THE PREVALENCE, MORPHOLOGICAL VARIATIONS, FAMILIAL TRAITS AND COMPLICATIONS OF TORI IN NORTHERN REGION OF MALAYSIA

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THE PREVALENCE, MORPHOLOGICAL VARIATIONS, FAMILIAL TRAITS AND COMPLICATIONS OF TORI IN NORTHERN REGION OF MALAYSIA

by

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LIST OF SYMBOLS

n	Number
%	Percentage
mm	Millimeter

LIST OF ABBREVIATIONS

TP	Torus palatinus
TM	Torus mandibularis
Notch 3	Unit Neurogenic locus notch homolog protein 3
SMAD 9	Suppressor of Mothers against Decapentaplegic 9
LRP 5	Low-density lipoprotein receptor-related protein 5
MSC	Mesenchymal stem cells
TMD	Temporomandibular Disorder
AMDI	Advanced Medical and Dental Institute
ICC	Interclass correlation coefficient
PID number	Patient's identification number
SD	Standard deviation
IQR	Interquartile range
Freq	Frequency
I	Incisor
C	Canine
P	Premolar
M	Molar
F	Female
M	Male

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ABSTRAK

Tori adalah tisu eksogen bukan patologi biasa dalam rongga mulut, yang kadangkala menghasilkan komplikasi, terutamanya yang menjejaskan pembinaan dan pemakaian gigi palsu. Tori boleh dibahagikan kepada torus palatinus (TP) pada maxilla dan torus mandibularis (TM) pada mandibel. Kewujudannya ditentukan oleh kedua-dua faktor genetik dan persekitaran. Objektif kajian ini adalah untuk menentukan perbezaan prevalens dan variasi morfologi tori di kalangan tiga kaum dan jantina utama di Malaysia. Di samping itu, untuk meneroka kebarangkalian sifat keluarga dan komplikasi yang dihadapi oleh pesakit yang mempunyai tori. Dalam kajian ini, 779 model kajian telah dipilih secara rawak dari klinik pergigian di Institut Perubatan dan Pergigian Termaju, USM. Kajian ini dibahagikan kepada dua bahagian: peperiksaan model kajian dan tinjauan soal selidik. Kelaziman dan ciri morfologi (saiz, bentuk, dan lokasi) tori pada model kajian telah diperiksa, dan maklumat tentang ciri-ciri kekeluargaan dan komplikasi mempunyai tori ditentukan daripada tinjauan soal selidik. Dapatan kajian menunjukkan prevalens tori ialah 64.3%, di mana TP ialah 58.5% dan TM ialah 18.6%. TP didapati lebih banyak pada wanita (61.8%) berbanding lelaki (50.9%) manakala TM didapati lebih banyak pada lelaki (26.9%) berbanding wanita (15%), semuanya berbeza secara statistik ($P_{\text{TP-jantina}} = 0.004$, $P_{\text{TM- jantina}} < 0.001$). Kelaziman tertinggi bagi TP adalah dalam kalangan orang Melayu (60.6%) manakala TM adalah dalam kalangan kaum India (27.3%), hanya TP yang mempunyai perbezaan statistik antara kaum ($P_{\text{TP-kaum}} = 0.001$, $P_{\text{TM-kaum}} = 0.534$). Dalam kalangan ahli keluarga terdekat, kebarangkalian pewarisan anak lelaki adalah lebih tinggi

(33.3%). Bagi komplikasi, kesukaran memakai gigi palsu menyumbang 33.3% pesakit dengan gigi palsu manakala tiga komplikasi lain menyumbang kurang daripada 5% pesakit positif-tori. Kesimpulannya, TP biasa berlaku pada perempuan dan kaum Melayu manakala TM biasa berlaku pada lelaki. Tiada perbezaan kaum atau jantina dalam variasi morfologi. Di kalangan ahli keluarga terdekat, anak lelaki menyumbang bahagian tertinggi. Kesukaran memakai gigi palsu adalah komplikasi terbesar yang dialami oleh pesakit.

THE PREVALENCE, MORPHOLOGICAL VARIATIONS, FAMILIAL TRAITS AND COMPLICATIONS OF TORI IN NORTHERN REGION OF MALAYSIA

ABSTRACT

Tori are common non-pathological exogenous tissue in oral cavity, which occasionally produce complications, especially affecting the construction and wearing of denture. Tori can be divided into torus palatinus (TP) on the maxilla and torus mandibularis (TM) on the mandible. Its existence is determined by both genetic and environmental factors. The objectives of this study were to determine the differences in the prevalence and morphological variations of tori among the three major races and sexes in Malaysia. In addition, to explore the probability of familial traits and complications faced by patients who have tori. In this study, 779 study models were randomly selected from the dental clinic at Advanced Medical and Dental Institute, USM. The study was divided into two parts: study models examination and questionnaire survey. The prevalence and morphological variations (size, shape, and location) of tori on study models were examined, and information on familial traits and complications of having tori was determined from the questionnaire survey. The findings showed that prevalence of tori was 64.3%, where TP was 58.5% and TM was 18.6%. TP was found more in females (61.8%) than males (50.9%) while TM was found more in males (26.9%) than females (15%), all were statistically significantly different ($P_{\text{TP-sexes}} = 0.004$, $P_{\text{TM-sexes}} < 0.001$). The highest prevalence for TP was in Malays (60.6%) while TM was in Indians (27.3%), only TP has statistical difference among races ($P_{\text{TP-races}} = 0.001$, $P_{\text{TM-races}} = 0.534$). Among the immediate family members, the probability of son inheritance was higher (33.3%). As for complications,

the difficulty in wearing dentures accounts for 33.3% of patients with dentures while the other three complications accounted for less than 5% of positive-tori patients. In conclusion, TP is common in females and Malays while TM is common in males. There is no racial or sex difference in morphological variations. Among immediate family members, sons account for the highest proportion. Difficulty in wearing dentures is the greatest complication experienced by patients.

