Anatomical Study of the Maxillary Artery at the Pterygomaxillary Fissure in a Thai Population: Its Relationship to Maxillary Osteotomy

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Background : *The maxillary artery (MA) and its terminal branches are commonly damaged in the maxillary osteotomy, especially during separation of the pterygomaxillary junction (PMJ).*
Objective : *To evaluate the positional relationship between the MA at the pterygomaxillary fissure (PMF) and the PMJ in Thais, as well as to measure the diameter of the MA as it enters the pterygopalatine fossa (PPF) and the heights of PMJ, maxillary tuberosity and posterior maxilla.*
Subjects and Method : *Both sides of 100 Thai adult cadavers (50 males and 50 females) were examined. The mean age of the subjects was 64.5 $\pm$ 12.8 years. With the lateral infratemporal approach, the branches from the third part of the MA, PMJ and posterolateral maxilla were dissected. Measurements taken included the following: First, the distance from the most inferior point of the PMJ to the most inferior position of the MA as it entered the PPF; second, the external diameter of the MA as it entered the PPF; third, vertical heights of the PMJ, maxillary tuberosity and posterior maxilla. Means, standard deviations and ranges were determined and statistical differences were calculated between sides and genders at $p < 0.05$.*
Results : *The MA entered the PPF at a mean distance of 23.5 $\pm$ 2.5 mm above the most inferior point of the PMJ. The mean external diameter of the MA as it entered the PPF was 2.8 $\pm$ 0.6 mm. The mean heights of the PMJ, maxillary tuberosity and posterior maxilla were 19.5 $\pm$ 2.3 mm, 6.1 $\pm$ 2.7 mm, and 25.6 $\pm$ 3.3 mm, respectively. There were no differences with respect to side and gender, except that the distance from the most inferior point of the PMJ to the most inferior position of the MA as it entered the PPF was longer in males than in females ($p < 0.05$).*
Conclusion : *The mean location of the MA was 23.5 mm apart from the most inferior point of the PMJ, therefore, dysjunction of the PMJ using an osteotome with a 15-mm cutting edge may be conducted without damaging to the MA. When properly placed, the margin of safety from the superior cutting edge of the osteotome to the MA is approximately 8 mm in adults.*

Keywords : *Maxillary artery, Maxillary osteotomy, Pterygomaxillary fissure, Pterygomaxillary junction, Pterygopalatine fossa*

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The maxillary osteotomy (Le Fort I, II, and III) is a commonly performed surgical procedure on the maxilla for the correction of dentofacial and craniofacial deformities[1,2]. The separation of the maxilla from its posterior articulation to the cranium at the pterygomaxillary junction (PMJ) is required in maxillary osteotomy and midfacial advancement procedures[1,2]. During the operation, it is important to preserve various structures in the pterygopalatine fossa (PPF), particularly the maxillary artery (MA) that lies immediately superior to the PMJ before entering the PPF. The MA branches from the external carotid artery deep to the

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mandibular condyle and runs medially in a superior course to enter the PPF through the pterygomaxillary fissure (PMF). The third portion of MA gives off several branches before entering the sphenopalatine foramen[2-4].

Maxillary osteotomy is performed in an extremely vascular region where bleeding control is frequently not possible until after completion of the operation and repositioning of segments[2]. Bleeding is always profuse. If brisk bleeding occurs during midfacial mobilization procedures, most likely the main trunk of the MA or its terminal branches have been damaged[1]. Postoperative complications such as hemorrhage, false aneurysm, arteriovenous fistula and aseptic necrosis were reported by Lanigan et al[5-7]. They also indicated that the main trunk of the MA and its terminal branches are most commonly involved in maxillary osteotomy.

To minimize damage to the MA during the separation of the PMJ in maxillary osteotomy, it is necessary for the surgeon to have adequate knowledge of the relationship between the MA at the PMF and the PMJ. In spite of the importance of this anatomical relationship, there have been few reports focusing on the anatomy of the MA at the PMF and in the PPF[1-3,8]. This research was done to evaluate the positional relationship between the MA at the PMF and the PMJ in Thais; no such study has ever been reported.

Subjects and Method

Both sides of 100 Thai adult cadavers, 50 males and 50 females, were examined in the present study. These subjects had been partially dissected in Gross Anatomy studies by both medical students at the Department of Anatomy, Faculty of Medicine Siriraj Hospital, Mahidol University and dental students at the Department of Anatomy, Faculty of Dentistry, Chulalongkorn University.

