The Journal of Pacific Research
PHD PACIFIC HEALTH DIALOG

Original Research **OPEN ACCESS**

Timings of Permanent Tooth Emergence in Children of Rural Vanuatu, Melanesia.

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ABSTRACT

Introduction: Global patterning and timing of permanent tooth emergence is influenced by ethnicity, with no known timings reported for ethnic Melanesian children living in the tropical archipelago of Vanuatu.

Aim: To determine timings of permanent tooth emergence and sequencing for children who reside in rural Vanuatu

Methods: Children aged 4-17 years (n=1026), part of a larger oral health cross-sectional study, were examined recording all permanent teeth present, across four spatially separated islands. Binary logistic modelling established children's median age of emergence of each permanent tooth for each study area.

Findings: The median emergence of first permanent molars for girls is 4.9-years and 5.3 -years for boys. In all locations, children had all permanent teeth emerge by age 11 years (excluding 3rd molars). Clinically important differences exist for permanent tooth emergence by study area.

Discussion: Permanent teeth emerge earlier for Ni-Vanuatu children compared to both Melanesian children of Papua New Guinea as well as other ethnicities across Oceanic countries. These results can be used as a set standard for Vanuatu. Early tooth emergence suggests oral health education programmes should target pregnant women with clinical preventive strategies commencing for their children before 5-years of age.

Key words: Set standard, permanent teeth, Vanuatu, Oceania, Melanesia

INTRODUCTION

Patterning of permanent tooth emergence and sequencing is used internationally in dental, medical and forensic settings, signalling normal growth and development in paediatric populations.[1-2] Ethnicity, oral health burden, nutritional disorders, congenital defects and climate are all factors suggested to alter the timing of permanent tooth emergence.[1-2]

Accurate knowledge of permanent tooth emergence enables oral health workers to provide best practice for age-appropriate restorative, preventive and orthodontic procedures. Additionally, age targeted oral health prevention programs allows the opportunity to reduce oral health inequalities for indigenous populations.[3] For example, it would be advantageous to know the age bracket for emerging permanent molars, to target for placement of occlusal fissure sealant, a

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Rec: 26.05.2021 **Acc**: 08.10.2121 **Pub**: 30.12.2021

Citation: Webb E, *et al*. Timings of Permanent Tooth Emergence in Children of Rural Vanuatu, Melanesia. Pacific Health Dialog 2021; 21(8):5110-518. DOI: 10.26635/phd.2021.143

Figure 1a. Study areas of Ambrym, Malekula and Maskelyne Islands, south of Malekula.

