

Research Article**Impact of contacting teeth on caries status of a tooth using spatial autologistic regression model: analyzing caries experiences among a sample of primary schoolchildren****Solaiman Afroughi^{1*}, Mohammad Ali Usofi²,
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Yasuj, Iran. Tel: +9833223505, Fax: +9833226715**ABSTRACT**

Objectives To investigate the specific effects of contacting teeth on caries status of a tooth using spatial autologistic regression model.

Methods In a cross-sectional study 460 7-12 year-old children from primary schools in urban and rural districts of Yasuj township, Iran, were randomly selected. Dental examinations were carried out at school for all selected children by two professional and calibrated dentists according to World Health Organization (WHO) criteria. Caries statuses of Teeth's surfaces were recorded in a dental chart by examiners, according to primary and permanent teeth. Furthermore, teeth caries statuses were regarded as correlated binary data (1 for caries presence and 0 for caries not present) on a spatial lattice. Considering a neighborhood structure and using an autologistic regression model, the impacts of the teeth in contact with a tooth were investigated.

Results The outputs of autologistic regression analysis showed the impacts of the left side tooth ($z=17.75$, $p<0.001$), the right side tooth ($z=17.09$, $p<0.001$) and the opponent tooth ($z=30.76$, $p<0.001$) were significantly higher than zero. Furthermore, the odds of caries presence in a tooth due to the left side tooth (OR= 3.34), the right side tooth (OR=3.21) and the opponent tooth (OR=6.7) are notably all greater than 1. In addition, the OR values of the three contacting teeth were different, such that the OR of left side tooth was greater than the OR of right side tooth and the OR value of the opponent tooth was twice more than the OR values of two adjacent teeth.

Conclusion In the present study it was identified that the three contacting teeth, two adjacent and one opponent teeth, had high impacts on caries experience of a tooth via autologistic regression modeling. In addition, the impacts of the three teeth were not as the same and the influence of the opponent tooth was twice as large as the two adjacent teeth.

Clinical relevance Therefore, in prophylactic dentistry it is imperative to inform practitioners and patients that the three contacting teeth of a carious tooth are vulnerable to caries development. The priority in treatment referrals must be towards checking up and protecting the three teeth in contact with a decayed tooth with a two-fold role of the opponent tooth.

Keywords: contacting tooth, autologistic model, tooth caries, impact

INTRODUCTION

Dental caries is one of the most prevalent and common oral diseases affecting all human age

groups around the world [1-3]. Dental caries is recognized as the primary cause of oral pain and

tooth loss [4]. It is the major concerned problem of public health condition in Asian and Latin American countries [5-6]. Dental caries (process) phenomena begin from infantile period when deciduous teeth are erupting and can extend in later lifetime periods [7]. According to the World Health Organization (WHO) reports 60-90% of schoolchildren around the globe has experienced dental caries [8]. Dental caries affects nutrition intake, beauty, speaking, body growth and daily functioning statuses of children and impose a treatment expenditure on their families [9-13]. Therefore, identifying causes of tooth decaying, particularly at early stages, and providing appropriate preventive and operative programs are of high priority [9].

Studies on detecting the determinants of tooth caries presence in children have been intensively concentrated on subjects, parents and/or caregivers and community conditions [2,10]. However, potentially, there exist threatening factors in the oral cavity such as nearing teeth that can develop caries in a tooth [14,15]. In spite of being in a same exposure space, susceptibility of a tooth from caries statuses of approximal teeth seems a reasonable insight [16]. Supporting this issue, Oliver et al. [14] reported that in second molar and premolar teeth adjacent to missing first molar significantly more decayed and filled occlusal surfaces were observed than those teeth where adjacent first molar was not lost. Mejäre et al. [15] have demonstrated that tooth surfaces with existing carious lesions have increased a 15-fold risk of caries presence on contacting baseline sound surfaces. Furthermore, it has been demonstrated that cavity preparation leads to damaging of adjacent tooth surfaces such that during restorations 69% of adjacent surfaces in permanent teeth have been damaged [17-18]. Finally, in last years, Kopperud et al. [19] explored the risk factors for caries development on tooth surfaces adjacent to newly placed class II composites. Though, several accomplished studies have attempted to show that the caries status of a tooth influences on contacting teeth, besides being

scarce, they suffer from having inadequate methodological approaches [20-21].

