



Prevalence and Pattern of Tooth Agenesis in Non-syndromic Thai Dental Patients

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Abstract

The aim of this study was to assess the prevalence and pattern of tooth agenesis in Thai dental patients. The study design was a retrospective cross-sectional study of 501 panoramic radiographs in a random sample of Thai dental patients from 15 to 20 years of age which were taken in 2016 at the Faculty of Dentistry, Chulalongkorn University. Demographic data (age and sex) and dental characteristics of the patients were recorded. A chi-square test was used to determine the differences in the prevalence of tooth agenesis between genders, maxillary-mandibular teeth, left-right sides, and numbers of missing teeth. The overall prevalence of tooth agenesis, excluding third molars, was 8.98% or 45 out of 501 patients. The prevalence in females (10.30%) was higher than males (7.00%). The single most common missing tooth was the mandibular right lateral incisor (14.43%; n=14), followed by the mandibular right second premolar (13.40%; n=13), mandibular left second premolar (13.40%; n=13), and maxillary right lateral incisor (9.28%, n=9). According to tooth type, the most common missing tooth was the mandibular second premolars (26.80%; n=26), followed by mandibular lateral incisors (22.68%; n=22), and maxillary lateral incisors (16.49%; n=16). Of all the 45 patients with tooth agenesis, 44.44% had one missing tooth, 37.77% had two missing teeth, 6.66% had three to four missing teeth, and 4.44% had six or more missing teeth. By location, tooth agenesis was found more often on the right side (53.61%) than on the left side (46.39%), and more in mandibular arch (60.83%) than maxillary arch (39.17%). No significant differences in the prevalence between males-females, right-left side, and maxilla-mandible were observed. The prevalence of tooth agenesis in Thai population observed in this study was lower than in the other two previous studies in Thailand. This study reported the prevalence of tooth agenesis at 8.98% in Thai population. A single tooth absence was the most common and the mandibular second premolar was the most frequently missing tooth. Based on these findings, it is suggested that tooth agenesis is a common oro-dental finding in Thailand. Careful examination should be considered in the dental management of the Thais.

Keywords: Congenitally missing teeth, Hypodontia, Oligodontia, Panoramic radiography, Tooth agenesis

1. Introduction

Tooth agenesis, dental aplasia, or congenitally missing teeth (CMT) is defined as a developmental absence of at least one tooth. It is one of the most common dental anomalies (Endo et al., 2006). Those missing teeth fail to erupt in the oral cavity and remain invisible in a radiograph, suggesting the disturbances during the early stages of tooth development (Endo et al., 2006). Hypodontia is the term most frequently used to describe the absence of fewer than six teeth while missing more than six teeth is defined as oligodontia. The complete absence of teeth is termed as anodontia. Tooth agenesis may occur as non-syndromic (isolated) or syndromic form associated with systemic anomalies including cleft lip, cleft palate, ectodermal dysplasia, Down syndrome, Kabuki syndrome, Rieger syndrome, and Book syndromes (Intarak et al., 2018a; Intarak et al., 2018b; Porntaveetus et al., 2018; Rakhshan V et al., 2015). Tooth agenesis is related to numerous etiologies including genetic and environmental factors. Environmental factors include medications, low birth weight, malnutrition, vitamin D deficiency, infections, and metabolic disorders (Khalaf, Miskelly, Voge, & Macfarlane, 2014). The previous meta-analysis has demonstrated a strong genetic influence on hypodontia (Khalaf et al., 2014). A recent advance in human genetics has improved our understanding of the cause of tooth agenesis. Several genes have been identified including muscle segment



homeobox 1 (MSX1), paired box 9 (PAX9), and ectodysplasin A as the causes of tooth agenesis (Shimizu, & Maeda, 2009).

The prevalence of tooth absence varies according to the studied population. The overall prevalence of tooth agenesis was 6.4%, which was highest in Africa (13.4%), followed by Europe (7%), Asia (6.3%) and Australia (6.3%) with a lower prevalence in North America (5.0%) and Latin America and Caribbean (4.4%). Tooth agenesis can lead to several consequences including esthetic and mastication problems, dislocation of non-affected teeth in the dental arch, alveolar bone atrophy, and malocclusion. Therefore, early intervention and appropriate treatment are vital.

