Dental Caries and Otitis Media Among Schoolchildren in Palau

Inger B. Appanaitis MPH; William E. Lambert PhD; Eli Schwarz DDS, PhD, MPH; Michael R. Lasarev MS; and Berry Moon Watson MPH

Abstract

Both oral disease and middle ear infections are highly prevalent in Pacific Island children. These diseases are multifactorial and likely attributable in part to both social and environmental factors. It has been two decades since these diseases were defined in Palau, and at the time were noted to be among the most common conditions and presented a substantial burden among Palau's children. In 2006, the Ministry of Health in Palau began conducting comprehensive school health screenings in grades 1-11. While primarily used as a referral tool, this survey can also be used in epidemiologic studies to describe health trends. The current study utilized this screening data from the 2011-12 school year to characterize the prevalence of dental caries and otitis media and explore a previously suggested relationship between the two conditions, including common risk factors. It was found that over one-quarter (28.9%) of Palauan students had abnormal tympanometry results, with up to 17% indicating active otitis media. In addition, 85% of students had at least one decayed or filled tooth, with an average of 3.9 decayed or filled teeth in 12-year-olds. Both conditions were found to be more prevalent in public than in private schools; however, the two disorders were not significantly associated with each other. These findings place the prevalence of decayed, missing, and filled teeth, and otitis media in Palauan schoolchildren among the highest reported in the world. The widely recognized consequences of poor oral health and hearing impairment on learning, nutrition, and chronic disease make urgent the need for early intervention.

Keywords

Oral Health, Dental Caries, Epidemiology, Global Health, School Health, Children, Pacific Islander, Micronesia, Pediatric Audiology, Health Disparities

Abbreviations

AIC = Akaike information criterion
AOM = acute otitis media
BIC = Bayesian information criterion
BMI = body mass index
CDC = Centers for Disease Control and Prevention
DFT = decayed, filled teeth index (primary dentition)
DMFT = decayed, missing, filled teeth index (permanent dentition)
MOH = Ministry of Health
OM = otitis media
OR = odds ratio
SD = standard deviation
ZINB = zero-inflated negative binomial

Introduction

A decade prior to this study, Greer and colleagues (2003) warned of a "silent epidemic" of oral disease among children in Pacific Island nations, characterizing the age-weighted mean for decayed and filled primary teeth (DFT) among children ages 5 to 9 years in Hawai'i, Guam, and the Republic of Palau to be three times that of the mainland United States.[1] Otitis media (OM), or middle ear infections, has also been documented as highly prevalent in Pacific Island children. For instance, an earlier survey in Palau found 16% of Head Start children and 10% of elementary school children having "active disease" and concluded that OM was one of the most common handicapping conditions among Palau's children.[2]

The etiologies of tooth decay and OM are complex and perhaps interrelated, as both diseases have shown evidence of genetic, lifestyle, and environmental risk factors.[3] In the mid-1990s, several studies in Finland proposed a connection between the two childhood diseases.[4-6] The hypothesized association was suggested after it was found that xylitol chewing gum, which has historically been used for the prevention of dental caries, reduced the incidence of acute otitis media (AOM) in preschool-aged children.[4,5,7,8]

Since then, two additional studies tested the association between OM and dental caries but produced mixed results. The first, a case-control study, found no difference in ear infection history between children experiencing or with history of dental caries and those that were caries-free.[6] However, despite failing to reach statistical significance at $P < .05$, the mean number of ear infections was higher in the dental caries group than in the caries-free group. The second study, an analysis of 30,000 Medicaid records, did demonstrate a significant association between OM and dental caries.[9] In this study, children with claims (ie, clinical visits) for AOM or respiratory infections were at a 29% higher risk of developing caries after their first year of life as compared to children with no claims. However, when OM and respiratory infections were evaluated individually, data showed that children with claims for OM only were at an 11% higher risk of developing caries, while children with claims for respiratory tract infections only were at a 34% higher risk.