As a basic subsection, appropriate statistical modeling plays an important role in understanding causes of tooth decaying in patients [22]. An advanced approach which is suitable for investigating occurrence of outcomes in terms of local positions of the teeth in the mouth is spatial methodology paradigm [23-25]. To assess the effects of adjacent teeth on caries status of a tooth via spatial modeling, the organized teeth in two jaws of the mouth is visualized as a lattice system and each tooth is considered as a spatial site [24]. Then, considering caries statuses of the teeth as correlated binary data and specifying a neighborhood structure on the teeth lattice (Fig.1), fitting the autologic regression model to dental caries data is evaluated [26]. In a study undertaken by [27] it has been demonstrated that caries statuses of nearest teeth have a significant influence on caries presence of a tooth. But, in this study the impacts of all neighboring teeth were considered as the same (as equal). However, regarding the local position of a tooth, assuming equal impacts for all its contacting teeth may not be correct and there is no undertaken investigation considering this issue [27]. Compensating this gap, we aimed to explore the specific effects of contacting teeth on caries status of a tooth using a spatial autologic regression model. To illustrate, tooth caries experiences data gathered from a sample of primary schoolchildren in Yasuj township, Iran, will be analyzed.

MATERIALS AND METHODS

study design and sampling

This analytical cross-sectional study was approved by research committee of Yasuj University of Medical Sciences, Iran. It was conducted from October 2013 to January 2014 among primary school children at Yasuj city and villages surrounding the city. Yasuj city is the center of the Kohgiluyeh Va Boyer Ahmad province in southern Iran, and about 1000 kilometers away from the capital city, Tehran. There were 40 primary

schools with 6000 students in this city in the time of study. The rural division surrounding Yasujcity comprised of five regions include Dashte Room, Kakan, SarroudeJenoubi, Sarroudeshomali and Deli ouladmomeni. In these regions there were 29 villages with 3000 children distributed in 29 primary schools. The city and environmentally related rural regions comprised the Yasuj Township, as a distinct administrative section, in the province.

Study participants

Primary school children aged 7-12 years (grade1-5) and were living at Yasuj city and others who lived in villages belong to Yasujtownship, were included in the study. Before the survey, the necessary permissions were obtained from central educational office management. Then with reference to primary schools, informed consent forms were distributed among children in one day. After day, signed and filled forms by children' fathers/mothers, were gathered. Ethical clearance was obtained from ethics committee of Yasuj University of Medical Sciences. Cases of dental caries were advised to visit a dentist.

Sample size and sampling

The prevalence rate of dental caries in children was estimated from a previous survey of school children in close area as 85%. Considering a 95% confidence interval and an error of 5% below or above the estimated 85%, and using single population proportion formula, the calculated sample size was 460 children. A three stage stratified cluster random sampling technique was employed to select the study participants. Yasuj city and surrounding villages were considered as the urban area and rural area, respectively. Yasuj city was divided in to five zones (strata) according to the type and number of schools, socio-economic situation and accessibility to municipality services. Then using the random digit table, from each section 2 schools were randomly selected. Also, five rural regions respective to distance from urban center, Yasuj, road type and available facilities, were considered in two clusters. Then from each cluster one region

was randomly selected. From one region two villages and from other sample region three villages using random digits table were selected. Since there was only one school in each village, so five school were selected. Following, proportional to the number of students in each area, 2/3 of the total sample (310 children) and the reminder(1/3)(150 children) were allocated to urban and rural area, respectively. Finally, considering class lists in each sample school and applying random digits table, based on the size of allocated subsamples, students were selected. The protocol of study was approved by the ethics committee of Yasuj University of Medical Sciences before dental examination and data collection.

Data collection

Dental examination was carried out at school for all selected children by two professional and calibrated dentists ($\kappa = 85\%$) according to World Health Organization (WHO) dental caries diagnosis criteria. The status of dental caries and teeth's surfaces were examined using flash light, disposable wooden spatulas, and flat dental mirror and blunt dental probe instruments. Dental caries was recorded as being present when a lesion in a pit or fissure on smooth tooth surface had a detectable softened floor, undermined enamel or softened wall. A tooth was considered missing because of caries if a person gave a history of pain and/or presence of cavity prior to extraction. Besides, tooth fillings were visually detected. Teeth's surface caries statuses were recorded in a dental chart by examiners, according to deciduous and permanent teeth. Finally, the number of decayed, missing due to caries and filed teeth for deciduous teeth (dmft) and permanent teeth (DMFT) were recorded.

Modeling caries data via spatialautologic regression

On a spatial domain, especially a lattice, due to uniform space, measures(observations) on response(dependent) variable are spatially correlated data or in other words spatially autocorrelated data[23]. Besag et al.[23]