CHAPTER 1

INTRODUCTION

1.1 Background of the study

Tori are defined as non-pathological and originated from the localised process of cortical bone in the oral cavity (García-García et al., 2010), which are formed by dense cortical and a small amount of bone marrow and are covered by a thin mucosa (García-García et al., 2010). They can be divided into torus palatinus (TP) and torus mandibularis (TM) according to different anatomical positions (Hsu et al., 2016). TM is commonly found on the lingual aspect of the mandible which is above the mylohyoid line whereas TP is found more frequently on the middle region of the hard palate (Maduakor & Nwoga, 2017).

Tori may obscure radiographic characteristics of the maxillary sinus and lower premolars (Telang et al., 2019). It may also impede the creation and function of both upper and lower dentures from a prosthetic viewpoint, and it even has impact on speech, deglutition, and mastication (Auškalnis et al., 2015, Al Quran & Al-Dwairi, 2006). Besides, patients with large tori frequently experience recurrent mucosal ulcers and inflammation as a result of trauma from hard foods (Ghahremani et al., 2020). Other medically related implications include the displacement of the tongue which may cause obstructive sleep apnoea (Ahn et al., 2019), as well as interference with endotracheal intubation during general anaesthesia (Durrani & Barwise, 2000).

The aetiology of tori has been controversial for many years (Sathya et al., 2012). Their emergence was previously considered as evolution or sustained growth, but research shows that their emergence is relatively multifactorial, with the interaction of genetic and environmental factors (Seah, 1995). Eggen and Natvig thought that the fraction of torus variation related to hereditary variants was estimated to be about 30%

while roughly 70% of the reasons appeared to be linked to environmental influences (Eggen & Natvig, 1991). Quasi-continuous inheritance and threshold model explained environmental factors must reach a threshold before genetic factors can be expressed in individuals (Eggen, 1989; Fraser, 1976). After the years 1940s, the aetiology of tori was believed to be autosomal recessive inheritance (Alvesalo & Kari, 1972) or polygenetic in origin (Sellevold, 1980). The aetiology of tori has shown that Y chromosomes and some signal factors Notch 3 (Neurogenic locus notch homolog protein 3), SMAD 9 (Suppressor of Mothers against Decapentaplegic 9) and LRP 5 (low-density lipoprotein receptor-related protein 5) may affect its occurrence (Gregson et al., 2020; Dou et al., 2017; Lassi Alvesalo, 2009; Boyden et al., 2002). For environmental factors, occlusal stress, eating habits, nutritional disorders, and stress caused by hyper-mastication have been mentioned in many previous research (Yoshinaka et al., 2014; Kerdpon & Sirirungrojying, 1999; Antoniades et al., 1998; Meir Gorsky et al, 1996).

Table 1.1 shows the prevalence of tori that varies among different races in the world (Chao et al., 2015).

Table 1.1 Comparison of prevalence of oral tori from different studies (Chao et al., 2015)

Study	Year	Area	Sample size (*n*)	TP (%)	TM(%)
Reichart et al.	1988	German	1317	13.5	5.2
Reichart et al.	1988	Thailand	947	23.1	9.2
Shah et al.	1992	India	1000	9.5	1.4
Gorsky et al.	1996	Israel	1002	21.0	-
Ruprecht et al.	2000	USA	1600	-	16.9
Bruce et al.	2004	Ghana	926	4.3	12.1
Yildiz et al.	2005	Turkey	1943	30.9	-
Jainkittivong et al.	2007	Thailand	1520	60.5	32.2
Sawair et al.	2009	Jordan	618	15.4	25.7
Sisman et al.	2008	Turkey	2660	4.1	-
Yoshinaka et al.	2010	Japan	664	17	-
Simunkovic et al.	2011	Croatia	1679	42.9	12.6
Mishra et al.	2011	Malaysia	65	50.8	4.6
Sisman et al.	2012	Turkey	91	41.7	-
Chiang et al.	2014	Taiwan	2050	21.1	24.2
Yoshinaka et al.	2014	Japan	664	-	29.7

*TP–Torus palatinus, TM–Torus mandibularis

As can be seen from Table 1, the prevalence of tori is seen more in Asia. Chaubal et al. concluded that tori had a higher prevalence in Asia (Chaubal et al., 2017). Meanwhile, Reichart et al. reported that TP was more common in females, while TM affected males more than females (Reichart et al., 1988). A few studies showed that the prevalence among people of East Asian ancestry was higher than among West African heritage, the main age range was 20-50 years old (Patil et al., 2014; Romanos et al., 2013; Hiremath et al., 2011).

Tori can exist in the maxilla, mandibular, or both, and they are often found by dentists through visual inspection and palpation during oral examination (Mirza et al., 2018). Morphological variations of tori are represented by size, shape and location.

For more accurate representation, they are also subdivided into different categories (Telang et al., 2019; Kumar Singh et al., 2017; Noor et al., 2013) as shown below:

- **Size** - small, medium, large
- **Shape** - flat, spindle, lobular, nodular
- **Location** - premolar, molar, premolar to molar, incisor to premolar, and incisor to molar areas

Tori are usually asymptomatic and have no abnormal feelings, thus they generally do not require treatment (Chaubal et al., 2017). Treatment of tori usually involves its removal using complex surgical intervention which is costly and risky. As the result of the surgery, patient may suffer from haematoma, excessive bleeding, nerve injury and infection (García-García et al., 2010). However, when patients' lives are seriously affected by tori such as regular pain (Rocca et al., 2012), difficulty in chewing, presence of chronic trauma (Karaca et al., 2019), and causing obstructive sleep apnoea (Saffran & Clark, 2004), these factors meet the surgical indications for tori removal. Surgical removal of tori using burs/bone chisel and mallet/peeling it with Er: YAG laser/piezoelectric surgery, together with postoperative anti-inflammatory drugs prescription could achieve a good healing effect (Sorrentino et al., 2019; Rocca et al., 2012;).

Tori can be used as an autogenous bone graft to repair periodontitis bone defects, to increase bone thickness for dental implantations and in maxillary sinus lift cases (Neiva et al., 2006). It was found that using tori to cover the bone defect in chronic periodontitis has a better effect compared to using full-thickness skin flap (Hassan et al., 2015). Besides, tori can also be an efficient marker for hyperparathyroidism and bioarchaeological investigation (Bezamat et al., 2021). In addition, as torus mandibularis is a non-metric feature frequently documented in

bioarchaeological research, therefore, it is often included in a non-metric trait to analyse the biological distance between populations (Hassett, 2018).