Nonetheless, few epidemiological studies have been carried out in an Asian population. Up to date, the prevalence and pattern of tooth agenesis in Thailand was found in only two reports. Tantanapornkul (2015) studied the population in the upper central area of Thailand and Kositbowornchai, Keinprasit and Poomat (2010) observed the patients in the northeastern area of Thailand.

2. Objectives

1. To assess the current prevalence of tooth agenesis in Thai population.
2. To assess the characteristics of tooth agenesis in Thai population.

3. Materials and Methods

Ethical statement

The study protocol was approved by The Human Research Ethics Committee of the Faculty of Dentistry, Chulalongkorn University, Bangkok, Thailand (Study code: HREC-DCU 2018-091).

The sample size was calculated from n4Studies. The Proportion (p) = 0.13, Error (d) = 0.03, Alpha (α) = 0.05, and $Z(0.975) = 1.959964$ were substituted in the following formula. In this study, the sample size (n) obtained was 483.

$$n = \frac{z_{1-\frac{\alpha}{2}}^2 p(1-p)}{d^2}$$

Figure 1 The sample size formula

530 panoramic radiographs of Thai patients taken between 1 January 2016 and 31 December 2016 at the Faculty of Dentistry, Chulalongkorn University were retrospectively collected. The panoramic radiographs were taken by CS8000c, CS9000c radiographic unit (Carestream Health., Inc., Rochester, USA) and Veraviewepocs 3D (J. Morita, Kyoto, Japan) with standard parameter settings. The inclusion criteria were the individual who has Thai nationality and 15 – 20 years of age on the day the radiographs were taken. The radiographs with a doubtful diagnosis, for example, teeth that might be lost due to trauma or previous extraction, were excluded. In cases with unclear diagnosis, previous dental history, dental casts, or any available information were examined. Subjects with congenital anomalies, records of extraction of the permanent teeth, trauma, and prior orthodontic treatment were excluded. By exclusion of 29 radiographs, the final sample of this study included 501 panoramic radiographs.

All selected radiographs were examined by one operator to identify the presence of dental agenesis (excluding third molars). A tooth was diagnosed as congenitally missing if the mineralization of its crown could not be identified on panoramic radiographs. All images were view on Infinitt[®] PACS software (Infinitt Healthcare Co., Ltd., Seoul, South Korea). The operator was allowed to use the PACS software tools such as window/level and zoom. Tooth number used to represent each tooth was according to Federation Dentaire International (FDI) (Keiser-Nielsen, 1971).



Statistical Analysis

The data were analyzed using IBM SPSS Statistics for Windows, Version 22.0 (IBM, Armonk, NY). The significant difference among groups was determined by the Chi-square test. The level of significance was set at $P < 0.05$. The statistical analysis was used to compare the prevalence of tooth agenesis between maxillary-mandibular arches, right-left sides, and males and females.

4. Results and Discussion

Results

A total of 501 panoramic radiographs of healthy patients aged 15-20 years, 301 females and 200 males were examined. Tooth agenesis in the permanent dentition (excluding third molars) was diagnosed in 45 subjects. The overall prevalence of tooth agenesis was found to be 8.98%. The prevalence of tooth agenesis in females was higher than males nearly in all tooth types (10.30% and 7.00%, respectively) (Table 1, 2).

Table 1 Distribution of prevalence of tooth agenesis by sex

Sex	Number of patients		Prevalence (%)
	Examined	Affected	
Male	200	14	7.00
Female	301	31	10.30
Total	501	45	8.98

The most common congenitally missing teeth were the mandibular right lateral incisors (14.43%; $n = 14$), followed by the mandibular right and left second premolar (13.40%; $n = 13$), the maxillary right lateral incisors (9.28%, $n = 9$), the mandibular left lateral incisors (8.23%; $n = 8$), the maxillary left lateral incisors (7.22%; $n = 7$), and the maxillary left second premolars (6.19%; $n = 6$). In this study, no tooth agenesis was found in the maxillary right central incisors, maxillary and mandibular left canines, and maxillary and mandibular first and second molars. (Table 2 and Figure 2).