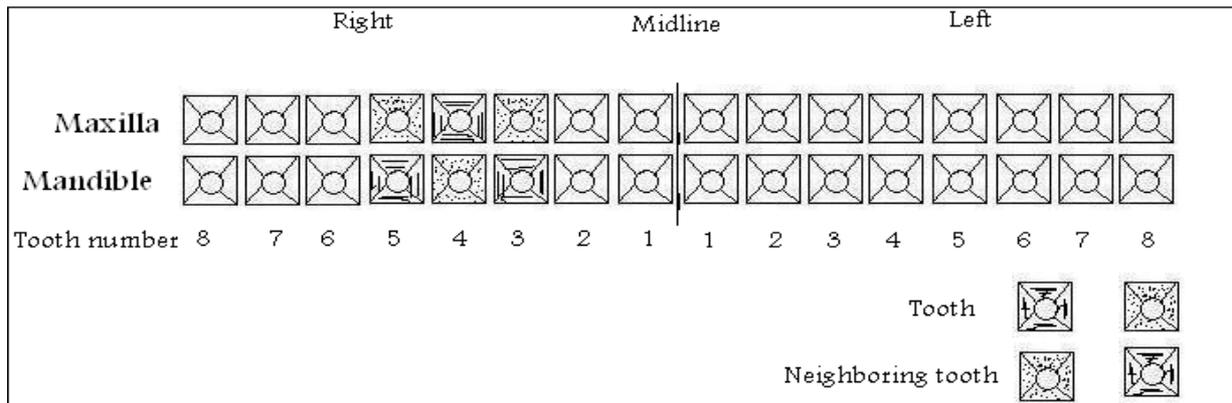
introduced the basicautologic regression model for analyzing spatially correlated binary (presence/absence) data on a lattice. This model is a special case of the general logistic model which incorporates a term to capture the spatial autocorrelation effects in the process of statistical analysis. The basic autologicistic regression model as the conditional probability of caries presence of a tooth for a child given all other teeth, is introduced as follows:

$$P(y_{ij} | y_{ik}, j \neq k, j \in \{1, \dots, 32\}) = \frac{\exp(\gamma_1 y_{ij2} + \gamma_2 y_{ij3} + \gamma_3 y_{ij3})}{1 + \exp(\gamma_1 y_{ij2} + \gamma_2 y_{ij3} + \gamma_3 y_{ij3})} \tag{1}$$

where, y_{ij} represents binary response variable (0 for caries not present or 1 for caries present) of the tooth in site ij , and parameters γ_1, γ_2 and γ_3 are the nonnegative coefficients of three neighboring

tooth), respectively, as demonstrated in Fig.1. For evaluating the effects of these neighbors on y_{ij} and fitting the autologicistic model(1) to the dental caries data, due to spatial dependency among y_{ij} , the parameters were estimated through pseudo likelihood method [29]. Then mean and variance of the parameters, were estimated by enumerating the hessian matrix induced from pseudo likelihood function of the model [30]. Following, the parameter estimates were considered as normal random variables and the z-Wald test was implemented to assess the effects of adjacent teeth on caries status of a tooth. Furthermore, to identify the intensity of association of caries status of a tooth with its adjacent teeth, Odds ratios (ORs) with related confidence intervals, were presented. Significant level considered when p value < 0.05.

Fig.1. Spatial lattice structure of complete teeth and neighboring (contacting) teeth of a tooth .



responses y_{ij1}, y_{ij2} and y_{ij3} of the response y_{ij} in the spatial lattice system of the teeth as in figure 1. The expression $(\gamma_1 y_{ij2} + \gamma_2 y_{ij3} + \gamma_3 y_{ij3})$ comprised the spatial autocovariate term in the autologicistic model(1).

Data analyzing and estimation method

Statistical computations and data analysis were performed using R free software version 3.3 [28]. In model(1), the binary variable y_{ij} represents the caries status of tooth j for child i ($y_{ij} = 1$ caries present, $y_{ij} = 0$ caries not present), where $j = 1, \dots, 32$ and $i = 1, \dots, 460$. The parameters γ_1, γ_2 and γ_3 denote the effects of three responses observed on adjacent teeth (the contacting tooth on right side, the contacting tooth on left side and the opponent

RESULTS

The outputs of the fitted autologicistic regression model to dental caries data, especially the estimates of coefficients and OR values, are presented in the Table 1. As the content of this table shows the coefficient of the left side tooth ($z=17.75, p=0.001$), the right side tooth ($z=17.09, p=0.002$) and the opponent tooth ($z=30.76, p=0.001$) are significantly higher than zero. Furthermore, the odds of caries presence in a tooth due to the left side tooth (OR=3.34), the right side tooth (OR=3.21) and the opponent tooth (Or=6.7) are notably all greater than 1. These results indicate that the three contacting teeth had significant impacts on decaying a tooth and are

positively correlated risk factors to its caries presence status. In addition, the OR values of the three contacting teeth are different, such that the OR of left side tooth is greater than the OR of right side tooth and the OR value of the opponent tooth is

twice more than the OR values of two adjacent teeth. Therefore, the odds of a tooth being decayed because of the carious left , carious right side and carious opponent tooth were respectively more than three times, three times and about seven times the case that the respective neighbor tooth being sound.