1.2 Problem statement

Although tori are asymptomatic and generally do not need treatment (Chaubal et al., 2017), their existence can increase the difficulty of denture making and affect denture retention (Al Quran & Al-Dwairi, 2006). The mucosa of tori patients tends to be thinner and cannot bear the occlusal load of the denture (Abrams, 2000). Excessive TM may hinder the complete fixation of the impression plate and denture, and a torus mandibularis may fix the denture in a fixed position or cover any lingual margin in this area (Abrams, 2000). Progressive enlargement of the tori can cause dental and medical problems such as periodontal disease (Morrison & Tamimi, 2013), recurrent mucosal ulcers and inflammation caused by trauma from hard foods (Ghahremani et al., 2020), interference with endotracheal intubation during general anaesthesia and tongue displacement that causes obstructive sleep apnoea (Ahn et al., 2019; Durrani & Barwise, 2000).

The prevalence of tori has been high, and even Malaysia has a slight upward trend (Table 1.2). Besides, the previous research on tori in Malaysia only focused on the prevalence and morphological variations (Hiremath et al., 2011), and so far there is no research on familial traits and complications of tori. Therefore, studying the prevalence and morphological variations of tori in the northern region of Malaysia can add to the latest data and be used to get the current trend. Adding familial traits and complications in the methodology can strengthen the theoretical cognition of tori, which may have reference value for the clinical data and pave for further research in the future. To know more details about the morphological variations of tori may help

dentists to design a better denture in order to improve the retention, stability and comfort for the patients with tori. The information on the familial traits and complications of tori can show more about family heritability and evaluate the treatment methods to treat the arised complications.

Table 1.2 Prevalence of tori among Malaysian population

No.	Authors (Year)	TP (%)	TM (%)	TP & TM (%)
1.	Hashim et al. (1983)	24.4	2.2	-
2.	Hiremath et al. (2011)	50.8	4.6	-
3.	Sathya et al. (2012)	12	2.8	-
4.	Noor et al. (2013)	38.05	0.3	-
5.	Singh et al. (2017)	65	10.5	14
6.	Telang et al. (2019)	77.08	6.73	16.86

*TP–Torus palatinus, TM–Torus mandibularis

1.3 Research Question(s)

1. What is the current prevalence of tori in Northern Malaysia?
2. Are the morphological variations of tori different?
3. Is there a significant difference in the prevalence of tori between sexes and races in Northern Malaysia?
4. What is the association of tori and familial traits in Northern Malaysia?
5. What are the complications faced by patients who have tori?

1.4 Objective

1.4.1 General objective

To determine the prevalence, morphological variations, familial traits, and complications of tori in the Northern region of Malaysia.

1.4.2 Specific objectives

1. To determine the prevalence of tori from the study models available from Dental Clinic, Advanced Medical and Dental Institute (AMDI).
2. To evaluate the morphological variations of tori from Dental Clinic, AMDI.
3. To compare the prevalence and morphological variations of tori among the main races and sexes.
4. To investigate the association of tori and familial traits.
5. To explore the complications faced by patients having tori through questionnaire.

CHAPTER 2

LITERATURE REVIEW

2.1 Aetiology and pathogenesis

The exact aetiology of tori is still unclear. Eggen and Natvig thought that the fraction of torus variation related to hereditary variants was estimated to be about 30%, while roughly 70% of the reasons appeared to be linked to environmental influences (Eggen & Natvig, 1991). There are differences in the prevalence of tori among people of different races living in the same environment (Hiremath et al., 2011), which is not consistent with the above conclusions. Quasi-continuous inheritance and threshold model explained environmental factors must reach a threshold before genetic factors can be expressed in individuals (Seah, 1995). This makes Eggen's conclusion more rigorous. For aetiological factor, the literatures will be reviewed from the perspectives of hereditary and environmental factors.

2.1.1 Hereditary factor

In the study of Gorsky et al., isolation analysis was used, and the results showed that more than half of families had vertical transmission of TP, suggesting that there was autosomal dominant inheritance (M. Gorsky et al., 1998). The prevalence of TP in females was higher than in males and it was believed that a dominant form may be associated with the X chromosome (Reino et al., 1990). In addition, the hereditary factors were also found to be autosomal recessive inheritance (L. Alvesalo & Kari, 1972) or polygenetic in origin (Sellevold, 1980). A study showed that children whose parents exhibited the trait were more likely to demonstrate the characteristics (Kerdpon & Sirirungrojying, 1999).

Studies in the 21st century showed that sex chromosomes might affect the occurrence, expression and development of mandibular torus, especially Y chromosome (Lassi Alvesalo, 2009). Besides, Boyden et al. (Boyden et al., 2002) unveiled that the LRP5 (low-density lipoprotein receptor-related protein 5) mutation induces increased bone density with enlarged mandible and torus palatinus. This mutation inhibits the activity of a normal Wnt (Wingless-related integration site) pathway antagonist (Boyden et al., 2002). Notch3 (Neurogenic locus notch homolog protein 3) signalling loss may contribute to bone expansion in TM via accelerated MSC (mesenchymal stem cells) driven osteogenic differentiation in the jawbone (Dou et al., 2017). Gregson et al. reported associations between common variation and a rare mutation in the SMAD 9 (Suppressor of Mothers against Decapentaplegic 9) gene and extreme high bone density phenotypes, including the presence of TP (Gregson et al., 2020). The research updates on hereditary aspect of tori is shown in Figure 2.1.