Table 2 Distribution of prevalence of tooth agenesis by tooth (n = 97)

Tooth	Gender (n)		Total (%)	Sig (P < 0.05)
	Male	Female		
17	0	0	0 (0)	1.000
16	0	0	0 (0)	1.000
15	2	2	4 (4.12)	0.399
14	1	4	5 (5.15)	0.587
13	0	1	1 (1.03)	0.501
12	2	7	9 (9.28)	0.553
11	0	0	0 (0)	1.000
21	0	1	1 (0.03)	0.501
22	2	5	7 (7.22)	0.889
23	0	0	0 (0)	1.000
24	2	3	5 (5.15)	0.895
25	3	3	6 (6.18)	0.478
26	0	0	0 (0)	1.000
27	0	0	0 (0)	1.000
31	0	1	1 (1.03)	0.501
32	1	7	8 (8.23)	0.239
33	0	0	0 (0)	1.000
34	1	3	4 (4.12)	0.793
35	5	8	13 (13.40)	0.528
36	0	0	0 (0)	1.000
37	0	0	0 (0)	1.000
41	0	2	2 (2.06)	0.339
42	4	10	14 (14.43)	0.837
43	0	1	1 (1.03)	0.501
44	2	1	3 (3.09)	0.174
45	5	8	13 (13.40)	0.528
46	0	0	0 (0)	1.000
47	0	0	0 (0)	1.000
Total	30 (30.93)	67 (69.07)	97 (100)	

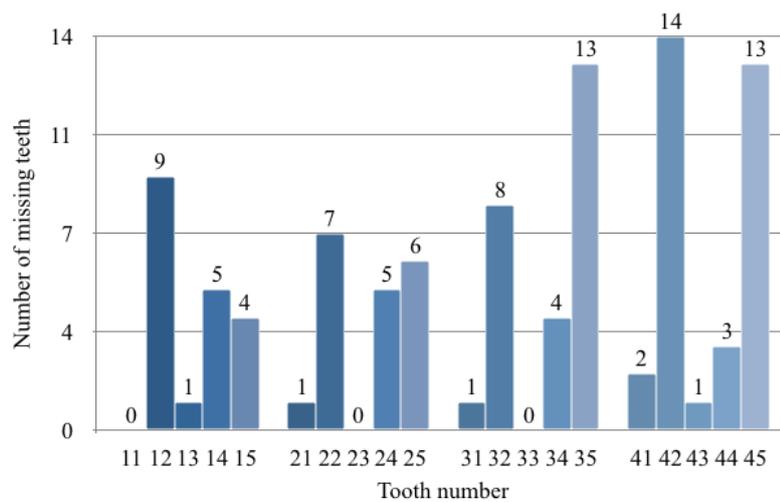


Figure 2 Distribution of tooth agenesis



The number of missing teeth per patient ranged from 1 to 13 in the study. All of 45 patients with tooth agenesis, 44.44% had one missing tooth, 37.77% had two missing teeth, 6.66% had three to four missing teeth, and 4.44% had six or more missing teeth (oligodontia). The differences in prevalence between the sexes were statistically significant for one and two missing teeth ($P < 0.05$) (Table 3).

Table 3 Distribution of prevalence of tooth agenesis by numbers of missing teeth (n = 45)

Number of missing teeth	Gender		Total (%)	Sig (P<0.05)
	Male (%)	Female (%)		
1	10 (22.22)	10 (22.22)	20 (44.44)	0.016
2	2 (4.44)	15 (33.33)	17 (37.77)	0.040
3	1 (2.22)	2 (4.44)	3 (6.66)	0.0846
4	0 (0)	3 (6.66)	3 (6.66)	0.160
5	0 (0)	0 (0)	0 (0)	1.000
≥6	1 (2.22)	1 (2.22)	2 (4.44)	0.635
Total	14 (38.67)	31 (61.33)	45 (100)	

Tooth agenesis was found more often on the right side (53.61%; n = 52) than on the left side (46.39%; n = 45), but not statistically significantly different. With regards to the dental arches, tooth agenesis was found more in the mandibular arch (60.83%; n = 59) than the maxillary arch (39.17%; n = 38). Distribution and statistical comparisons of tooth agenesis according to the right-left sides and the maxillary-mandibular arches are shown in Table 4-7 and Figure 3.

