to receive care. Women were recruited and monitored for 24 months after childbirth. The recruitment process commenced in July 2016, while the follow-up was concluded in November 2018.

Out of the 647 women who were registered, 454 women were included in our study (intervention n = 239, control n = 215). Among them, 239 were in the intervention group and 215 were in the control group. In total, 18 cases were lost to follow-up (intervention group n = 3 and control group n = 15). The consort diagram is depicted in Figure 1.

The inclusion criteria were those aged 15 years or older and the absence of advanced oral and dental disease in the mothers. The exclusion criteria were having psychological disorders and failure to complete the informed consent form to participate in the study. In addition, pregnant women with documented systemic illness, high-risk pregnancies, prolonged medication use, and failure to respond to three consecutive phone calls were not included.

Intervention methods

The educational–behavioral intervention was administered to the pregnant women using four educational methods. In the first method, health-care workers trained by dentists presented the training. In the second method, the dentists provided the training, and in the third method, the educational content was presented online; a channel was created on the Telegram social network application to present the educational material virtually. This channel aimed to provide mothers enrolled in health-care centers with a comprehensive range of behavioral and nutritional content, including audio, video, and text messages. These mothers received weekly messages throughout the entire duration, from the pregnancy to 18 months after delivery.[24] In the fourth method, the training involved a combination of the three mentioned methods; the women of the intervention group participated in three training sessions (15 h workshops) presented by health-care workers under the supervision of a dentist.

The control group exclusively received the standard training mandated by the Iranian Ministry of Health and Medical Education for all centers, which encompassed routine maternal and child health services, both oral and general. The pregnant women were provided with interventions from the onset of pregnancy until 18 months postdelivery.

The checklist used for data collection examined various aspects, such as the mother's age, education, occupation, and demographic characteristics. Furthermore, the mothers were examined regarding brushing, flossing habits, and other dental clinical examinations (gingival condition and bleeding).

Outcome measurements

If there were missing teeth, the examiner would ask the participant if the tooth had been extracted for possible reasons, including dental caries, orthodontic treatment, or other reasons. We only calculated the missing cases because of dental caries in the DMFT index.

The DMFT index provides information on the combined number of decayed, missing, and filled permanent teeth. This index is calculated by summing up the individual's decayed, missing, and filled permanent teeth, resulting in a DMF score. Note that DMF counts are often heavily skewed, with a predominant mode of zero.

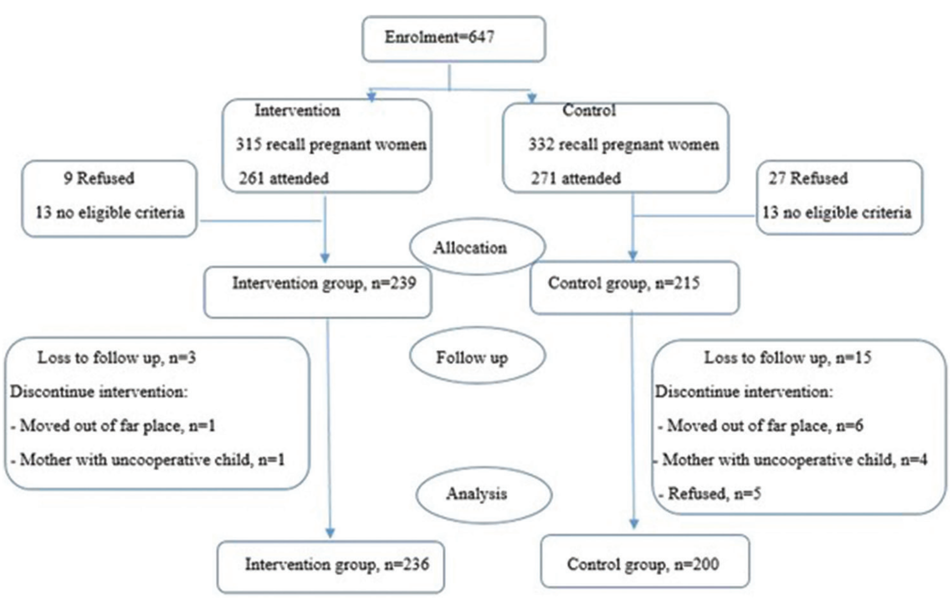

Figure 1: Consort diagram.