Although the epidemiological evidence for a relationship between these two childhood disorders is limited, at least two biological hypotheses have been proposed to explain this relationship. The first claims that OM may directly contribute to the development of dental caries when high levels of bacteria (eg, *Streptococcus pneumonia)* disrupt enamel formation, causing enamel hypoplasia and leaving teeth more susceptible to lesions or cavities.[9,10] The second biological hypothesis posits that OM and tooth decay are indirectly related but are comorbid conditions due to shared risk factors such as inappropriate bottle use, inadequate personal hygiene, and poor living conditions.[11-16]

This report presents a secondary analysis of data from a comprehensive school health survey of children in Palau. The school health survey is conducted annually by trained teams from the Ministry of Health. Through standardized methodology, the survey allows for estimation of the prevalence of dental caries and AOM and further analysis of the co-occurrence of these two conditions.

Methods

Setting

The Republic of Palau has been an independent sovereign nation since 1994 when it signed The Compact of Free Association with the United States. Located in Western Micronesia, the nation is made up of approximately 340 volcanic and limestone islands spread across 700 square miles of ocean. The population of Palau, estimated at 17,501 in 2012, inhabits twelve of these islands, which are divided into 16 political states. The residents of Koror, the commercial capital of Palau, and Airai, its neighboring state, make up approximately three-quarters of the total population.

Data Source

This study was a secondary analysis of data with protocol approval from the Institutional Review Boards of the Ministry of Health (MOH) in Palau and Oregon Health & Science University in Portland, Oregon. The MOH School Health Program Physical Examination Screenings began in the 2006-07 school year. Both physical and behavioral health are examined with data collected on demographics, vital signs, body mass, vision, dental health, hearing, substance use, and depression. The annual screenings are conducted on students of the odd-numbered grades 1-11 to ensure screening of all students every other year. This analysis was restricted to data collected in 2011 of students between the ages of 5 and 12 for a final sample of 831 students, which was equivalent to 31% of the country's total school enrollment for the 2011-12 school year.

Measurement and Data Collection

All data were collected between August 16, 2011 and November 18, 2011 by a team of clinical and public health professionals from the MOH. Dental nurses conducted regular dental exams, recording the number of decayed teeth, treated and untreated, in each child, and identifying if the decay was in the primary or permanent dentition. Each tooth was classified as healthy, decayed (ie, carious), or previously treated decay (ie, filled), and recorded as healthy or decayed.

Specialists from the Ministry's Ear, Nose, and Throat Clinic conducted tympanometry tests of each ear to measure the mobility of the eardrum and conduction bones.[17] The mobility results are classified according to three types of curves (Type A, B, and C) and have high sensitivity and specificity in diagnosing middle ear effusions in children.[17-18] Both Type B and Type C were categorized as abnormal results. An overall result was created based on the weakest compliance of the two ears, with Type A representing the best compliance, Type C representing moderate compliance, and Type B representing poor compliance. An additional dichotomous variable was created to classify 'normal' (Type A) and 'abnormal' (Type B and Type C) results.

Statistical Analysis

Zero-inflated negative binomial (ZINB) regression was used to model dental caries. Multivariate regression models were constructed using the backwards elimination method. Along with age, sex, and school type, the confounders considered included: ethnicity (self-identified Palauan or 'Other'); BMI, continuous (kg/m2) and categorical (in adherence to CDC classification according to age: underweight, healthy weight, overweight, and obese); self-reported physical activity levels (light, moderate, or vigorous); school location (urban or rural); self-reported nicotine use (yes or no); and self-reported alcohol use (yes or no). Lastly, tympanometry variables were added to the models to test if the inclusion of these variables significantly improved fit and explained variance. Significant predictors were based on Wald χ^2 statistics at $P < .01$. Candidate models were compared using Nagelkerke (adjusted) R^2 statistics, Akaike Information Criterion (AIC), and Bayesian Information Criterion (BIC).

Results

831 students between the ages of 5 and 12 had complete data from the 2011-12 school physical examinations. The mean age of students was 8.8 (SD 2.2) years and the sample was evenly distributed between male (51%) and female (49%) students (Table 1). Nearly 60% of the students came from urban schools and three-quarters attended schools that were public. While substance use was reported as early as 7 years of age, the overall proportion of students reporting substance use was low (nicotine users, n = 23; alcohol users, n = 6). Nicotine use was significantly associated with age (OR = 1.73, $P =< .001$), but alcohol use was not (OR = 1.33, $P = .171$).