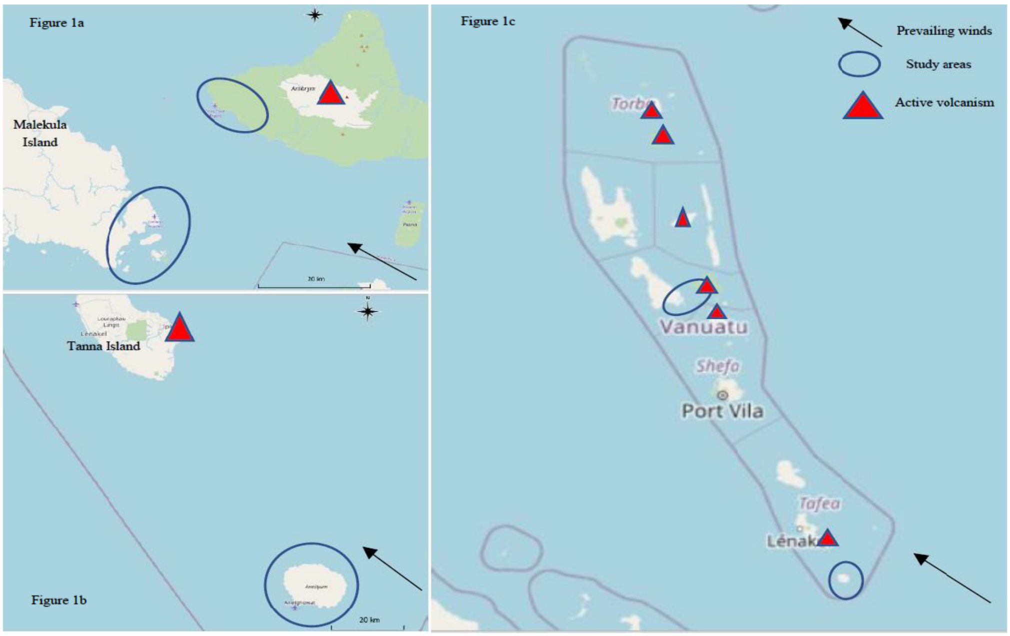


Figure 1b. Study area of Aneityum Island.
Figure 1c. Map of Vanuatu showing study areas and active volcanism.

preventive treatment preventive treatment known to reduce health burden and inequalities across all populations.[4]

There have been limited studies of permanent tooth emergence and sequencing in South Pacific island populations. Historical tooth emergence studies were conducted in Melanesian populations (1965-69), for mainland children of Papua New Guinea and also for children who were permanent residents of Bougainville Island, Papua New Guinea.[5-8] These early studies report the age of median tooth emergence for first permanent molars for both boys and girls at 5.2 years. These timings were significantly earlier than their European counterparts, where studies had reported first permanent molars emerging almost a year later.[5-8]

To date there has been no set standard (pattern of tooth emergence) established for Melanesian children of Vanuatu. The independent nation of Vanuatu is in the Melanesia subregion of Oceania, along with Papua New Guinea, the Solomon Islands, Fiji and New Caledonia. Seventy-five percent of Vanuatu's >270,000 population reside as subsistence farmers on more than 80 rural islands which are widely-dispersed and isolated with limited access to health services.[9] Using a clinical estimation method of permanent tooth emergence would be advantageous as access to workforce is limited with no equipment available to utilise the radiographic estimation method of tooth emergence.[10-11]

Tooth emergence timings and sequencing for children from Vanuatu may potentially differ to Polynesian counterparts in the South Pacific; archaeological studies of the mandible show differences exist between Melanesian and Polynesian populations, with Melanesian having smaller jawbones and teeth than that of their Polynesian neighbours.[12-13]

The aim of this study was to determine the timing and patterns of permanent tooth emergence in a cohort of ethnic Melanesian children, from rural Vanuatu as the country has never had a developed set standard for use.

MATERIALS AND METHODS

Study area

A cross-sectional study recruited participants aged 4-17 years (n = 1026, **Table 1**), (**Figure 1c**), life-time residents of the rural islands of Ambrym, south east Malekula (including Avock Island), Uliveo Island in the Maskelyne Islands Group (**Figure 1a**), and Aneityum Island (Figure 1b). The children attended schools in north west Ambrym, Uliveo Island, schools on the south east coast of Malekula Island, in Lamap Village and Namaru School on Avock Island. Children also participated from schools at Analcauhat village, Aneityum Island, the most southern Island in the archipelago (**Figure 1b**). This cohort of children were part of a larger study determining dental caries and dental fluorosis which is reported separately.

Table 1. Numbers of children, by age, who participated in this study

Age (years)	Aneityum Island	Uliveo Island	NW Ambrym Island	SE Malekula Island	Total Number
4	3	1	7	2	13
5	10	3	5	34	52
6	20	20	27	39	106
7	26	13	12	41	92
8	44	25	27	34	130
9	35	16	14	29	95
10	25	24	19	28	96
11	17	26	27	24	94
12	11	18	25	24	78
13	12	38	17	22	89
14	9	34	20	25	88
15	8	17	12	21	58
16	3	6	2	17	28
17	1	0	1	5	7
	224	**241**	**215**	**346**	**1026**

Ethical Approval

Approval for this study was granted by Victoria University of Wellington, New Zealand (approval HEC#19916). Additionally, consent was granted, at each site by local health staff, village chiefs, parents and school staff for clinical examinations (to be performed on children by a New Zealand oral health professional), with all children assenting to participate.