Therefore, linear models are generally unsuitable when using the DMF count as a dependent variable.[25,26]

The DMFT index as an outcome measurement was examined on three occasions: during pregnancy, 6 months after delivery, and 24 months after delivery. In our study, two trained dentists were in charge of oral examination and recording the number of DMFT. This was done using battery-operated lights and a mouth mirror. The data were collected in the maternal care rooms in public health centers.

Ethical considerations

This research was approved by the Ethics Committee of Shahid Beheshti University of Medical Sciences (code: IR.SBMU.RETECH.REC.1399.1208).

Sample size and statistical method

According to a study conducted by Deghatipour *et al.* in 2019, the standard deviation (SD) of decayed teeth among Iranian pregnant women was recorded as 4.40.[27] Taking into account the anticipated impact of the intervention, which is expected to result in about 20% decrease in decayed teeth, with a significance level (α) of 0.05 and a power of 80%, approximately 200 participants were deemed necessary for both the intervention and control groups.

For the data analysis, the Chi-square test was used for nominal variables and the Mann–Whitney *U* test for the ordinal variables. The ZIP model with and without heterogeneous random effects was used for assessing the impact of intervention on outcome data. The univariate tests were performed using the SPSS software, version 26.0 (Armonk, NY: IBM Corp., 2019), and missing data analysis was handled by multiple imputation methods using the R 4.2.1 software (Vienna, Austria: R Foundation for Statistical Computing, 2022). In addition, the model fitting process was done using the SAS software, version 9.4 (Cary, NC: SAS Institute Inc., 2023).

Zero-inflated Poisson model with heterogeneous random effects

The ZIP model is a two-part modeling approach where the response variable includes zero value with probability φ_{ij} and other values with probability $1-\varphi_{ij}$. ($0\leq \varphi_{ij} \leq 1$).

$$Y_{ij} : \begin{cases} 0 & \text{with probability } f_{ij} \\ \text{Poisson}(\lambda_{ij}) & \text{with probability } 1 - f_{ij} \end{cases} \quad (1)$$

In equation (1), Y_{ij} shows the counting response for the i^{th} person at the j^{th} time and λ_{ij} is the Poisson distribution parameter ($0< \lambda_{ij} <\infty$) $j = 1., t$ and $i = 1., n$. The probabilities of the zero part and the counting part can be written as follows:

$$P(Y_{ij} = 0 \mid Z_{ij}) = \phi_{ij} + (1-\phi_{ij})e^{-\lambda_{ij}}$$

$$P(Y_{ij} = y_{ij} \mid X_{ij}) = (1 - \varnothing_{ij})\frac{\lambda_{ij}^{y_{ij}} e^{-\lambda_{ij}}}{y_{ij}!}, y_{ij} = 1,2,.. \quad (2)$$

Where X_{ij} and Z_{ij} are auxiliary variables and the mean and variance are estimated by the equations $\mu = \lambda_{ij}(1-\varphi_{ij})$ and $\sigma^2 = \lambda_{ij}(1-\varphi_{ij})(1+\lambda_{ij}\varphi_{ij})$. If $\varphi = 0$ in the zero part of the model, this model turns to a Poisson regression model.

To provide a model for the heterogeneity of the random effects, the logarithmic and logit link functions are defined for the ZIP model, in which u_i and v_i are, respectively, the zero and count parts of the random effects.

$$\text{logit}(\varnothing_{ij}) = \alpha Z_{ij} + u_i . \log(\lambda_{ij}) = \beta X_{ij} + v_i \quad (3)$$

To include heterogeneous random effects, the following covariance matrix was used, in which the variance of different individuals is considered follows:

$$\begin{pmatrix} u_i \\ v_i \end{pmatrix} \sim N(0, \begin{bmatrix} \sigma^2_{ui} & \rho\sigma_{ui}\sigma_{vi} \\ \rho\sigma_{ui}\sigma_{vi} & \sigma^2_{vi} \end{bmatrix}) \quad (4)$$

Then, by modeling the logarithm of the variance in the zero and count parts, the two components of heterogeneous random effects variance are related to the auxiliary variables of *Wi* and *Gi*. The coefficients of the zero and count parts are represented by ζu and ζv.