Description of Tympanometry Findings

Approximately 71% of the students had a normal tympanometry finding (Type A), while 29% had abnormal results (17% Type B and 12% Type C). Abnormal results ranged from 19% in the 12-year-olds to 37% in the 7-year-olds, with a significant inverse association between age and proportion of abnormal tympanometry results (OR = 0.92, $P = .02$). There were no significant differences in tympanometry results by gender (two-sample test of proportions: $z = 0.52$, $P = .60$), but differences were observed by school type. Among children who attend public schools, only 68% had normal tympanometry results, while 81% of children attending private schools had normal results (Figure 1; two-sample test of proportions: $z = -3.01$, $P = .003$).

Table 1. Population Characteristics of Children Surveyed in 2011-2012 School Health Screening (n=831)					
		Primary Dentition		Permanent Dentition	
	Total Sample	Decay-Free	Mean Decay[a] (SD)	Decay-Free	Mean Decay[a] (SD)
Sex					
Boys	51.3%	37.6%	4.79 (3.45)	37.1%	3.30 (2.49)
Girls	48.7%	42.2%	4.85 (3.14)	33.3%	3.39 (2.43)
School Type					
Private	21.8%	47.5%	3.86 (2.65)	48.6%	2.70 (1.77)
Public	78.2%	37.7%	5.05 (3.41)	31.5%	3.48 (2.56)
Ethnicity					
Palauan	91.0%	39.3%	4.89 (3.29)	33.6%	3.37 (2.48)
Other	9.0%	45.3%	4.10 (3.43)	52.0%	2.94 (2.18)
BMI (cat)					
Underweight	5.1%	26.2%	5.42 (3.35)	26.2%	3.42 (1.95)
Healthy weight	65.7%	37.0%	4.99 (3.42)	35.5%	3.32 (2.37)
Overweight	12.0%	48.0%	4.46 (3.32)	38.0%	3.26 (2.71)
Obese	17.2%	49.0%	4.04 (2.60)	35.0%	3.45 (2.76)
Physical Activity (PA)					
Light PA	12.0%	42.0%	4.71 (3.07)	40.0%	3.02 (2.31)
Moderate PA	73.9%	41.0%	4.77 (3.28)	34.0%	3.38 (2.49)
Vigorous PA	14.1%	31.6%	5.11 (3.60)	37.6%	3.40 (2.39)
School Location					
Urban	57.2%	40.0%	4.64 (3.03)	35.8%	3.57 (2.54)
Rural	42.8%	39.6%	5.07 (3.64)	34.6%	3.04 (2.32)
Nicotine					
No	97.2%	39.2%	4.81 (3.27)	35.6%	3.30 (2.41)
Yes	2.8%	60.9%	5.44 (5.20)	21.7%	4.67 (3.41)
Alcohol					
No	99.3%	40.0%	4.83 (3.31)	35.5%	3.33 (2.46)
Yes	0.8%	16.7%	4.20 (3.03)	16.7%	4.83 (1.47)
Tympanometry					
Type A (normal)	71.1%	41.6%	4.75 (3.24)	35.9%	3.35 (2.55)
Type B (abnormal)	17.0%	32.6%	5.05 (3.41)	34.8%	3.15 (1.92)
Type C (abnormal)	11.9%	39.4%	4.87 (3.56)	32.3%	3.60 (2.58)

[a] Mean decay in students experiencing decay in one or more teeth.