Table 4 Frequency of tooth agenesis in relation to the maxillary and mandibular arches

Maxillary arch		Mandibular arch			Maxillary arch		Mandibular arch		
Tooth Number	Number (n)	Tooth Number	Number (n)	Sig (P<0.005)	Tooth Number	Number (n)	Tooth Number	Number (n)	Sig (P<0.05)
11	0	41	2	0.274	21	1	31	1	0.017
12	9	42	14	0.730	22	7	32	8	0.670
13	1	43	1	0.687	23	0	33	0	1.000
14	5	44	3	0.124	24	5	34	4	0.365
15	4	45	13	0.175	25	6	35	13	0.217
16	0	46	0	1.000	26	0	36	0	1.000
17	0	47	0	1.000	27	0	37	0	1.000

Table 5 Frequency of tooth agenesis in relation to the right and left sides and to the maxillary and mandibular arches

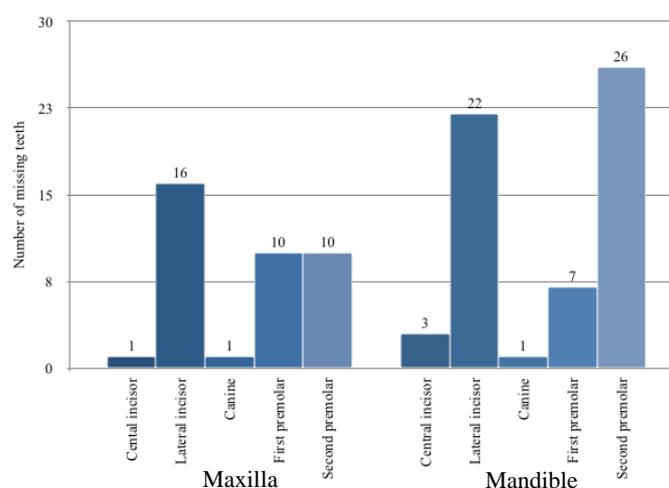
Maxillary arch					Mandibular arch				
Right side		Left Side		Sig (P<0.005)	Right Side		Left Side		Sig (P<0.05)
Tooth Number	Number (n)	Tooth Number	Number (n)		Tooth Number	Number (n)	Tooth Number	Number (n)	
11	0	21	1	0.311	41	2	31	1	0.979
12	9	22	7	0.511	42	14	32	8	0.617
13	1	23	0	0.311	43	1	33	0	0.482
14	5	24	5	0.920	44	3	34	4	0.136
15	4	25	6	0.461	45	13	35	13	0.415
16	0	26	0	1.000	46	0	36	0	1.000
17	0	27	0	1.000	47	0	37	0	1.000

**Table 6** Distribution of prevalence of tooth agenesis by tooth type in relation to maxillary-mandibular arches

Tooth	Maxillary arch (%)	Mandibular arch (%)	Total (%)	Sig (P<0.05)
Central incisor	1 (1.03)	3 (3.09)	4 (4.12)	0.553
Lateral Incisor	16 (16.49)	22 (22.68)	38(39.17)	0.635
Canine	1 (1.03)	1 (1.03)	2 (2.06)	0.751
First premolar	10 (10.30)	7 (7.22)	17 (17.52)	0.058
Second premolar	10 (10.30)	26 (26.80)	36 (37.10)	0.077
Total	38 (39.17)	59 (60.83)	97 (100)	

Table 7 Distribution of prevalence of tooth agenesis by tooth type in relation to left-right sides

Tooth	Right side (%)	Left side (%)	Total (%)	Sig (P < 0.05)
Central incisor	2 (2.06)	2 (2.06)	4 (4.12)	0.085
Lateral Incisor	23 (23.71)	15 (15.46)	38(39.17)	0.273
Canine	2 (2.06)	0 (0)	2 (2.06)	0.184
First premolar	8 (8.25)	9 (9.27)	17 (17.52)	0.551
Second premolar	17 (17.53)	19 (19.57)	36 (37.10)	0.333
Total	52 (53.61)	45 (46.39)	97 (100)	