With the lateral infratemporal approach, the mandibular ramus and the lateral pterygoid muscle were removed from each specimen to expose the pterygomaxillary region. Upon dissection of the pterygomaxillary region, branches of the third portion of the MA, lateral pterygoid plate, PMJ, and posterolateral portion of the maxilla were identified (Fig. 1). The status of the upper molar teeth was observed and recorded as being with or without upper molars. A sliding caliper (with output to the nearest 0.01 mm) was utilized to measure the distance from the most inferior point of the PMJ to the most inferior position of the MA as it entered the PPF (distance A in Fig. 1). The external diameter of the MA as it entered the PPF (5 in Fig. 1) was also measured. In addition, vertical heights of the PMJ (distance B in Fig. 1), maxillary tuberosity (distance C in Fig. 1) and posterior maxilla (distance B+C in Fig. 1) were determined. The height of the maxillary tuberosity was defined as the distance from the lowest point of the maxillary tuberosity to the lowest point of the PMJ, while that of the posterior maxilla was recorded from the lowest point of the maxillary tuberosity to the most superior point of the PMJ[9].

All measurements were tabulated and separated according to side, gender and status of upper molars. The statistical Package for Social Science (version 11.0) was used for the analyses. The mean, standard deviation and range for each of the measurements were assessed. A comparison of the values of all measurements were made between sides of each subject using the paired-*t*-test, while comparisons between gender and status of upper molars were made using the unpaired-*t*-test. Differences between groups with $p < 0.05$ were considered statistically significant.

Results

The age of the subjects ranged from 33 to 87 years with a mean of 64.5 $\pm$ 12.8 years. There was no significant age difference between the 50 male (64.0 $\pm$ 12.6 years) and 50 female cadavers (64.9 $\pm$ 13.2 years) examined in the present study ($p = 0.693$). Observations of the status of the upper molar teeth indicated that 42.5% of the subjects had upper molar teeth.

The MA branched from the external carotid artery and passed horizontally deep to the condylar neck of mandible into the infratemporal fossa (Fig. 1). Using the lateral pterygoid muscle as a landmark, the MA was divided into three portions, the mandibular (first), the pterygoid (second) and the pterygopalatine (third). Before entering the PPF, the third portion of the MA gave off the posterior superior alveolar artery and the infra-orbital artery at the posterior wall of the maxilla (Fig. 1). The posterior superior alveolar artery descended on the posterolateral wall of the maxilla before it entered the posterior superior alveolar foramen. The infra-orbital artery ascended to enter the orbit through the inferior orbital fissure. In the PPF, the MA branched into the descending palatine artery, the artery of the pterygoid canal, the pharyngeal branch and the sphenopalatine artery.

From the present study, the MA entered the PPF at the mean distance of 23.5 $\pm$ 2.5 mm above the most inferior point of the PMJ (Table 1). The mean

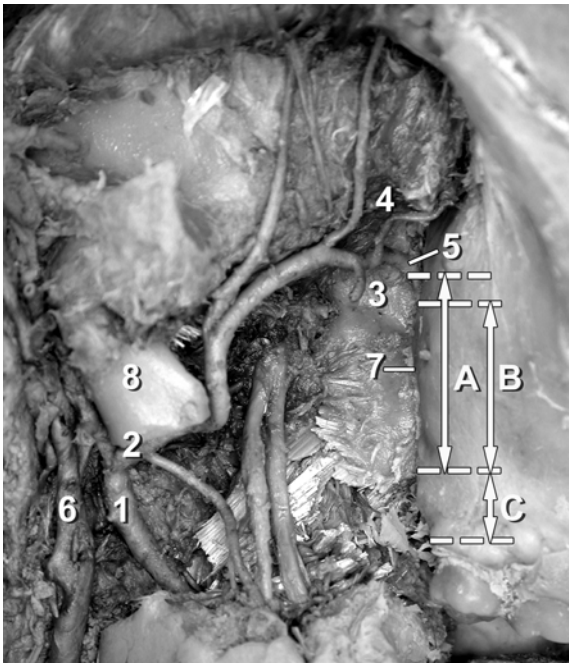

Fig. 1. The lateral aspect of the infratemporal fossa, pterygomaxillary junction and posterolateral maxilla showing the branches of the maxillary artery and vertical measurements. 1: External carotid artery. 2: Maxillary artery. 3: Posterior superior alveolar artery (cut). 4: Infra-orbital artery. 5: Maxillary artery at the pterygomaxillary fissure. 6: Retromandibular vein. 7: Pterygomaxillary junction. 8: Mandibular condyle. A: Distance from the most inferior point of the pterygomaxillary junction to the most inferior position of the maxillary artery at the pterygomaxillary fissure. B: Height of the pterygomaxillary junction. C: Height of the maxillary tuberosity. B+C: Height of the posterior maxilla.