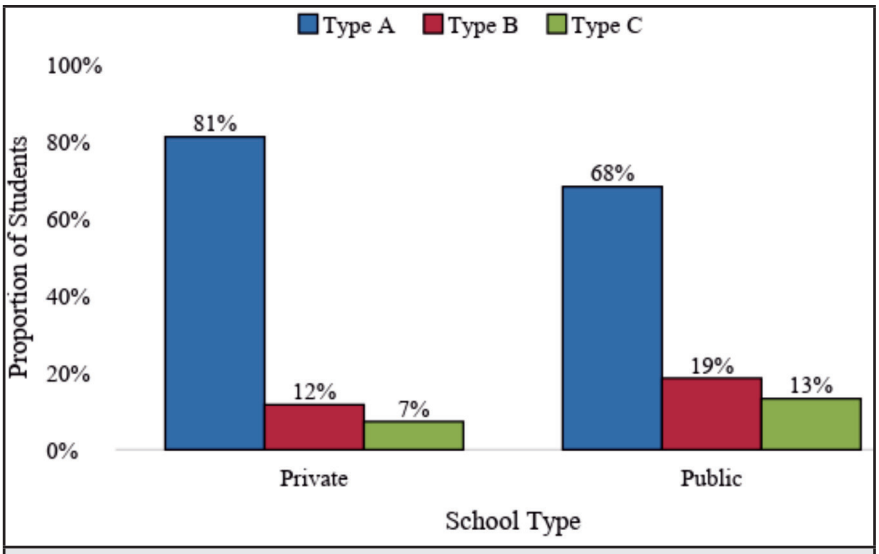

Figure 1. Tympanometry Results of Palauan Children by School Type

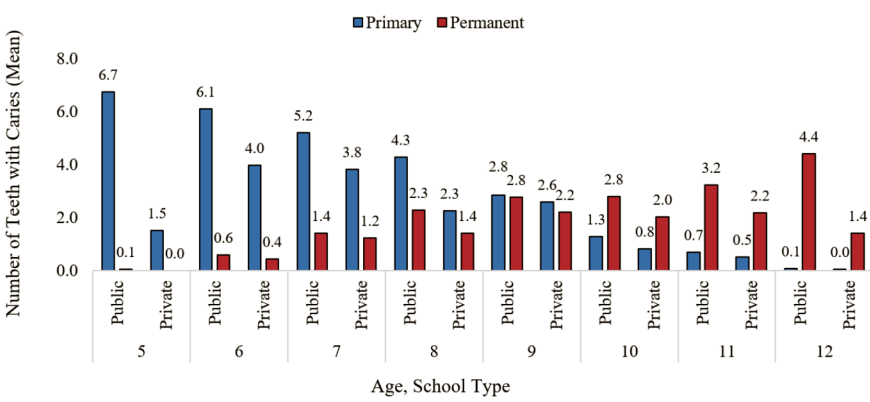

Figure 2. Mean Number of Teeth with Caries in Primary and Permanent Dentition by Age and School Type

Description of Dental Caries Findings

Caries experience (both treated and untreated decay) was identified in 85% of students. The mean number of primary and permanent teeth with caries experience is summarized in Figure 2. A significant inverse correlation was observed between total number of teeth with caries and student age (ρ=-0.24, P<.001). There was no significant difference in total number of teeth with caries between male and female students in public schools (5.66 vs 5.39; rank-sum test, P=.52) nor in private schools (3.07 vs 3.81; rank-sum test, P=.12). However, there was a significant difference between students of the same sex attending different school types; the mean number of teeth with caries in public schools was 1.5 times that of in private schools. For example, the mean number of total teeth with caries for boys in public schools was 5.66 (SD 4.13), but only 3.07 (SD 3.25) in private schools (rank-sum test, P<.001). Also, the mean number of total teeth with caries for girls in public schools was 5.39 (SD 3.89) compared to 3.81 (SD 3.22) in private schools (rank-sum test, P<.001).

Analysis of Caries in Primary Dentition

ZINB models were inflated by age under the assumption that age explains the excess of zero counts in the data. Univariate analyses were conducted to assess the individual influence of each predictor on primary caries. To minimize type II error, significant predictors were identified at α<0.2 level. Following this criteria, *age* (P<.001), *school type* (P<.001), *ethnicity* (P=.071), *BMI* (P<.001), and *school location* (P=.047) were identified as significant predictors of primary caries in univariate analyses. *Primary caries* was regressed on these five variables. From this model, variables that did not achieve a stricter P<.10 level of significance were eliminated and Wald test statistic was

Table 2. Final Zero-Inflated Negative Binomial (ZINB) Multivariate Model(s) Relating Mean Number of Teeth with Caries by Primary and Permanent Dentition