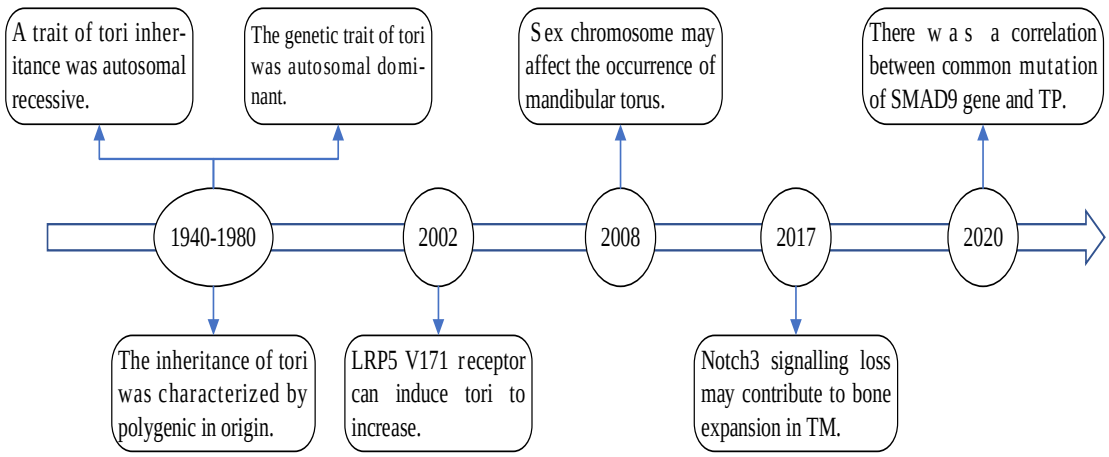

Figure 2.1 Updates of tori on hereditary factors

2.1.2 Environmental factor

The main environmental factor is occlusal pressure on the teeth (Eggen & Natvig, 1991). Recent research on occlusal pressure mainly focuses on different age

groups and the specific causes of occlusal pressure. Yoshinaka et al. used a pressure-sensitive sheet to test the bite force of the elderly over 60 years old with tori (Yoshinaka et al., 2014). On the other hand, Jeong et al. measured the bite force of 345 patients with tori using bite force record. They found that TM was specially linked to mechanical stimulation from the occlusal interaction (Jeong et al., 2019; Yoshinaka et al., 2014). Bertazzo-Silveira et al. investigated 575 bruxism patients, who experienced teeth grinding, jaw clenching and abnormal tooth wear, using questionnaires and clinical examinations. They found that abnormal tooth wear increased the probability of developing tori, particularly the TM (Bertazzo-Silveira et al., 2017).

Another cause is superficial injuries or in patients with abraded teeth due to occlusion or its occurrence as a functional response in individuals with well-developed chewing muscles (García-García et al., 2010). Cheon et al. studied 375 patients who were diagnosed with Temporomandibular Disorder (TMD) and 433 control patients, self-reported bruxism and torus mandibularis in each group were investigated and compared statistically. The prevalence of self-reported bruxism and torus mandibularis was higher in TMD group than in the control group ($p < 0.05$). Therefore, they suggested that bruxism and torus mandibularis may be helpful as predictors of TMD risk (Cheon et al., 2019). Khan et al. reported a woman who had been taking calcium and vitamin D supplements in the form of tablets, in random doses, for approximately 18 months. They found that vitamin D supplements and malocclusion may be held responsible for the concurrent development of TP, TM, and buccal exostoses (Khan et al., 2016). In conclusion, dietary habits, nutritional conditions, and medicines involved in calcium homeostasis, such as phenytoin, are other environmental variables contributing to oral tori development (Jeong et al., 2019).

2.2 Sociodemographic features

The prevalence of TP and TM varies from 0.4% to 61.7% and 1% to 64%, respectively, in different populations across the globe (Sathya et al., 2012). The prevalence of the tori is not simple or static, and the complexity of prevalence has been expressed in articles for many years. The manifestations related to different prevalences of tori are ethnic group, sex and age (García-García et al., 2010). The complexity of prevalence on of tori has always been the focus of human research.

2.2.1 Ethnic group

Several studies have already been conducted, and racial disparities in the incidence of oral tori have been widely established (Telang et al., 2019; Yoshinaka et al., 2014). When Sonnier et al. compared the prevalence of torus among North Americans, they found that African Americans (33.8%) were among those who presented the highest incidence of TM, whereas Caucasians (22.8%) were more likely to present TP (Sonnier et al., 1999). A recent study of a multi-ethnic population discovered that TP is at around double the prevalence among people of East Asian ancestry compared to people of West African heritage, with the difference being restricted to females (Sergani et al., 2020). Tori has repeatedly been more common among Mongoloids than in Caucasians (Noor et al., 2013).

The data from the last ten years shows that the prevalence of TP and TM in different countries is still within the scope of previous statistics (Table 2.1). However, the prevalence of tori is statistically different within the same country. For example, in the prevalence of tori in Malaysia, Kumar Singh's study in 2017 found that the prevalence of TP was 27.9% and TM was 8.9%, but Telang in 2019 showed the prevalence of TP and TM were 13.2% and 3.3%, respectively (Telang et al., 2019;

Kumar Singh et al., 2017). The prevalence difference may be due to several factors, such as Malaysia being a multi-ethnic country with different prevalence among different races, conflicting tori's definition and identification, and the inconsistency of the proportion calculation method between the studies.

Table 2.1 Summary of the tori's prevalence in the recent ten years

Study	Year	Country	Sample size(n)	TP (%)	TM (%)	TP&TM (%)
Sisman et al., 2012	2012	Turkey	91	41.7	-	-
Romanos et al., 2013	2013	United States	1323	-	37.8	-
Patil et al., 2014	2014	India	3087	1.3	6.9	-
Yoshinaka et al., 2014	2014	Japan	664	-	29.7	-
Chiang et al., 2014	2014	China	2050	21.1	24.2	-
Scrieciu et al., 2016	2016	Romania	74	8.1	9.5	4.1
Maduakor & Nwoga, 2017	2017	Nigeria	3000	8	4.2	2.5
Kumar Singh et al., 2017	2017	Malaysia	2666	27.9	8.9	4.6
Mirza et al., 2018	2018	Pakistan	1203	11.7	-	-
Telang et al., 2019	2019	Malaysia	4443	13.2	3.3	2.3
Prasad et al., 2020	2020	India	14208	-	1.1	-
Alqahtani et al., 2020	2020	Saudi Arabia	1943	30.9	-	-