Clinical data collection

Gender, age and village details along with individual medical histories were collected at the time of examination, which took place inside school classrooms. Teachers were present during all examinations and were able to confirm the current age of each participant. One examiner, identified and recorded all permanent teeth present for each child. If any part of a cusp or incisal edge had pierced the gingiva, the tooth was considered as present.[14] Data was paper-recorded in the classroom, at each school, then transferred to a Microsoft Excel spreadsheet upon return to New Zealand. Children who identified as having a mixed ethnic background were not included in this study (n=1) as were those children who presented with treated or untreated cleft lip and palate (n=2).

Statistical analyses

We performed separate statistical analyses of each tooth present, using SPSS version 26 software (IBM Corp, USA). Using binary logistic models, tooth emergence predictions were able to be defined by deriving the median age at which 50% of the children are most likely to have a tooth emerged,[15](**Table 2**). McNemar's test was used to compare median emergence age between genders, and regression analyses were used to correlate tooth eruption ages and compare study areas.

RESULTS

Gender differences in emergence and sequencing for this cohort.

An almost equal gender balance of 495 (48%) boys and 534 (52%) girls participated who were present at their respective schools on the day examinations were conducted (**Table 1**). There was an approximately equal number of children participating from each area with south east Malekula having a higher rate of community participation due to more schools visited in this area; north west Ambrym (n=215, 20.9% of overall sample), south east Malekula (including Avock Island) (n=348, 33.8%), Uliveo (n=241, 23.4%), and Aneityum (n=225, 21.9%) (**Table 1**).

Table 2. **Age in years, n=1026, permanent tooth emergence and sequence, rural children aged 4-17 years, Vanuatu**

	Girls	Boys	Set Standard	Girls	S.E.	Boys	S.E.	Girls	S.E.	Boys	S.E.
	median	median	median	RHS	RHS	RHS	RHS	LHS	LHS	LHS	LHS
M_1	4.90	5.33	5.12	4.86	0.35	5.35	0.43	4.95	0.32	5.30	0.41
M^1	5.16	5.38	5.27	5.15	0.33	5.40	0.45	5.17	0.32	5.36	0.48
I_1	5.22	5.38	5.30	5.22	0.26	5.38	0.37	5.22	0.25	5.38	0.30
I^1	5.58	5.76	5.67	5.59	0.29	5.74	0.22	5.57	0.24	5.77	0.26
I_2	5.85	6.14	6.00	5.83	0.20	6.14	0.16	5.87	0.18	6.14	0.20
I^2	6.39	6.82	6.60	6.48	0.11	6.83	0.17	6.29	0.09	6.80	0.14
C_1	8.95	9.29	9.12	8.95	0.16	9.30	0.13	8.96	0.17	9.28	0.13
C^1	9.18	9.32	9.25	9.21	0.16	9.40	0.14	9.15	0.15	9.23	0.14
P_1	9.11	9.20	9.28	9.08	0.16	9.19	0.16	9.13	0.15	9.20	0.13
P^1	8.95	9.01	8.98	8.95	0.14	9.11	0.14	8.95	0.15	8.91	0.15
P_2	9.94	10.16	10.05	9.96	0.13	10.14	0.17	9.91	0.14	10.18	0.15
P^2	9.88	9.79	9.84	9.92	0.14	9.89	0.14	9.84	0.13	9.69	0.13
M_2	10.49	10.66	10.58	10.45	0.13	10.68	0.11	10.53	0.14	10.63	0.13
M^2	10.71	10.94	10.82	10.73	0.13	10.96	0.13	10.69	0.14	10.92	0.14

Girls in this study were noted to have permanent teeth emerge before boys' permanent teeth, but timing differences between gender were not statistically significant (**Table 2**). Permanent teeth showed no statistically significant differences in tooth emergence between left and right sides of the maxilla and of the mandible.

Sequencing of first permanent teeth differed slightly between girls and boys for emergence of mandibular and maxillary canines and first premolars. Sequencing for girls was; M_1, M^1, I_1, I^1, I_2, I^2, C_1, P^1, P_1, C^1, P^2, P_2, M_2, M^2 and sequencing for boys was; M_1, M^1, I_1, I^1, I_2, I^2, P^1, P_1, C_1, C^1, P^2, P_2, M_2, M^2. Participants presented with a median third molar eruption age of 16.1 years; however, the sample size was small for this age group.