$$\log(\sigma^2_{ui}) = \zeta_u W_i . \log(\sigma^2_{vi}) = \zeta_v G_i . \log(\sigma^2_{vi}) = \zeta_v G_i \quad (5)$$

According to the zero and count parts of the response variable, an indicator function is defined, and the likelihood function is written as follows, in which $f(u_i, v_i)$ is the normally distributed random effects with the above-mentioned covariance matrix Σ_i.

$$L_i(\theta) = \prod_j P(Y_{ij} = 0 \mid \theta)^{I(Y_{ij}=0)} P(Y_{ij} = y_{ij} \mid \theta)^{I(Y_{ij}>0)}$$

$$L_i = \int L_i(\theta_i \mid u_i, v_i) f(u_i, v_i \mid \theta \Sigma_i) d_{ui}, d_{vi} \quad (6)$$

Zero inflation in DMFT data was assessed using the Broek or score test.

Goodness of fit indices

The efficacy of the suggested model was compared to another model without heterogeneity using the goodness of fit (GOF) indices such as Akaike Information Criterion (AIC) and Bayesian Information Criterion (BIC). These indices utilize the likelihood function (L) and the number of parameters in the model (P) to determine the model with the best fit. The lower values of indices indicate better GOF. These indices can be calculated as $AIC = -2\log L + 2p$ and $BIC = -2\log L + p \log n$.

RESULTS

In this study, the data from 436 pregnant women, aged between 15 and 43 years, were analyzed. The mean ± SD age in the intervention and control groups was 27.05 ± 5.4 and 27.98 ± 5.7 years, respectively ($P = 0.274$). Mothers' demographic characteristics are reported separately in two groups in Table 1. The rate of missing flossing habit data was high, so we ignored it in the analysis. The results of comparing demographic variables showed no significant difference between groups. Hence, none of them were considered confounding variables in the data analysis process.

Findings based on statistical tests

In our study, an agreement rate between two trained dentists was obtained as Kappa = 0.85. The oral health condition, assessed by the DMFT index, was compared between groups, and the results were reported in Table 2 using a bivariate approach. The mean ± SD of DMFT was 10.33 ± 5.12 (ranging from 0 to 31).

Table 1: Demographic information of mothers, separated into two intervention and control groups

Variable	Level	Intervention (*n*=236), *n* (%)	Control (*n*=200), *n* (%)	*P**
Education	Under diploma	14 (5.9)	11 (5.5)	0.373
	Diploma	114 (48.3)	110 (55)	
	Academic	108 (45.8)	79 (39.5)	
Job	Employed	3 (1.3)	4 (2)	0.546
	Housewife	233 (98.7)	196 (98)	
Smoking	Yes	4 (1.7)	3 (1.5)	0.872
	No	232 (98.3)	197 (98.5)	
Brushing	One time per day	84 (35.6)	72 (36)	0.93
	More than one time	152 (64.4)	128 (64)	

*Based on Chi-square and Fisher's exact test

Table 2: Descriptive results of the decayed, missing, and filled teeth index and its components according to the assessment time

Index	Time (months)	Mean±SD		*P*
		Intervention (*n*=236)	Control (*n*=200)	
DMFT (*n*)	Baseline	10.96±5.108	9.44±5.096	0.002
	6	11±5.09	9.57±5.083	0.003
	24	11.04±5.057	9.58±5.072	0.004
Mean difference*		−0.0763±0.336	−0.1400±0.448	
*P**		0.078		
Decay (*n*)	Baseline	7.6±4.58	6.02±4.01	<0.001
	6	6.91±4.14	5.91±3.92	0.01
	24	6.72±4.02	5.89±3.93	0.032
Mean difference		0.8771±1.37	0.13±0.682	
*P**		<0.001		
Missing (*n*)	Baseline	2.32±2.81	2.06±2.43	0.43
	6	2.46±2.802	2.14±2.41	0.28
	24	2.53±2.8	2.15±2.41	0.161
Mean difference		−0.2161±0.513	0.13±0.682	
*P**		0.004		
Filling (*n*)	Baseline	1.05±2.05	1.36±2.48	0.071
	6	1.63±2.18	1.51±2.46	0.255
	24	1.78±2.18	1.53±2.46	0.032
Mean difference		−0.737±1.155	−0.175±0.441	
*P**		<0.001		

**P*-values were obtained based on the Mann–Whitney *U*-test for comparing baseline minus 24-month measures. DMFT: Decayed, missing, and filled teeth; SD: Standard deviation

Comparing the DMFT index between the two groups in Table 2 shows that although the mean difference in DMFT index was not significant between the two groups ($P = 0.078$), the results were significant in different assessment times, which can be due to baseline differences.