*TP–Torus palatinus, TM–Torus mandibularis

2.2.2 Sex

It is more frequent for TP to appear in females than in males (Telang et al., 2019; Scrieciu et al., 2016; Sisman et al., 2012;), and it is believed that there may be a dominant type linked to the X chromosome (Reino et al., 1990). Although not all studies have pointed out that females are more likely than males to have it, in the study by

Bruce et al., the conclusion is just the opposite (Bruce et al., 2004). As for TM, Bruce et al. did not find significant differences between males and females in the study (Bruce et al., 2004). On the contrary, Noor et al. found that males were more affected than females (Noor et al., 2013), although it was more common among males in two studies (Yoshinaka et al., 2014; Apinhasmit et al., 2002). Table 2.2 is a sex-specific survey of tori prevalence in Malaysia using a unified algorithm. From the table, studies showed the prevalence of TP in Malaysia was higher among females. However, in Karachi, Pakistan, Mirza et al. found that TP was more prevalent in males (53.9%) (Mirza et al., 2018). Although this phenomenon still occurred for TM, a study showed that the prevalence for females was higher than for males (Sathya et al., 2012). However, other studies found it was more common among males (Telang et al., 2019; Hiremath et al., 2011).

2.2.3 Age

It is difficult to compare the average age in the previous studies because these studies are not standardised in age groups. According to a study conducted by Bruce et al., the average age for onset of tori was 34 years old (Bruce et al., 2004). According to Al-Bayaty et al., the average age when experiencing the onset for patients with TP was 30.7 years old and 39.2 years old for those with TM (Al-Bayaty et al., 2001). Tori appears earlier in those with TP, where such onset has been documented from birth and the first decade of life (Al-Bayaty et al., 2001). According to Reichart et al., the most common age range for the onset of TP in females was between 11 and 20 years old (Reichart et al., 1988). Although most studies found that the most common age range for such onset was between 30 and 50 years old (the third and fourth decade of life)

(Sathya et al., 2012; Hiremath et al., 2011;). Haugen et al. found that the age range that experienced the most frequent onset could reach as high as 65 years old (Haugen, 1992).

For the difference in tori prevalence among different age groups in Malaysia, it was evident that TP was more prevalent in the 20 to 30 years of age group (Telang et al., 2019; Hiremath et al., 2011). On the contrary, Noor et al. found that the TP age tended to be higher in the younger patients (Noor et al., 2013). Sathya et al. showed the highest incidence was found in the 40-year-old and older age group, but in their study, they divided people over 40 into the same group (Sathya et al., 2012). As for TM, almost half of the studies showed that the highest prevalence was at the age of 20 to 29; the other half showed that the age group was 30 to 39. However, Hiremath et al. found that TM was more common in the 40 to 49-year-old age group (12.5%) (Hiremath et al., 2011). In India, Patil et al. found that TM was more common in the 41 to 50-year-old age group (37.9%) (Patil et al., 2014). Finally, the observations in the United States of America revealed a significant incidence of TM (37.8%), with a mean population age of 40 years (Romanos et al., 2013). Most studies showed that the predisposing age of tori was from 20 to 50 years old.

Table 2.2 Summary of the sex and main age of tori prevalence in Malaysia

Study	**Year**	**Sex (prevalence)**		**Main age (prevalence)**	
		TP (%)	**TM (%)**	**TP (%)**	**TM (%)**
Zaw et al., 2009	2009	F (76.8), M (23.2)	-	-	-
Hiremath et al., 2011	2011	F (58.8), M (21.4)	F (3.9), M (7.1)	20-29 (36)	40-49 (12.5)
Sathya et al., 2012	2012	F (15.7), M (8.4)	F (3.7), M (1.9)	⩾40（42.9）	30-39 (30.2)
Noor et al., 2013	2013	F (39.6), M (33.9)	-	10-19 (54.4)	20-29 (100)
Kumar Singh et al., 2017	2017	F (14.9), M (5.9)	F (1.5), M (2.0)	21-30 (39.2)	21-30 (51.6)
Telang et al., 2019	2019	F (6.3), M (4.6)	F (0.4), M (0.6)	20-29 (25.6)	30-39 (23.8)
Mary Donald et al., 2020	2020	F (34.3), M (13.0)	F (4.6), M (1.9)	21-30 (72.5)	21-30 (85.7)

*TP– Torus palatinus, TM– Torus mandibularis, F– Females, M– Males

2.2.4 The relationship between the prevalence of TP and TM

The TP appears more frequently than the TM in the majority of the studies reviewed; however, there were reviews such as those by Kerdpon & Sirirungrojying and Bruce et al. that showed a higher prevalence of TM than TP (Bruce et al., 2004; Kerdpon & Sirirungrojying, 1999). Seah suggested there was no correlation between TP and TM (Seah, 1995). Noor et al. proved this when they assessed the study models of 996 subjects and found that no one had TP and TM simultaneously (Noor et al., 2013). On the contrary, Al-Bayaty et al., in their study found that there was a strong correlation between TP and TM, where half of TM-positive patients had TP, while only 30% of TP-positive patients had TM (Al-Bayaty et al., 2001). However, it is noteworthy that the study by Noor et al. only found three patients with TM. Thus, it could not explain the relationship between TP and TM much.

2.3 Morphological variations

2.3.1 Classification

Both torus palatinus and torus mandibularis have undergone several classification attempts. The classification of tori was varied in the earlier years, but there is no workable solution yet. Both torus palatinus and torus mandibularis most often can be categorised by size, shape, or location.

2.3.1(a) Size

According to the Igarashi Torus Index, the presence or absence of TM was graded on a scale of 0 to 3. This index designates classes 0 as no TM recognised visually or by palpation, class 1 as TM recognised only by palpation, class 2 as a TM high enough to cast a distinct shadow on the mandible, and class 3 as a TM whose contour

can be visually traced entirely around the base of the TM (Table 2.3) (Igarashi, 2016). Some authors classified the torus as trace, small, medium or large (Reichart et al., 1988; Thoma & Goldman, 1960; Woo, 1950), while Haugen left out the category of trace because he believed that using this term in ambiguous situations produced wildly divergent results (Haugen, 1992). Haugen did not categorise the torus using measurements because he thought it to be a non-metric object; instead, he used a standard inspection procedure to evaluate the various sizes (Haugen, 1992). Regarding different size values according to actual measurements, tori were graded according to the previous description as being > 2 cm or < 2 cm (Meir Gorsky et al., 1996). By measuring the maximum lingual projection or thickness of the tori, the size of the TM, if it could be seen, was recorded as small (2 mm), medium (2 - 4 mm), or large (> 4 mm). The usual lingual outline was thought to consist of small thickenings or roughnesses that could be felt rather than seen (Eggen, 1989). It has been reported that the mean value was used to represent the size of tori (Sonnier et al., 1999). Recently, the majority of researchers used Reichart's classification when describing the size of tori: mild (3 mm), moderate (3 mm - 6 mm), and marked (> 6 mm) as the standard measurement (Reichart et al., 1988).