Differences in tooth emergence between study areas.

Tooth emergence differences existed by study area; during the first stage of permanent tooth eruption (age 4-7 years-of-age) a delay was noted with permanent incisors on Ambrym Island, Uliveo and SE Malekula than those children who lived in Aneityum Island: I_1 (0.47 years), I^1 (0.73 years), I_2 (1.2 years), I^2 (0.62 years). At a later age (8-9 years of age), i.e., during the secondary phase of tooth emergence, the inverse was noted with both mandibular and maxillary canines having earlier eruption times between children from Ambrym, Uliveo and SE Malekula and Aneityum Island: C_1 (0.42 years), C^1 (0.42 years), (**Table 3, Figure 2**)

DISCUSSION

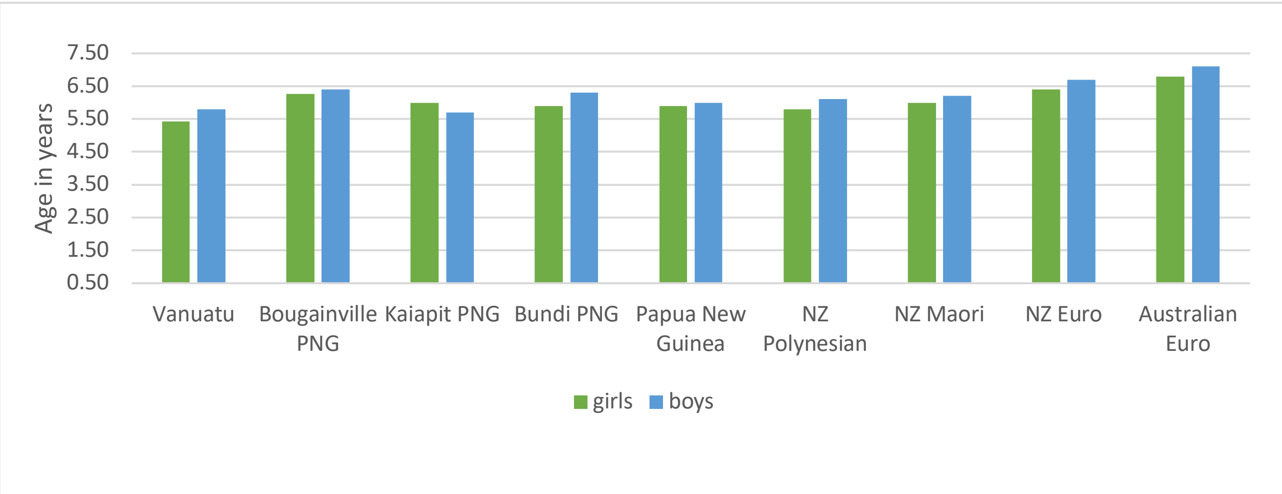
It has been often reported that girls generally have earlier tooth emergence than boys.[16-17] The results for this cohort of children are consistent with these previous observations, with all permanent teeth of girls erupting before boys.

In global populations, the most common sequence of permanent tooth emergence is M_1, M^1, I_1, I^1, I_2, I^2, C, P^1, P_1, P^2, P_2, M_2, M^2, with sequencing differences existing between mandibular and maxillary canines (C_1, C^1) and first and second premolars[15](P_1, P^1, P_2, P^2). The children in this study followed this sequencing pattern with slight differences between mandibular and maxillary canines and first premolars (C_1, C^1, P_1, P^1). Girls had mandibular

Table 3. Age in years of permanent tooth emergence (RHS), for children aged 4-17 years (n=1026), living in differing islands of rural Vanuatu. Superscripts denote highly significant differences between fluoride concentration.