**Figure 3** Distribution of tooth agenesis by tooth type

Discussion

Since tooth agenesis is proven to be one of the most common anomalies in human, many studies on the prevalence of tooth agenesis in permanent teeth have been published in the dental literature over the past decades. Studies based on the prevalence and distribution of tooth agenesis demonstrated a high variability depending on sample size, gender, race, and ethnicity (Hashemipour, Tahmasbi-Arashlow, & Fahimi-Hanzaei, 2013). The latest systematic review by Khaled Khalaf et al. (2014) reported the overall prevalence of tooth agenesis to be 6.4% calculated from 93 studies. Khaled et al. found a statistically significant difference in the prevalence of tooth agenesis by continent. The prevalence was highest in Africa (13.4%), followed by Europe (7%), Asia (6.3%) and Australia (6.3%) with a lower prevalence in North America (5.0%) and Latin America and Caribbean (4.4%).

When comparing the figures of the prevalence of tooth agenesis in Polder, Van't Hof, Van der Linden, & Kuijpers-Jagtman (2004) study, it appears that the prevalence of tooth agenesis has increased over time in Asia (from 4.7 to 6.3%), Europe (from 5.5 to 7%), and North America (from 3.9 to 5%).



Studies among Asians have reported varieties of the prevalence rates, including 9.4%, 11.2% and 6.9% in Japanese (Goya, Tanaka, Maeda, & Akimoto, 2008), Koreans (Chung, Han, & Kim, 2008), and Chinese (Davis, 1987), respectively.

Until now, the prevalence and pattern of tooth agenesis in Thailand have studied in only two reports. Tantanapornkul (2015) showed that the prevalence of hypodontia was 13.7% (84 out of 638 patients in the upper central area of Thailand). They found that the most commonly missing tooth was the lower lateral incisor (26.32%), followed by the lower premolars (24.81%), and the upper lateral incisor (19.55%). Kositbowornchai et al (2010) observed the prevalence at 26.4% (150 out of 570 patients) in the northeastern area of Thailand. In their study, the lower lateral incisor had the highest prevalence of missing, followed by the upper lateral incisor and the lower second premolar respectively. Both of Thai studies included only orthodontic patients and showed different results. The prevalence of hypodontia reported by Tantanapornkul (2015) was 13.7% which was lower than that reported by Kositbowornchai et al (2010) at 26.4%. On the other hand, this study observed the prevalence of tooth agenesis at 8.98%, which was lower than the other two previous studies. These could be due to the differences in populations included in the studies.

Prevalence by sex

Hobkirk, Goodman, and Jones (1994) reported that females were more affected by hypodontia than males in the permanent dentition, but not the primary dentition. Polder et al. (2006) found the incidence of tooth agenesis in females was 1.4 times higher than that in males.

In this study, the prevalence of tooth agenesis in females was higher than males nearly in all tooth types (10.30% and 7.00%, respectively), although the difference between gender was not statistically significant.

Prevalence by type of missing teeth

The permanent third molars are the most commonly absent teeth in the dentition (Vahid Rakhshan, 2013). When the third molar is excluded from studies, the reported prevalence rates for each tooth vary according to the population (Shimizu, & Maeda, 2009). The third molar is the most frequently affected tooth in association with hypodontia, and it has been reported that at least one of the third molar is congenitally absent in 20–30% of the European population (Khalaf, 2014). However, the third molars are generally excluded from hypodontia studies due to the high frequency of their absence. Polder et al. (2004) found that an absence of maxillary lateral incisors usually occurred bilaterally, whereas unilateral agenesis was commonly found in the second mandibular premolar (Polder BJ et al., 2004).

In Thai population, Tantanapornkul (2015) showed that the most commonly missing tooth was the lower lateral incisor (26.32%), followed by lower premolars (24.81%), and upper lateral incisor (19.55%). Kositbowornchai et al. (2010) observed that the lower lateral incisor had the highest prevalence of missing, followed by the upper lateral incisor and the lower second premolar, respectively.