external diameter of the MA as it entered the PPF was 2.8 ± 0.6 mm (Table 1). Table 1 also lists the vertical heights of the PMJ, maxillary tuberosity and posterior maxilla, the mean values of which were 19.5 ± 2.3 mm, 6.1 ± 2.7 mm and 25.6 ± 3.3 mm, respectively.

A comparison of the values of all measurements between sides of subjects were made using the paired-t-test. There were no statistically significant differences between any of the results at $p<0.05$. Regarding a comparison between genders, a difference was found only in regards to the mean distance from the most inferior point of the PMJ to the inferior border of the MA (Table 1). The mean distance was longer in males than in females ($p = 0.018$). In addition, a comparison of the values of all measurements between the group with and without upper molars was made (Table 2). It was found that only the mean heights of the maxillary tuberosity and posterior maxilla were longer in the group with upper molar teeth than in the group without upper molar teeth (Table 2).

Discussion

The MA and its branches are most vulnerable to damage in their course through the PPF during osteotomy of the medial or lateral maxillary sinus walls, pterygomaxillary dysjunction or the down-fracturing of the maxilla[1,6,8,10]. The authors, therefore, decided to record data concerning the relationship between the MA at the PMF and the PMJ in the Thai population. In the present study, the mean distance from the most inferior point of the PMJ to the most inferior position of the MA as it entered the PPF was 23.5 ± 2.5 mm, which did not differ from that reported in Americans (25.0 ± 1.5 mm) by Turvey and Fonseca[1].

Before its entrance into the PPF, the external diameter of the MA from the present study was 2.8 ±

Table 1. Measurements of the maxillary artery and related structures, and their comparisons between genders

Measurements	Total (n = 200 sides)		Males (n = 100 sides)		Females (n = 100 sides)	
	Mean±SD (mm)	Range (mm)	Mean±SD (mm)	Range (mm)	Mean±SD (mm)	Range (mm)
PMJ-MA (A)	23.5±2.5	15.1-29.1	23.9±2.3	19.6-28.6	23.1±2.6*	15.1-29.1
MA	2.8±0.6	1.8-5.5	2.9±0.6	1.8-4.8	2.7±0.6	1.8-5.5
PMJ (B)	19.5±2.3	13.7-24.4	19.7±2.3	13.7-24.4	19.3±2.4	14.1-24.1
MT (C)	6.1±2.7	0.8-14.1	5.9±2.6	0.8-14.1	6.4±2.8	0.8-13.7
PM (B+C)	25.6±3.3	18.6-32.8	25.6±3.4	19.2-32.8	25.7±3.3	18.6-32.5

PMJ-MA: Distance from the most inferior point of the pterygomaxillary junction to the most inferior position of the maxillary artery as entering the pterygopalatine fossa. MA: External diameter of the maxillary artery as entering the pterygopalatine fossa. PMJ: Height of the pterygomaxillary junction. MT: Height of the maxillary tuberosity. PM: Height of the posterior maxilla. *Different from males at $p<0.05$.

Table 2. Comparison of the measurements of the maxillary artery and related structures between the group with and without upper molars

Measurements	With upper molars (n=85 sides)		Without upper molars (n=115 sides)	
	Mean±SD (mm)	Range (mm)	Mean±SD (mm)	Range (mm)
PMJ-MA (A)	23.2±2.8	15.1-28.5	23.8±2.3	19.1-29.1
MA	2.7±0.5	1.8-4.8	2.8±0.6	1.8-5.5
PMJ (B)	19.5±2.5	13.7-24.2	19.5±2.2	14.9-24.4
MT (C)	6.7±3.1	0.8-14.1	5.7±2.3*	0.8-12.7
PM (B+C)	26.2±3.6	18.6-32.8	25.2±3.0*	19.2-32.1

PMJ-MA: Distance from the most inferior point of the pterygomaxillary junction to the most inferior position of the maxillary artery as entering the pterygopalatine fossa. MA: External diameter of the maxillary artery as entering the pterygopalatine fossa. PMJ: Height of the pterygomaxillary junction. MT: Height of the maxillary tuberosity. PM: Height of the posterior maxilla. *Different from the group with upper molars at $p<0.05$.