The intervention group exhibited a higher mean DMFT at baseline in comparison with the control group ($P = 0.002$), and this disparity persisted during the final follow-up assessment. Besides, in both groups, the decayed teeth had approximately decreased, whereas the missed and filled teeth had increased at the last follow-up [Figure 2].

Findings from statistical modeling

The accumulation of zero in DMFT data was mostly related to the filled teeth (51%), whereas missed and decayed teeth involved zero in 27% and 4.7%, respectively. DMFT index accounted for 1.3% of zeros, with 6 cases in the control group and 11 cases in the intervention group. The presence of zero inflation was confirmed by the Broek test ($P < 0.001$). Therefore, in the multivariate approach, the ZIP model was fitted to the filled teeth data under the conditions of the model with and without heterogeneous random effects [Figure 3].

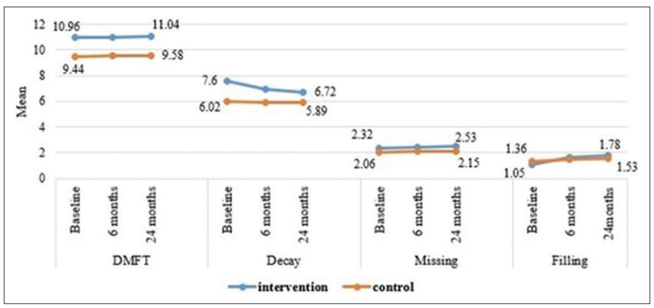

Figure 2: Mean decayed, missing, and filled teeth index and its components according to two groups and the assessment time. DMFT: Decayed, missing, and filled teeth.

To compare the model performance, the model selection indices were used as reported in Table 3. The zero-inflated model with heterogeneous random effects incorporated the lower values of AIC and BIC, so we considered this model as the most appropriate one. Indeed, this model simultaneously captures both the zero inflation and the correlation structure in data.

The interpretation of the results in the zero and Poisson parts of the model can be carried out separately. According to the findings derived from fitting the ZIP model, taking into account heterogeneous random effects, the group-by-time interaction effect was significant in the Poisson part of the model ($P = 0.021$). On average, the

Table 3: Estimation of model selection indexes for filled teeth data

Index	ZIP model with homogeneous random effects	ZIP model with heterogeneous random effects
−2log-liklihood	3306.9	3289.8
AIC	3336.9	3309.8
BIC	3398.1	3350.5

ZIP: Zero-inflated Poisson; AIC: Akaike Information Criterion BIC: Bayesian Information Criterion (BIC)