Table 2.3 Torus Index for torus mandibularis

Class	**Diagnostic index - Torus mandibularis**
Class 0	Not recognised visually or by palpation
Class 1	Recognised only by palpation
Class 2	High enough to cast a distinct shadow on the mandible
Class 3	Contour can be visually traced entirely around the base of the TM

2.3.1(b) Shape

Classification by shape is frequently challenging because there are many transitional forms and no distinct boundaries. Even after manual palpation, challenges such as trying to differentiate between a spindle torus and a prominent palatine suture continue to exist. Haugen avoided trying to register numbers precisely because he thought it was dishonest and misleading (Haugen, 1992). The most popular shape classification was by Al-Bayaty et al., who classified them as flat, spindle, nodular or lobular (Al-Bayaty et al., 2001). The details of the classification are as follows:

- **Flat torus** – a slightly convex protuberance with a smooth surface extending symmetrically on both sides of the palate
- **Spindle torus** – present along the midline ridge along the palatal raphe area
- **Nodular torus** – can be single/multiple protuberances with individual bases; these protuberances may coalesce, forming grooves between them
- **Lobular torus** – a pedunculated or sessile lobular mass that arises from a single base

Figure 2.2 shows pictures of different shapes of tori, as summarised by Jeong et al., 2019.

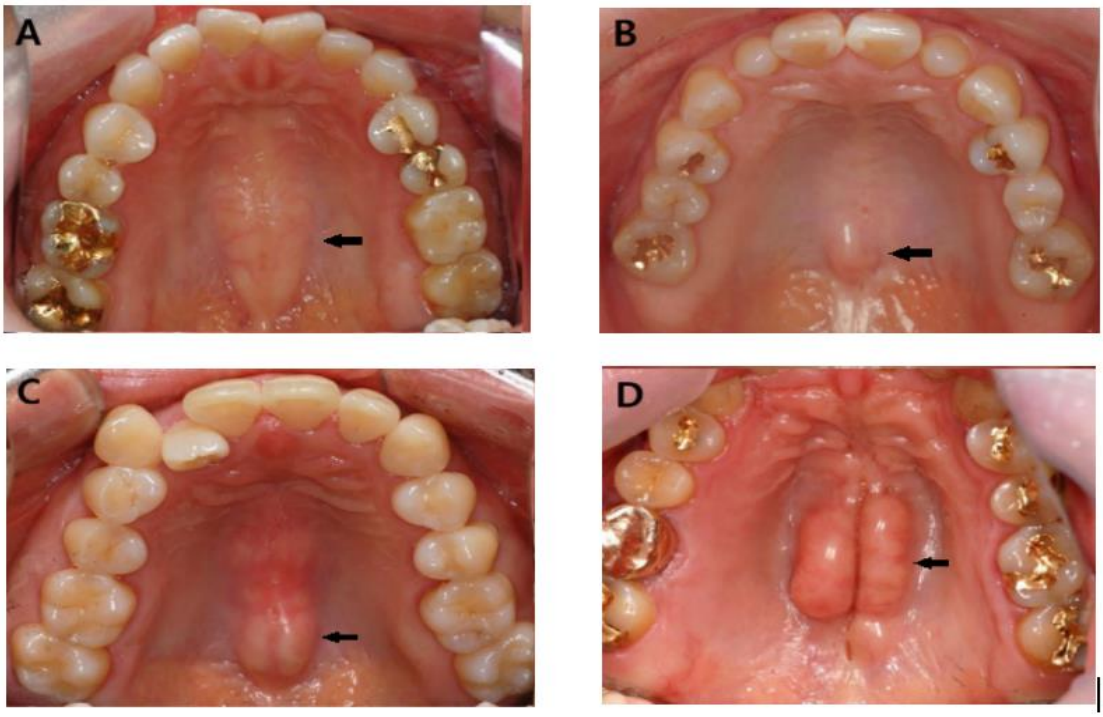

Figure 2.2 Types of torus palatinus (TP) as shown by arrows. (A) flat; (B) nodular; (C) spindle; (D) lobular (Adapted from Jeong et al., 2019)

Regarding torus mandibularis, Kolas et al. distinguished four clinical varieties based on the number of nodes. The classification was divided into four categories: unilateral single, unilateral multiple, bilateral single, and bilateral multiple (Kolas et al., 1953). This classification was used to be the most common classification method. Recently, a new and more convenient classification method was used where the shape of the torus mandibularis was classified as nodular and band-like (Telang et al., 2019), as shown in Figure 2.3 below.