	Primary dentition[a]		Permanent dentition[b]	
Variable	**Multiplicative effect[c]**	**95% CI**	**Multiplicative effect[c]**	**95% CI**
Age	0.77	0.74, 0.82	1.16	1.11, 1.20
School Type				
Private	Referent		Referent	
Public	1.44	1.20, 1.73	1.84	1.54, 2.20
Ethnicity				
Palauan	Referent		Referent	
Other	0.78	0.60, 1.01	0.74	0.57, 0.96
BMI (1 kg/m2)	0.96	0.95, 0.98		
State			*P*<.001	
1			Referent	
2			1.89	1.08, 3.30
3			0.10	0.01, 0.83
4			0.70	0.20, 2.37
5			2.91	1.72, 4.94
6			0.80	0.33, 1.94
7			2.14	1.13, 4.08
8			2.35	1.26, 4.39
9			2.42	1.14, 5.11
10			1.45	0.75, 2.80
11			1.23	0.55, 2.76
12			0.97	0.49, 2.01
13			1.22	0.58, 2.55
14			2.22	1.20, 4.09
Nicotine				
No	Referent			
Yes	1.65	0.96, 2.83		

[a] Estimates of Pr(caries=0) inflated by age; Estimated dispersion parameter =0.46 (95%CI:0.33, 0.60).
[b] Estimates of Pr(caries=0) inflated by age; Estimated dispersion parameter =0.29 (95%CI:0.21, 0.39).
[c] Multiplicative effect for a Poisson-like regression is the ratio of two means.

used to test improvements. After eliminating *school location*, various models were tested with additional variables. *Nicotine* significantly improved the final model (based on AIC and Nagelkerke R^2; Table 2), and therefore was included. A final model including *age, school type, ethnicity, BMI* and *nicotine* tested the hypothesis that tympanometry was a significant predictor of caries in primary teeth. However, neither Type B nor Type C tympanometry findings were significant predictors of caries in primary teeth (P= .970 and P=.994, respectively).

Analysis of Caries in Permanent Dentition

Univariate analysis of each independent variable found *age* (P<.001), *school type* (P<.001), *ethnicity* (P=.005), *school location* (P=.006), and *state* (P<.001), as well as *nicotine* (P=.083) and *alcohol* (P=.077), to be significant predictors of permanent caries at an α level <0.2. These variables were used to begin building the final model for permanent teeth. After eliminating *school location* at the P<.10 level, the addition of other variables of interest were explored. Several of these models with different variable combinations had relatively similar goodness-of-fit measures. A final model for permanent teeth was selected based on goodness-of-fit as well as concordance with the model for caries in primary teeth and known risk factors. This final model included *age, school type, ethnicity,* and *state*, but again, neither of the tympanometry variables met the P<.1 level of significance (Type A/Type B/Type C, P=.598; and normal/abnormal, P=.312).

Discussion

Findings from the 2011-12 student health surveys indicate that dental caries and OM remain prevalent conditions, with 85% of surveyed students having had at least one tooth with signs of decay and over one-quarter of students with abnormal (Type B and Type C) tympanograms. Moreover, 17% of Palauan students had a Type B tympanogram, a sign of poor or no mobility in the tympanic membrane and indicative of an active middle ear infection.[15]

The burden of oral disease observed in this study is consistent with the earlier findings of Greer, et al, (2003) indicating 87.7% of 6-year-olds in Palau experiencing decay in primary teeth. The prevalence of both studies falls within the estimated range reported by Petersen, et al, (2005) for industrialized countries (ie, 60%-90%). Of great concern, however, is the severity and distribution of oral disease within the population. Of surveyed students, the number of teeth with caries ranged from 1 to 16 in primary dentition and 1 to 15 in permanent dentition. Of students with at least one cavity in a primary tooth, the mean number of total cavities was 4.8 (n = 500, SD 3.31). Likewise, of students with at least one cavity in a permanent tooth, the mean number of total cavities was 3.3 (n=538, SD 2.46). School type was a significant predictor of dental caries, with children in public schools having a greater burden of disease. These findings also suggest the total caries burden to be higher among younger children (age-total caries, $\rho = -0.24$, $P < .001$).

The level of oral disease among Palauan schoolchildren remains much higher than the global goal established by the World Health Organization (WHO). The mean Decayed, Missing, or Filled Teeth (DMFT) measure for 12-year-olds is used as an indicator of oral health status within a given population. The mean number of decayed and filled permanent teeth for 12-year-old Palauans from the school health survey is 3.88 (n = 138, SD 3.79). Interpretation of this prevalence estimate is somewhat limited since this survey recorded only decayed and filled teeth without considering permanent teeth lost to decay. Including missing teeth in the survey would have allowed a direct comparison to the WHO statistics in DMFT units. Even so, this estimated prevalence—though an underestimation—remains above the WHO goal of 3.0 DMFT.