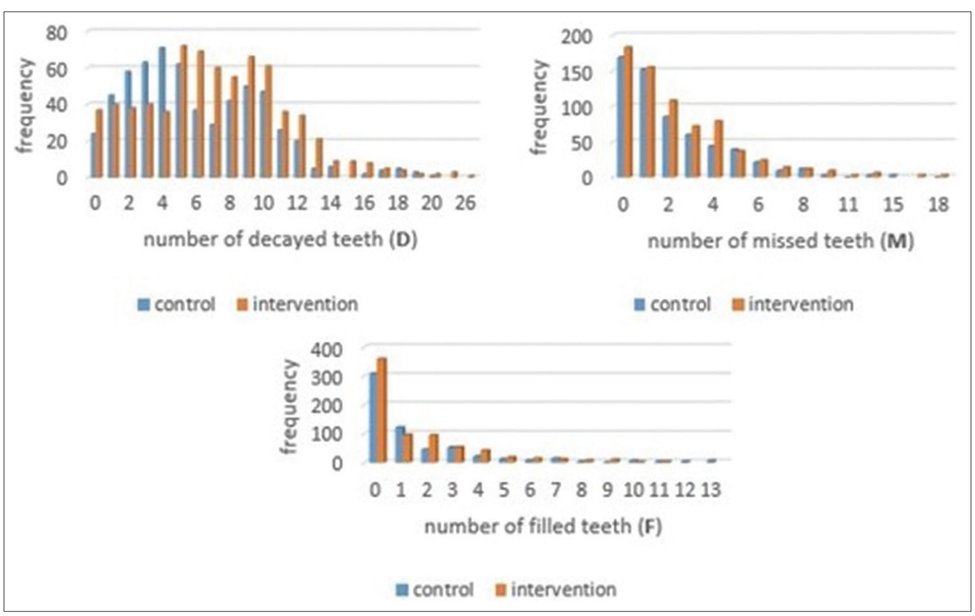

Figure 3: The frequency of decayed, missing, and filled teeth components (decayed, missing, and filled) regarding two groups.

intervention group exhibited a higher rate of change over time compared to the control group. In other words, the pattern or profile of the change during the period was significantly different in the two groups [Table 4 and Figure 2].

Regarding the results obtained from the zero part of the ZIP model in Table 4, the odds of having no filled teeth showed a significant decrease over time ($P < 0.001$). Furthermore, the intervention group exhibited higher odds of having filled teeth compared to the control group, on average ($P = 0.011$).

Finally, the results of fitting the Poisson part of the ZIP model with homogeneous and heterogeneous random effects in terms of different times are summarized in Table 5. The findings showed that the rate of filling teeth in the intervention group was higher than in the control group. In addition, the participants experienced a higher rate of filling teeth in the follow-up time compared with the baseline.

DISCUSSION

The health of the mother and fetus is of crucial importance in pregnant women.[28] It is necessary to provide oral health education to pregnant women and health-care professionals before and during pregnancy, as women often lack knowledge about oral health and its associated issues during this period. Providing oral health training during pregnancy for six sessions over 3 weeks can positively influence their beliefs and behaviors toward oral health.[29]

The DMFT index is used to measure the oral health condition. A valuable metric that can be obtained from the DMFT is the ratio of the population that is free from dental caries (DMFT = 0). This measure helps illustrate the extent to which the dental burden is concentrated in a subpopulation. The DMFT index assesses and monitors oral health interventions within the community through developing policies and programs in this domain. Nevertheless, the DMFT does not provide information regarding the specific teeth that are susceptible to oral health problems. Furthermore, it fails to differentiate between DMFT or surfaces, nor does it account for tooth loss due to factors unrelated to dental caries.[30,31]

The distribution of DMFT exhibits a significant skewness as it has a zero value. Consequently, linear models are unsuitable for predicting this variable.

Table 4: The results of fitting the zero-inflated Poisson model with homogeneous and heterogeneous random effects on filled teeth

Structure	Variable	ZIP model with homogeneous random effects				ZIP model with heterogeneous random effects			
		RR	95% CI		*P*	RR	95% CI		*P*
			Lower	Upper			Lower	Upper	
Zero part*	Group (intervention/control)	1.06	0.98	1.15	0.431	1.058	0.965	1.160	0.108
	Time (month)	0.98	0.93	1.02	0.321	0.960	0.922	0.998	<0.0001**
	Interaction (group and time)	1.14	1.04	1.24	0.005**	1.259	1.097	1.443	0.011**
Poisson part&	Group	1.05	0.73	1.26	0.731	1.246	0.795	1.93	0.34
	Time (month)	1.03	0.97	1.04	0.315	1.040	0.97	1.046	0.378
	Interaction (group and time)	1.06	0.95	1.17	0.208	1.012	1.002	1.022	0.021**

*RR values in this part are based on OR estimation, &RR values in this part are based on RR estimation. ZIP: Zero-inflated Poisson; CI: Confidence Interval; RR: Rate ratio; OR: Odds Ratio; **: Statistically Significant

Table 5: The results of fitting the zero-inflated Poisson model with homogeneous and heterogeneous random effects in terms of different times in the Poisson part of the model