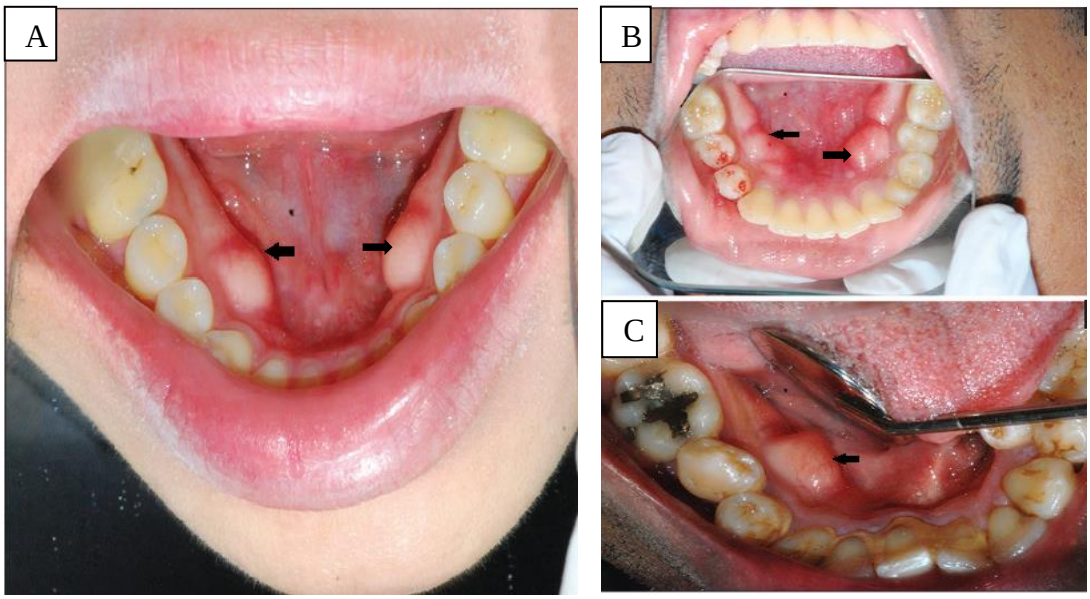

Figure 2.3 Types of torus mandibularis (TM) as shown by arrows. (A) band-like; (B) nodular bilateral; (C) nodular unilateral (Adapted from Telang et al., 2019)

2.3.1(c) Location

Few researchers have attempted to categorise the location of tori, especially TM (Antoniades et al., 1998; Eggen & Natvig, 1991; Reichart et al., 1988). Chew and Tan classified the torus by location, the palate's anterior, middle, and posterior regions, and the torus's position was identified by the segment or segments it occupied (Chew & Tan, 1984). Some researchers have used tooth areas to indicate the location of tori (Tai et al., 2018; Scrieciu et al., 2016; Noor et al., 2013; Hiremath et al., 2011). The most commonly used classification method for location is where TP was divided into premolar, molar, premolar to molar, incisor to premolar, and incisor to molar areas (Noor et al., 2013) while the locations for TM were recorded as incisor, incisor to canine, incisor to premolar, incisor to molar, incisor and premolar, canine, and canine to premolar areas (Hiremath et al., 2011).

2.3.2 Dental complications of tori

2.3.2(a) Denture design

Denture instability resulting from denture interference is the most frequent issue linked to tori. For example, an undercut on a large torus palatinus makes the positioning of the tray during impression taking or inserting the dentures difficult, decreases the stability and retention from dentures and causes mucosal inflammation (Al Quran & Al-Dwairi, 2006). Due to its thin nature, the mucosa cannot withstand the occlusal loading of a denture. Besides, denture and impression tray seating may be impeded by large mandibular tori (Abrams, 2000). A traditional denture design for an edentulous patient without tori is shown in Figure 2.4. The denture base should be attached to the mucosa, and the edge should be coordinated with the anatomical and functional limitations of adjacent tissues (Massad et al., 2008).

Figure 2.4 Denture design without tori which extends to the full palate and mandibular areas (Adapted from Habib & Vohra, 2013)

A clinical research showed that for medium and large tori, the risk of denture breakage was greater, thus surgical removal, implant-supported removable denture and reinforcement of the acrylic base of a complete maxillary denture were suggested to improve the quality of denture (Muntianu et al., 2011). A case report of a 76-year-old female with torus mandibularis, showed that a butterfly-shaped design denture (Figure

2.5) was used, hence, the top of torus mandibularis was not covered with the denture material to avoid mucosal irritation (Ezzat et al., 2013).

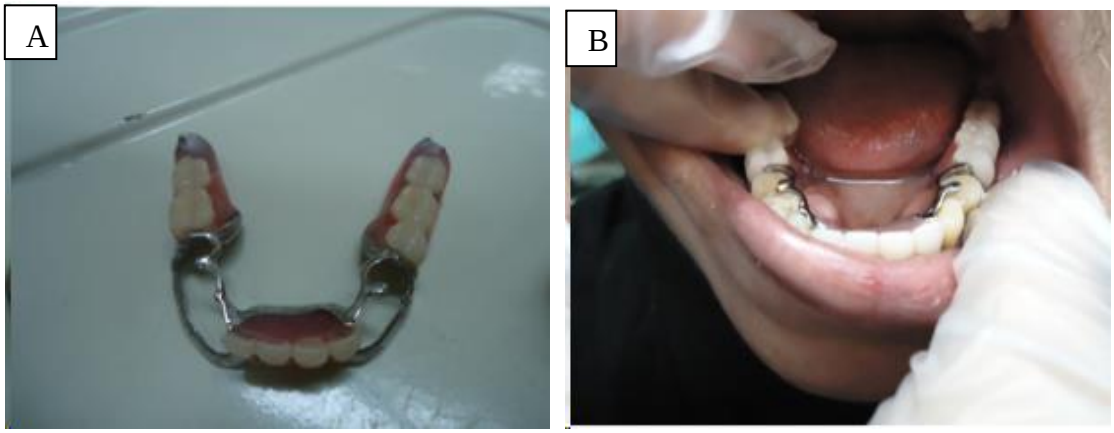

Figure 2.5 (A) A modified denture design shaped as butterfly; (B) Butterfly-shaped denture inside the patient's mouth (Adapted from Ezzat et al., 2013)

Vaithilingam et al. followed up 66 torus palatinus positive patients using two designs of complete dentures which were complete denture with window and horseshoe-shaped complete denture. The results for both designs showed that the retention values were approximately the same but there was a significant difference in the bite force values where horseshoe-shaped denture was better than complete denture with window (Figure 2.6) (Vaithilingam et al., 2022).