Consistent with previous studies in Thailand, it was noticed that the most common missing teeth in the Thai population were the lower lateral incisors. The second and third most common missing teeth of this study were the lower second premolar followed by upper lateral incisor. These are similar to Tantanapornkul (2015) and the study of Chung et al. (2007) in Korea, but different from Kositbowornchai et al. (2010) (the upper lateral incisor and the lower second premolar are the second and third common missing teeth). In other populations, the upper lateral incisors were the most common missing teeth in Turkish, Indian, Mexican and Brazilian populations and the lower second premolar in the Japanese population.

The maxillary central incisors, mandibular canines, maxillary and mandibular first molars were found to be the least affected teeth in the study of Polder et al. (2004) and Endo et al. (2006). In accordance with this study, the maxillary and mandibular first and second molars and mandibular left canines were not found to be absent in our study.

Prevalence by number of missing teeth

The systematic review of Khaled Khalaf et al. (2014) found that tooth agenesis of 1 or 2 teeth was the most common (81.6%) followed by tooth agenesis of 3 to 5 teeth (14.3%) and tooth agenesis of 6 or more teeth (3.1%). All of 45 patients in our study with tooth agenesis, 44.44% had one missing tooth, 37.77% had two missing teeth, 6.66% had three to four missing teeth, and 4.44% had six or more missing



teeth. The differences in prevalence between the genders were statistically significant for one and two missing teeth ($P < 0.05$)

Prevalence by location

Tooth agenesis was found more often on the right side (53.61%) than on the left side (46.39%), but the statistically significant differences were not detected. By dental arches, tooth agenesis was found more in the mandibular arch (60.83%) than the maxillary arch (39.17%). In accordance with the study of Tantanapornkul (2015), the percentage of tooth agenesis of the mandibular arch was higher than the maxillary arch (55.64% and 44.36%, respectively). Whereas, the study of Khaled Khalaf et al. (2014) found a higher percentage of tooth agenesis located in the maxilla (53.2%) compared with 46.8% in the mandible. Furthermore, the study of Kositbowornchai et al. (2010) in Thai population reported a prevalence of 53.7% in maxillary arch and 46.3% in the mandibular arch. However, a finding by Polder et al. (2004) reported the comparable prevalence of tooth agenesis in the mandible and maxilla. These suggest that the location of tooth missing according to the right-left and upper-lower arches are variably found.

Since there are dissimilarities between the present study and previous Thai studies, it is possible that there might be the differences among ethnic groups in Thai populations (North, Northeast parts, and central of Thailand). The ethnicity of the participants, syndromic involvements, and environmental factors could be included for future studies to expand the knowledge of tooth agenesis. We suggest that the inclusion criteria, diagnostic criteria, and design of the studies may affect the prevalence of tooth agenesis.

In general, the diagnosis of tooth agenesis in the permanent dentition should be made after the age of 6 years, excluding the third molar, and after 10 years of age if the third molar is also studied (Goya et al., 2008). A meta-analysis by Vahid Rakhshan (2013) recommended that the subjects younger than 12-13 years of age should be excluded to avoid the possibility of delayed tooth development and both sexes should be equally included. It was also suggested that the study should not include only the orthodontic patients as the patients having tooth agenesis were more likely to seek orthodontic treatment which could bias the prevalence of tooth agenesis. We noticed that both previous two studies in Thailand reported the prevalence of tooth missing in orthodontic patients. Instead, our study examined general dental patients, not only the orthodontic ones. The prevalence found in our study could, therefore, be a valid prevalence of tooth agenesis in Thailand. In addition, two or more observers should examine larger samples to reduce the false negative error tied with such samples.

5. Conclusion

This study reported the lower prevalence of congenitally missing teeth (8.98%) compared to previous studies in Thai population, but higher compared to the overall prevalence from the previous meta-analysis. This showed that tooth agenesis is a common anomaly in the Thai population. A single tooth absence was the most common and the mandibular second premolar was the most frequently missing tooth.

Early detection of missing teeth by careful clinical and radiographic examinations would minimize the complications of missing teeth and restore the patient's esthetics and functionality at the earliest time and the most beneficial way. Further studies of molecules and cellular mechanisms in tooth development may provide more clues to understand the pathomechanism of tooth agenesis.