Structure	RR	Homogeneous model	Heterogeneous model
The Poisson part			
Time=Baseline	Intervention/control	1.05	1.25
Time=6th month	Intervention/control	1.42	1.074
Time=24th month	Intervention/control	4.12	1.33
Intervention	Month 24/baseline	8.6	2.7
	Month 6/baseline	1.66	1.19
Control	Month 24/baseline	2.21	2.55
	Month 6/baseline	1.22	1.26

RR: Rate ratio

Therefore, our investigation fitted the ZIP model to longitudinal count data obtained from pregnant women under educational oral health intervention. We enhanced the zero-inflated count models by incorporating random effects heterogeneity and modeling the variance of these effects as a function of covariates. The heterogeneity in longitudinal zero-inflated data has not been provided by other studies, especially in dental research; to the best of our knowledge, only one study by Zhu *et al*. suggested this model for substance abuse data.[32]

In our study, zero accumulation in DMFT was mostly related to the filled teeth (51%) (missed and decayed teeth: 27% and 4.7%, respectively). In both studied groups, decayed teeth almost decreased. However, the missed and filled teeth increased on the last follow-up. The results of our study demonstrated that the ZIP model, incorporating heterogeneous random effects and fewer model selection indices, was superior to the model with homogeneous random effects. The intervention group exhibited a greater rate of change in the number of filled teeth over time compared to the control group. Moreover, our findings revealed a decline in the odds of having no filled tooth over time. Notably, the intervention group exhibited a greater change in the odds of having no filled tooth compared to the control group.

The oral health training positively affected pregnant women's behavior compared to the baseline. In a recent study by Saffari *et al*., the researchers investigated the efficacy of MI as a behavior-change technique in enhancing self-efficacy and oral health among 112 Iranian pregnant women. The intervention group received a comprehensive education program on oral health utilizing MI during two sessions, in addition to routine health education over 2 weeks. On the other hand, the control group attended two 1-h lectures on oral health changes during pregnancy. The results indicated a significant increase in the number of filled teeth in the intervention group. These findings suggest that health education interventions incorporating MI techniques can improve pregnant women's oral health-related self-efficacy and behaviors.[14] A study by Hu *et al*. examined the impact of oral health promotion management on enhancing oral healthcare knowledge, attitudes, and behaviors among pregnant women. The intervention group received oral health promotion management, whereas the control group did not. The results revealed statistically significant enhancements in the number of filled teeth and the CPI scores in the intervention group. In addition, the oral health-care habits of the intervention group exhibited a statistically significant improvement of 56.8%. These findings suggest that providing oral health-care education and implementing promotion management strategies for pregnant women can effectively enhance their oral health, knowledge, attitudes, and behaviors related to oral health care.[33] Similar results have been reported by Khademi Jahromi *et al*.'s study, which examined the impact of training about the DMFT index on enhancing oral health among pregnant women. Their study involved four 2 h educational sessions focused on oral health. After 3 months, the intervention group exhibited a significant increase in the number of filled teeth compared to the control group. In addition, the researchers observed that the educational program had a noteworthy influence on enhancing expectant mothers' knowledge, attitude, and oral health indicators.[34] The results of these recent studies confirm our findings. It seems that training during pregnancy can be an effective and low-cost method; given the frequent examinations during pregnancy, it is a favorable opportunity to transfer training for enhancing oral and dental hygiene in pregnant women. The results of our study can be generalized to communities similar to our study population where the socioeconomic status is low.

Our study had certain limitations. First, the limited population size of Pishva and Pakdasht hindered us from recruiting adequate participants. In addition, the geographical proximity of the participants' residences in each area made it impractical to implement random assignment, as this increased the likelihood of data transmission between the groups. We recommend multicenter studies involving oral health professionals to carry out educational interventions during and after pregnancy.

CONCLUSION

Based on the findings presented in this study, the ZIP model with heterogeneous random effects is suitable as an alternative for a two-part model. The findings in our research indicated that an educational intervention during pregnancy can improve oral health in long-term follow-up. Consequently, it is necessary to incorporate oral health education into the comprehensive care offered to pregnant women in private clinics and health centers during and after pregnancy.

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Conflicts of interest

The authors of this manuscript declare that they have no conflicts of interest, real or perceived, financial or nonfinancial in this article.

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