In this analysis, the strongest predictor of caries in permanent dentition was the type of school a child attended. This variable, as well as the variable, *age*, was found to be highly significant across several alternative models for both primary and permanent dentition. For caries in primary teeth, this final model included the following predictors: age, the type of school a child attended, ethnicity, BMI, and nicotine use. Although nicotine was not significant at the $\alpha = 0.05$ level, it did significantly improve the model fit for primary caries, explained total variance, and is a known risk factor for oral disease. Groups at higher risk of dental caries in primary teeth were children who attended public schools, identified as Palauan ethnicity, or used nicotine. Additionally, both age and BMI were inversely related with mean number of caries in primary teeth. Significant predictors for dental caries in permanent dentition included: age, school type, ethnicity, and state of residence.

The prevalence of OM in this population is higher than previously reported by Dever, et al, (1990), who focused on a younger population, specifically preschool-aged children attending Head Start schools. The present study found Type B tympanograms to be even more prevalent among students ages 5 and 6 (19.1% and 22.0%, respectively) than previously reported by Dever, et al, however, not significantly higher than the prevalence among all age groups in this study. The differences between this study and the Dever, et al, study may be due to the small sample sizes. The World Health Organization has identified several other indigenous Pacific Rim populations with high prevalence of chronic OM, including Inuits at 12%-46% and Australian Aboriginals at 12%-25%.[19] The prevalence of active OM within Palau's student population falls in these ranges. Including the students with Type C tympanograms, the prevalence of abnormal tympanograms is 29%. In addition, children attending public schools had a higher proportion of abnormal tympanometry results than their counterparts attending private schools. An estimated 18.5% of students in public schools showed signs of active middle ear infections. A second WHO report indicated that populations with greater than 4% prevalence of OM (specifically, chronic suppurative otitis media) represent a "massive public health problem" that requires urgent attention.[20,21]

Although both dental caries and OM are highly prevalent in school children in Palau, this analysis failed to establish an association between the two conditions. In the multivariate models for caries in primary and permanent teeth, tympanometry variables as predictive measures, whether classified as normal/abnormal or type of tympanogram (Type A/B/C), were not statistically significant. In light of this, several strengths and limitations should be considered in the interpretation of these findings. First, the sample population was large and provides a good representation of the general population of Palauan children. Second, trained survey teams used clinically accepted methods, producing accurate measurements of decayed and filled teeth, and objectively ascertaining the presence of OM using tympanometry. Because the numbers of missing teeth were not recorded, the DFT is expected to slightly underestimate DMFT, the preferred metric used in many reports. It was not feasible to use otoscopy in this survey to visualize the tympanic membrane and diagnose OM, however tympanometry as a diagnostic tool has reasonably high positive and negative predictive value.[18]

In conclusion, the school health surveys conducted by the MOH serve as an important tool for revealing the health profile of Palau's children and the current study demonstrates the potential of these data to support translational research. Both OM and dental caries are highly prevalent in the school-aged population of

Palau. The identification of school type as a significant predictor suggests that these diseases may share common social causal factors. There is insufficient information to conclude that the observed disparity by school type is related to socioeconomics; however, it will be important for future surveys to obtain more detailed information on demographics and health care behavior that may illuminate demographic differences between children attending public and private schools in Palau. In the meantime, school-based interventions may be an effective strategy for addressing these conditions, especially interventions which incorporate daily toothbrushing and hand washing. Improving hygiene standards and community knowledge of preventive health strategies may be effective in combatting OM and dental caries in children.

Conflict of Interest

None of the authors identify any conflict of interest.

Acknowledgments

The team would like to thank the Republic of Palau Ministry of Health for supporting this project by granting access to the dataset. We would also like to thank the Ministry of Health workers who collected data in the field. This project was partially funded by the Global Health Center at Oregon Health & Science University.