Table 1- Output of statistics and indexes due to impacts of three contacting teeth found by fitting

Contact status (autocovariate)	Coefficient estimate(B)	Standard-deviation (sd)	Wald statistic	p	Odds Ratio(OR)	95% CI for OR	
						lower	upper
Left side tooth	1.206	0.068	17.75	<0.001*	3.34	2.923	3.814
Right side tooth	1.167	0.068	17.09	<0.001*	3.21	2.811	3.674
Opponent tooth	1.902	0.062	30.76	<0.001*	6.7	5.935	7.563
constant	-2.839	0.040	-	-	-	-	-

spatial autologic regression model

*:significant

Model validation

To assess the validation of the model, the goodness of fit indexes such as chi-square and Cox & Snell R square statistics were obtained. The results showed that the chi-square value(17.8) of the model is highly significant(p<0.0001) and Cox & Snell R square index (0.11) is sufficiently high. Farther, the Relative Operating Characteristic(ROC) value of the model was computed as 0.76 which indicates the model appropriateness[31]. Therefore, the presented autologic regression model has a valid goodness of fit.

DISCUSSION

In this study it was shown that caries experiences of the three adjacent teeth had significant and different effects on caries presence of a tooth using spatial autologic regression model. This result presents a detected manner for operating

and treating agents in prophylactodontics and clinical dentistry. In this investigation we demonstrated that the odds of decaying a tooth due to caries status of the left side and right side teeth in same jaw and the opponent tooth in opposite jaw were high. Oliver et al. [14] in a study to analyze the relationship between loss of first permanent molar teeth and the prevalence of caries and restorations in the surfaces of adjacent teeth concluded that children with missing first molars had significantly more decayed and filled occlusal surfaces in the adjacent second molar and premolar teeth than those which had not lost the first molar. In a study conducted by [19] it was shown that restoration the surfaces of a carious

tooth has developed caries on adjacent tooth surfaces. Furthermore, Kang et al. [21] in a study revealed that caries prevalence in the mandibular second molar was associated with eruption Status of adjacent mandibular third molar. The findings of our study are supported by results from all these studies. But, the shortcoming of the above investigations is implementing the logistic model in analyzing caries data. Researchers reported that caries events of teeth in individuals occur in a correlated cluster manner [32-33]. While, observations not being independent, logistic regression model could not be implemented to analyze data[20].

The local positions of the teeth on each jaw and all together on mandible and maxilla in the mouth has a spatial structure that may be visualized as a lattice[26]. The observations of caries statuses on this discipline are spatially correlated binary data and wrong use of logistic regression analysis leads to presence of biasedness in estimations and computations (results) [20]. The autologic

regression model developed by Besag et al. [23] is appropriate for analyzing such data. We showed that the proposed model in assessing the impact of contacting teeth on caries status of a tooth has the necessary feasibility and validity.

In present study it was revealed that two adjacent teeth in same jaw and the in-face tooth in opposite jaw had highly significant impact on caries experience of a tooth. Also, the impacts were not as the same and the effect of the opponent tooth was two times as large as the specific effects of two adjacent teeth. A previously conducted investigation[27] confirm the findings of this study, but, in that study the impacts of all contacting teeth were considered as equal. Contacting teeth are emerged in a same space and have same susceptibility conditions for caries development. An adjacent tooth have least distance to a tooth and when eating and chewing, pieces of foods remain in between them and can lead to decaying at least one of them. It is possible that caries from a carious tooth transmit to adjacent tooth [27]. In addition, treatment and restoration of a decayed tooth influence in caries presence of adjacent tooth[[19]. Furthermore, it can be argued that two opponent teeth are contacting via occlusion surfaces and cooperate in cutting and chewing foods. During this process occlusion surfaces are facing with destructive and erosive conditions more than other surfaces of two teeth. So, they are more in exposing to caries experience conditions.

CONCLUSION

In the present study it was identified that the three contacting teeth, two adjacent and one opponent teeth, had high impacts on caries experience of a tooth via autologistic regression modeling. In addition, the impacts of the three teeth were not as the same and the influence of the opponent tooth was twice as large as the two adjacent teeth. Therefore, in prophylactic dentistry it is imperative to inform practitioners and patients that the three contacting teeth of a carious tooth are vulnerable to caries development. The priority in

treatment referrals must be towards checking up and protecting the three teeth in contact with a decayed tooth with a two-fold role of the opponent tooth.

Compliance with Ethical Standards

Conflict of Interest: Solaiman Afroughi declares that he has no conflict of interest. Mohammad Ali Usofi declares that he has no conflict of interest. Karam Behroozpour declares that he has no conflict of interest. Sayedeh Azam Kazemi declares that he has no conflict of interest.

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Ethical approval: All procedures performed in this study were in accordance with the ethical standards of the Iranian national research committee and with the 1964 Helsinki declaration and its later amendments or comparable ethical standards.

Informed consent: Informed consent was obtained from all individual participants included in the study.

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