(RHS)	Aneityum (n = 224) F = <0.05[a]	SE Malekula (n=346) F = 0.27[b]	Uliveo (n=241) F= 0.66[c]	NW Ambrym (n=215) F = 1.20[d]
M^1	5.05	5.28	5.27	5.44
M_1	5.05	5.11	5.48	5.05
M^2	11.15	11.15	10.31	10.83
M_2	10.85	10.65	10.08	10.69
M^3	16.10	16.46	16.96	tooth not present*
M_3	16.16	16.46	17.34	tooth not present*
I^2	6.38	6.74	6.08	7.00
I_2	5.29	5.29	5.89	6.49
I^1	5.37	5.70	5.43	6.10
I_1	4.77	5.27	5.48	5.24
C^1	9.57	9.33	9.08	9.15
C_1	9.30	9.27	8.92	8.88
P^1	9.03	9.13	8.65	9.24
P_1	9.30	9.22	8.53	9.30
P^2	9.95	10.39	9.54	9.99
P_2	9.97	9.99	10.05	10.15

Figure 2. Comparison of emergence of mandibular first molar (M_1) in children who live in Oceania.



canines erupt before maxillary and mandibular premolars, followed by their maxillary canine (C_1, P^1, P_1, C^1). Boys had both maxillary and mandibular premolars erupt before their mandibular canine and maxillary canine (P^1, P_1, C_1, C^1). The sequencing differences between canines and first premolars found in this study, is a common difference and has been reported in other studies of permanent tooth emergence [2-3] as well as in local populations living in New Zealand and Australia.[16-17]

Leroy et al. suggest that very early extraction of deciduous molars, and deciduous molars that exfoliate early due to dental caries, significantly accelerates the emergence of permanent first and second premolars.[18]We cannot exclude the possibility that first and second premolars in the maxilla and mandible for children in the present study did not erupt earlier or later due to the results of extensive decay in deciduous molars, as no prior dental records or radiographs existed for the participants.

Comparisons with Melanesian populations

Children in this study have their first permanent teeth emerge earlier than children than other groups within Oceania (Table 4, Figure 2). Children in this study showed similar yet slightly earlier permanent tooth emergence when compared with the early studies of children from Melanesian mainland Papua New Guinea and also the children of Bougainville Island, Papua New Guinea (Table 4, Figure 2). There were slightly later differences with the emergence of C^1, C_1, M^2 and M_2 for girls in this study compared to the girls studied in Papua New Guinea. The Kaiapit boys of Papua New Guinea had their M_1 emerge slightly earlier than the boys in this study (5.2 and 5.3 years respectively), (Table 4, Figure 2).

Comparisons with other South Pacific Populations

Girls and boys in this study had tooth emergence patterns for M^1 and M_1 0.4-0.5 years earlier than New Zealand Polynesian children ($M^1$5.8, $M_1$5.5) and 0.6 years earlier than New Zealand Maori children ($M^1$5.9, $M_1$5.6). However, for emergence of the same permanent molars, children in this study were 0.9-1.0 years and 1.1-1.2 years earlier than children who identified as New Zealand European ($M^1$6.2, $M_1$6.0) and Australian European ($M^1$6.6, $M_1$6.5), (Table 4, Figure 2).

Comparisons with other global populations

In comparing permanent tooth emergence for children in this study, with children of European, Asian, and North American descent, the children in this study have earlier permanent tooth emergence. Comparing the mandibular central incisor and first mandibular molar emergence timings between these populations, Sindelarova and colleagues' study of children living in Czechoslovakia report children have emergence of I_1 at 6.2 years and M_1 at 6.2 years compared with Ni-Vanuatu children who have I_1 emerge at 5.3 years and M_1 at 5.1 years. Again, when comparing children studied in other European countries, emergence for ni-Vanuatu children is also considerably earlier; Belgium (I_1 6.2, M_1 6.2), Finland (I_1 5.9, M_1 6.1), Lithuania (I_1 5.9, M_1 6.0), Holland (I_1 6.3, M_1 6.1), Spain (I_1 6, M_1 6.1), Great Britain (I_1 6.4, M_1 6.5).[3]

Ni-Vanuatu children also have earlier permanent emergence than children from other ethnicities from the Northern Hemisphere; Turkey (I_1 6.7, M_1 6.2), Jordan (I_1 6.3, M_1 6.1), Iran (I_1 6.5, M_1 6.7) and the United States of America (Oregon) (I_1 6.1, M_1 6.3).[3]