Authors' Affiliations:
- Department of Public Health & Preventive Medicine, Oregon Health & Science University, Portland, OR (IBA, WEL, MRL)
- Office of Health Policy, Research, & Development, Ministry of Health, Republic of Palau (IBA, BMW)
- Department of Community Dentistry, Oregon Health & Science University, Portland, OR (ES)

Correspondence to:
Inger B. Appanaitis MPH; Email: inger.appanaitis@gmail.com

References

1. Greer M, Larson K, Sison S. Comparative analysis of oral health indicators among young children in Hawai'i, the Republic of Palau and Territory of Guam, 1999-2000. *Pac Health Dialog*. 2003;10(1):6-11.
2. Dever G, Stool SE, Manning S, Stewart J. Otitis Oceania: Middle ear disease in the Pacific Basin. *Ann Otol Rhinol Laryngol*. 1990;suppl 149:25-27.
3. Scroth RJ, Harrison RL, Moffatt ME. Oral health of indigenous children and the influence of early childhood caries on childhood health and well-being. *Pediatr Clin North Am*. 2009;56(6):1481-99.
4. Uhari M, Kontiokari T, Koskela M, Niemala M. Xylitol chewing gum in prevention of acute otitis media: double blind randomized trial. *BMJ*. 1996;313(7066):1180-4.
5. Uhari M, Kontiokari T, Niemela M. A novel use of xylitol sugar in preventing acute otitis media. *Pediatrics*. 1998;102(4 Pt 1):879-84.
6. Nelson S, Nechvatal N, Weber J, Canion S. Dental caries and ear infections in preschool-aged children. *Oral Health Prev Dent*. 2005;3(3):165-71.
7. Muhlemann HR, Regolati B, Marthaler TM. The effect on rate fissure caries of xylitol and sorbitol. *Helv Odontol Acta*. 1970;14(1):48-50.
8. Makinen KK, Bennett CA, Hujoel PP, Isokangas PJ, Isotupa KP, Pape HR Jr, Makinen PL. Xylitol chewing gums and caries rates: a 40-month cohort study. *J Dent Res*. 1995;74(12):1904-13.
9. Alaki SM, Burt BA, Garetz SL. Middle ear and respiratory infections in early childhood and their association with early childhood caries. *Pediatr Dent*. 2008;30(2):105-10.
10. Pascoe L, Seow WK. Enamel hypoplasia and dental caries in Australian aboriginal children: prevalence and correlation between the two diseases. *Pediatr Dent*. 1994;16(3):193-9.
11. Selwitz RH, Ismail AI, Pitts NB. Dental caries. *Lancet*. 2007;369(9555):51-9.
12. Irvine J, Holve S, Krol D, Schroth R. Early childhood caries in Indigenous communities: A joint statement with the American Academy of Pediatrics. *Paediatr Child Health*. 2011; 16(6):351-64.
13. Kagihara LE, Niederhauser VP, Stark M. Assessment, management, and prevention of early childhood caries. *J Am Acad Nurse Pract*. 2009;21(1):1-10.
14. Chan KH, Swarts JD, Rudoy R, Dever GJ, Mesubed Y. Otitis media in the Republic of Palau. A case-series study. *Arch Otolaryngol Head Neck Surg*. 1993;199(4):425-8.
15. Gould JM, Matz PS. Otitis media. *Pediatr Rev*. 2010;31(3):102-16.
16. Cunningham M, Guardiani E, Kim HJ, Brook I. Otitis media. *Future Microbiol*. 2012;7(6):733-53.
17. Lous J, Ryborg CT, Damsgaard JJ, Munck AP. Tympanometry in general practice: use, problems and solutions. *Fam Pract*. 2012;29(6):726-32.
18. Palmu A, Puhakka H, Rahko T, Takala AK. Diagnostic value of tympanometry in infants in clinical practice. *Int J Pediatr Otorhinolaryngol*. 1999;49(3):207-13.
19. World Health Organization. Prevention of hearing impairment from chronic otitis media: Report of a WHO/CIBA Foundation workshop. London: UK, The CIBA Foundation; 19-21 November 1996. Available from: http://www.who.int/pbd/deafness/en/chronic_otitis_media.pdf
20. Acuin J. Chronic suppurative otitis media—Burden of Illness and Management Options. Geneva: *World Health Organization*; 2004. 84 p.
21. Petersen PE, Bourgeois D, Ogawa H, Estupinan-Day S, Ndiaye E. The global burden of oral diseases and risks to oral health. *Bull World Health Organ*. 2005;83(9):661-9.