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7. References

- Chung, C. J., Han, J. H., & Kim, K. H. (2008). The pattern and prevalence of hypodontia in Koreans. *Oral Diseases*, 14(7), 620-625.
- Davis, P. J. (1987). Hypodontia and hyperdontia of permanent teeth in Hong Kong schoolchildren. *Community Dentistry and Oral Epidemiology*, 15(4), 218-220.
- Endo, T., Ozoe, R., Kubota, M., Akiyama, M., & Shimooka, S. (2006). A survey of hypodontia in Japanese orthodontic patients. *American Journal of Orthodontics and Dentofacial Orthopedics*, 129(1), 29-35.



- Goya, H. A., Tanaka, S., Maeda, T., & Akimoto, Y. (2008). An orthopantomographic study of hypodontia in permanent teeth of Japanese pediatric patients. *Journal of Oral Science*, 50(2), 143-150.
- Hobkirk, J. A., Goodman, J. R., & Jones, S. P. (1994). Presenting complaints and findings in a group of patients attending a hypodontia clinic. *British Dental Journal*, 177(9), 337-9.
- Hashemipour, M. A., Tahmasbi-Arashlow, M., & Fahimi-Hanzaei, F. (2013). Incidence of impacted mandibular and maxillary third molars: a radiographic study in a Southeast Iran population. *Medicina Oral, Patologia Oral Y Cirugia Bucal*, 18(1), e140.
- Intarak, N., Theerapanon, T., Ittiwut, C., Suphapeetiporn, K., Porntaveetus, T., & Shotelersuk, V. (2018). A novel PITX2 mutation in non-syndromic orodontal anomalies. *Oral Diseases*, 24(4), 611-618.
- Intarak, N., Theerapanon, T., Srijunbarl, A., Suphapeetiporn, K., Porntaveetus, T., & Shotelersuk, V. (2018). Novel compound heterozygous mutations in KREMEN 1 confirm it as a disease gene for ectodermal dysplasia. *British Journal of Dermatology*, 79(3), 758-760.
- Keiser-Nielsen, S. (1971). Federation Dentaire Internationale. Two-digit System of designating teeth. *Dental Practice*, 3(4), 6.
- Khalaf, K., Miskelly, J., Voge, E., & Macfarlane, T. V. (2014). Prevalence of hypodontia and associated factors: a systematic review and meta-analysis. *Journal of Orthodontics*, 41(4), 299-316.
- Kositbowornchai, S., Keinprasit, C., & Poomat, N. (2010). Prevalence and distribution of dental anomalies in pretreatment orthodontic Thai patients. *Khonkean Dental Journal*, 13(2), 92-100.
- Polder, B. J., Van't Hof, M. A., Van der Linden, F. P., & Kuijpers-Jagtman, A. M. (2004). A meta-analysis of the prevalence of dental agenesis of permanent teeth. *Community dentistry and oral epidemiology*, 32(3), 217-226.
- Porntaveetus, T., Abid, M. F., Theerapanon, T., Srichomthong, C., Ohazama, A., Kawasaki, K & Shotelersuk, V. (2018). Expanding the Oro-Dental and Mutational Spectra of Kabuki Syndrome and Expression of KMT2D and KDM6A in Human Tooth Germs. *International Journal of Biological Sciences*, 14(4), 381.
- Rakhshan, V. (2013). Meta-analysis and systematic review of factors biasing the observed prevalence of congenitally missing teeth in permanent dentition excluding third molars. *Progress in orthodontics*, 14(1), 33.
- Rakhshan, V. (2015). Congenitally missing teeth (hypodontia): A review of the literature concerning the etiology, prevalence, risk factors, patterns and treatment. *Dental Research Journal*, 12(1), 1-13.
- Shimizu, T., & Maeda, T. (2009). Prevalence and genetic basis of tooth agenesis. *Japanese Dental Science Review*, 45(1), 52-58.
- Tantanapornkul, W. (2015). Prevalence and distribution of dental anomalies in Thai orthodontic patients. *International Journal of Medical and Health Sciences*, 4(2), 165-172.