Additionally, children in this study have I_1, M_1 emerge earlier than the majority of children who are of sub-Saharan descent. Permanent tooth emergence in these differing ethnic groups was reported in a comparison study of children who were South Black African (I_1 5.8, M_1 5.7), Zambian (I_1 5.5, M_1 5.3), Ugandan (I_1 5.9, M_1 5.8), Kenyan (I_1 5.7, M_1 5.8), Nigerian (I_1 5.5, M_1 5.7) and Ghanaian (I_1 5.7, M^1 5.2).[2]

Children in this study had tooth emergence timings similar for I_1, M_1 as ethnic Baka children of Africa (I_1 5.6, M_1 5.0) with Baka girls having the same M_1 emergence time of 4.9 years.[2]

Geographic variance between study areas

The results for permanent tooth emergence across differing study areas were not statistically significant; this may be due to the sample sizes in each area being too small to determine this effect (Table 3). However, some teeth were found to have delayed eruption which could be described as clinically important,[19] suggesting a geographic variation of permanent tooth emergence in the island chain.

During the first stage of permanent tooth eruption, (age 4-7 years), a delay was noted in the northern islands of Ambrym, Uliveo and SE Malekula while children residing on Aneityum, almost 500km to the south-south-east, had earlier emergence: I_1 (0.47 years), I^1 (0.73 years), I_2 (1.2 years), I^2 (0.62 years), (Table 3). At a later age, (8-9 years of age), during the secondary phase of tooth eruption, the inverse was noted for both mandibular and maxillary canines having earlier eruption times with children residing in the islands of Ambrym, Uliveo and SE Malekula than the children in Aneityum: C_1 (0.42 years), C^1 (0.42 years), (Table 3).

Smith et al. (1978), discuss a geographic variation of mandibular arch length and width in historic study of the people of Bougainville Island, Papua New Guinea. They report for adult populations, jaw arch length and width decreasing in size from the north to the south of the Island. With climate and diet similarthroughout the island and unable to allocate a direct environmental cause, it was suggested this variation may be due to genetic difference within the population.[20]

Table 4. Established set standards for permanent tooth emergence across differing ethnicities and geography in South Pacific populations. This study[1], Friedlander[2], Malcolm[3], Malcolm[4], Barker[5], Kanagaratnam [6], Diamanti [7]

Country	Vanuatu[1]		Bougainville[2]		Kaiapit	(PNG)[3]	Bundi	(PNG)[4]	PNG[5]		NZ Polynesian[6]		NZ Maori[6]		NZ Euro[6]		Australian Euro[7]	
Year	**this study**		**1969**		**1969**		**1968**		**1965**		**2012**		**2012**		**2012**		**2003**	
Gender	**girls**	**boys**	**girls**	**boys**	**girls**	**boys**	**girls**	**boys**	**girls**	**boys**	**girls**	**boys**	**girls**	**boys**	**girls**	**boys**	**girls**	**boys**
I^1	5.6	5.7	6.5	6.4	6.7	6.5	6.7	7.2	6.5	6.7	6.3	6.5	6.5	6.7	6.8	7.0	7.2	7.4
I^2	6.4	6.8	7.6	7.5	7.3	7.4	7.5	8.2	7.4	7.8	7.2	7.6	7.4	7.7	7.8	8.2	8.2	8.6
C'	9.2	9.4	9.1	9.5	9.3	10.7	9.8	10.6	9.3	10.1	9.7	10.2	9.8	10.4	11.0	11.6	11.2	11.8
P^1	9.0	9.0	9.7	9.7	9.5	10.2	9.9	10.5	9.3	9.4	9.3	9.7	9.6	10.0	10.4	10.9	10.8	11.3
P^2	9.9	9.8	10.2	10.6	10.4	11.3	10.5	11.2	10.4	10.7	10.3	10.5	10.4	10.7	11.5	11.8	11.7	12.1
M^1	5.2	5.4	5.8	5.9	5.7	5.7	5.5	5.9	5.5	5.6	5.7	5.9	5.8	6.0	6.0	6.3	6.5	6.7
M^2	10.7	10.9	10.9	11.3	10.3	11.3	10.9	11.5	10.5	11.1	11.1	11.5	11.4	11.8	12.2	12.6	12.3	12.7
I_1	5.2	5.4	6.0	6.1	6.5	6.1	6.4	6.6	6.1	6.2	5.6	6.0	5.7	6.0	5.8	6.2	6.3	6.6
I_2	5.9	6.1	6.9	7.0	6.9	6.8	7.0	7.5	6.8	7.0	6.5	6.8	6.6	6.9	7.0	7.4	7.4	7.8
C,	9.0	9.3	8.9	9.3	8.9	10.0	9.5	10.1	8.9	9.7	9.0	9.7	9.1	9.8	10.0	10.8	10.1	11.0
P_1	9.1	9.2	9.4	9.9	10.1	10.4	9.9	10.4	9.4	9.8	9.4	9.8	9.4	9.9	10.3	10.8	10.6	11.2
P_2	9.9	10.2	10.3	10.6	10.4	11.4	10.6	11.2	10.4	10.8	9.9	10.3	10.3	10.7	11.4	11.9	11.7	12.1
M_1	4.9	5.3	5.8	5.9	5.5	5.2	5.4	5.8	5.4	5.5	5.3	5.6	5.5	5.7	5.9	6.2	6.3	6.6
M_2	10.4	10.5	10.5	11.0	10.3	11.3	10.9	11.5	10.2	10.8	10.7	10.9	10.8	11.1	11.7	12.0	11.8	12.2