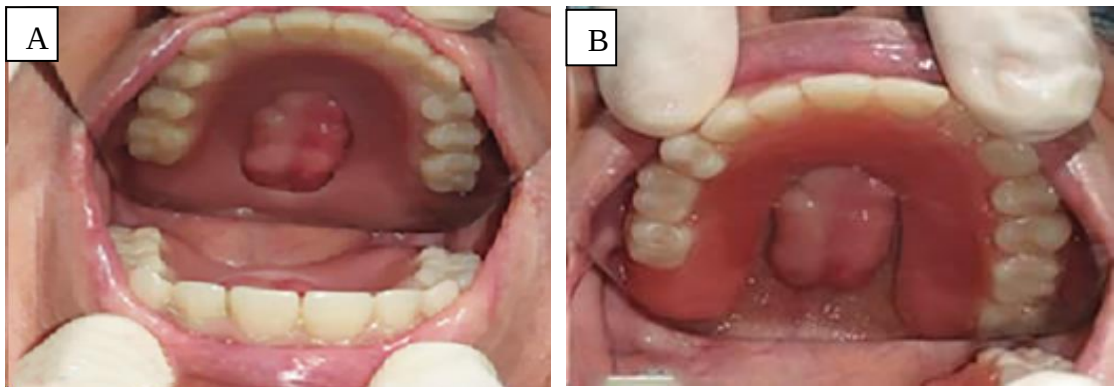

Figure 2.6 (A) Complete denture with window design; (B) Horseshoe-shaped complete denture (Adapted from Vaithilingam et al., 2022)

2.3.2(b) Other dental complications

Other dental complications that can be caused by tori are displacing and inhibiting tongue movement, interfering with mastication and impairing speech (Auškalnis et al., 2015). In addition, food retention around the tori can cause an increased in plaque formation and periodontal disease (Morrison & Tamimi, 2013). Furthermore, patients with large tori frequently experience recurrent mucosal ulcers and inflammation due to trauma from hard foods (Ghahremani et al., 2020). In a previous study, they found that some patients may have osteonecrosis or experience cancerophobia (Valentin et al., 2021).

2.3.3 Medical complications of tori

Tori can also produce some medical complications. This includes the displacement of the tongue which causes obstructive sleep apnoea, which sometimes can be fatal (Ahn et al., 2019). In addition, painful ulceration and osteonecrosis of the tori can be seen in patients receiving bisphosphonates for osteoporosis and cancer treatment (Godinho et al., 2013), as well as interference with endotracheal intubation during general anaesthesia (Durrani & Barwise, 2000).

2.4 Function and Treatment

2.4.1 Function

Previous literature mainly emphasised the influence of tori and their functions have been mentioned in recent years. Bezamat et al. noted that tori could be an efficient marker for an increased bone mass phenotype and hyperparathyroidism (Bezamat et al., 2021). Hassan et al. used mandibular tori and full-thickness flap to treat the intraosseous defect in periodontitis. They found that the mandibular tori was more effective as an

autogenous bone graft to treat the defect (Hassan et al., 2015). Neiva et al. established an acceptable bone height and breadth for implant placement, using mandibular tori as an autogenous graft material for horizontal bone augmentation and sinus lifting operations (Neiva et al., 2006). In addition, Redor et al. found that regarding elemental composition and crystal compounds, tori's bone and bone graft alternatives were comparable (Redor et al., 2021). Besides, Wang et al. used torus block bone grafts for vertical ridge augmentation (Wang et al., 2016). Torus mandibularis is a non-metric feature frequently documented in bioarchaeological research. A non-metric trait often used for the analysis of the biological distance between populations (Hassett, 2018). The research progress of tori's function is summarised in Figure 2.7.

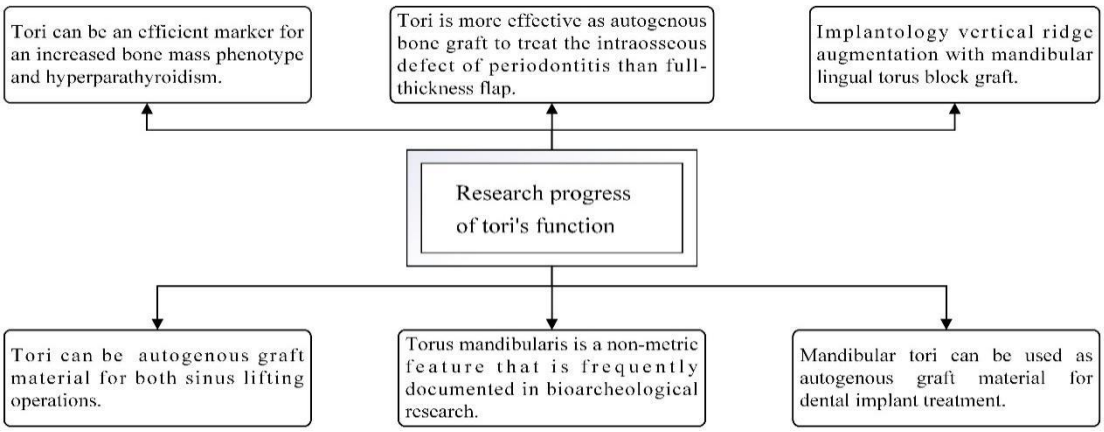

Figure 2.7 Summary of updates on tori's functions

2.4.2 Treatment

Case reports in the literature have shown a few indications for tori removal; torus may be indicated for surgical removal due to pain (Rocca et al., 2012), difficulty in chewing, presence of chronic trauma (Karaca et al., 2019), and causing obstructive sleep apnoea (Saffran & Clark, 2004). Goncalves et al. (Goncalves et al., 2013) surgically removed the torus mandibular of a 45-year-old man whose pronunciation was

affected. By carving a groove in the superior lesion region and chiselling, an intrasulcular lingual incision from the molar to the contralateral molar side of the bone volume was meticulously removed in three distinct blocks (Goncalves et al., 2013). A 34-year-old woman suffered from torus mandibular pain for a long time and Sorrentino et al. used piezoelectric surgery to remove exostosis, and stitches were applied (Sorrentino et al., 2019). A 67-year-old woman was referred to the clinic for TP removal; Rocca et al. chose to smooth it with Er: YAG laser (Rocca et al., 2012). The postoperative medication included antibiotics, analgesics and anti-inflammatory drugs, the prognosis was good and there was no sign of inflammation (Sorrentino et al., 2019; Rocca et al., 2012). The indications, preoperative morphological variations and surgical methods of the operation are summarised in Table 2.4.