The early Melanesian studies also reported slight variations in timing of permanent tooth emergence for children within differing geographic locations of Papua New Guinea, with diet and climate similar within these populations.[5-8] Gaur and Singh (1994) also note a geographic variation of permanent tooth emergence reporting child populations in Northern India have permanent teeth erupt earlier than children from Southern India.[21]

Children in this cohort were part of a larger study and had like the Melanesian children of Papua New Guinea, reported similar diet and climate. This cohort were part of a larger study who had their community drinking-waters as proxy for an overall measure for volcanogenic fluoride concentration. Fluoride concentrations were highly significant between study areas (Table 3) with further investigations required as to whether fluoride ingestion is a possible factor which influences the tooth emergence process.

The results of this study for permanent tooth emergence are of clinical importance for this population. Due to earlier emergence of the permanent dentition, a large focus on oral health education throughout pregnancy and from a very early age for children is essential and would assist children's oral health burden. The girls in this cohort appear to be the most vulnerable with such early emergence of their permanent molars compared to other girls from other studies in Oceania (Table 4). Results from this study suggest all clinical preventive strategies aimed at permanent tooth preservation should commence far earlier than for other children in Oceania, at preschool age (age 4 and 5 years) rather than at 6 years of age, when first permanent teeth are suggested to emerge.[3]

These results will be of great benefit to oral health workers who treat any children who may be able to access dental treatment in the two large towns, Port Vila and Luganville. Knowing the earlier emergence timings to provide preventive treatments to permanent molars will improve oral health burden as well as efficient and competent restorative approaches appropriate for early exfoliation of deciduous teeth.

Implementing age-targeted oral health prevention programmes in future oral health policies, will allow the opportunity to lower oral health inequalities for this indigenous population, improving not just oral health but also general health.

Results from this study can be used as set standards for Vanuatu for permanent tooth emergence, the first for this population. Girls in this study have permanent teeth emerge before boys with Ni-Vanuatu children noted to have permanent teeth emerge earlier than those of their European and Pacific counterparts with first mandibular permanent molars present before age 5 years-of-age for girls.

Developing future strategies associated with oral health preventive programmes for Vanuatu, such as oral health education in pregnancy and permanent molar protection for children, should consider the initiation of these strategies from age 4 to 5 years-of age. We noted children residing in differing areas of the archipelago of Vanuatu had altered timings with permanent tooth emergence of clinical importance. Future studies are required to investigate the phenomenon of geographic variation further.

Conflict of Interest

All authors declare no conflict of interest.

Acknowledgements:

We are grateful to the school children in rural Vanuatu who took part in this study.

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