0.6 mm which was consistent with that reported in Americans (2.6 ± 0.4 mm)[1] but was smaller than that reported in Koreans (3.2 ± 0.6 mm)[2]. If an artery of this diameter is damaged it is capable of producing a significant amount of hemorrhage in a short period of time[1].

In another approach, Li et al[8] exposed the pterygomaxillary region of eight fresh cadavers via the Caldwell-Luc approach and reported that the mean distance from the MA down to the nasal floor was 16.6 mm with a range of 13.0 to 21.0 mm. Because the method of approaching the MA was different in their study, it was difficult to directly compare their results with those from the present study.

Conventional techniques for mobilization of the maxilla at any Le Fort level, or mobilization of the posterior maxilla alone, require separation of the maxilla from the pterygoid plates. The instrument used for this pterygomaxillary dysjunction is a curved osteotome. The cutting end of the osteotome ranges in length from 10 to 15 mm, depending on the manufacturer. The vertical extension of pterygomaxillary dysjunction depends on the particular type of osteotomy[1]. In Le Fort III osteotomy, the entire height of the PMJ must be separated, whereas in Le Fort I osteotomy, the margin of safety can be greater if the cut in the posterior lateral maxillary wall is kept low. In the present study, the mean distance from the most inferior point of the PMJ to the most inferior position of the MA as it entered PPF was 23.5 mm, and if the length of cutting end of the osteotome is 15 mm the margin of safety for separation of the entire PMJ is approximately 8 mm. Turvey and Fonseca[1] have shown that if a pterygomaxillary osteotome was positioned correctly the margin of safety for damaging the MA with its superior edge was approximately 10 mm in adult Americans. They also established the following surgical guidelines for safely conducting pterygomaxillary dysjunction: The placement and orientation of the pterygomaxillary osteotome is crucial in avoiding damage to the main trunk of the MA. The instrument should be placed under the periosteum inferiorly in the PMJ. After placement of the osteotome at the PMJ, the inferior edge of the osteotome should be palpated from the palatal aspect to assure its proper inferior placement. The osteotome should be directed medially and anteriorly while separating the middle third of the face from its posterior attachments. Directing the osteotome superiorly should be avoided. Robinson and Hendy[10], however, reported unfavourable fractures of the pterygoid plates when a curved chisel was used to achieve the pterygomaxillary dysfunction. The fracture lines also extended upwards disrupting the integrity of the PPF which could result in damage to the MA and its branches. Hiranuma et al[11] have shown that it is safer to use a swan's-neck osteotome than a curved Obwegeser osteotome when achieving the pterygomaxillary dysjunction, as the pattern of principal strain distribution suggests that there is less risk of accidental fracture of the pterygoid plate with this osteotome. Trimble et al[12] have advocated avoiding the PMF and making the posterior osteotomy through the maxillary tuberosity itself, whereas Epker and Fish[13] and Precious et al[14,15] have proposed not using an osteotome to achieve the pterygomaxillary dysjunction to minimize the risk of damage to the MA and its branches.

Furthermore, the mean heights of the PMJ, maxillary tuberosity, and posterior maxilla were also measured in the present study. The mean height of the PMJ in Thais was 19.5 ± 2.3 mm which was longer when compared with 14.6 ± 3.1 mm reported in

Americans[1] and 12.1 ± 2.0 mm reported in Chinese[9]. Similarly, mean heights of the maxillary tuberosity (6.1 ± 2.7 mm) and posterior maxilla in Thais (25.6 ± 3.3 mm) were longer than those in Chinese (4.9 ± 1.9 mm and 17.1 ± 2.1 mm)[9]. These differences are probably due to the racial differences. When using the curved pterygoid osteotome with 15-mm cutting edge to separate the PMJ in Le Fort I osteotomy, the safety margin from the PPF is 4.5 mm in Thais. Instead, with the osteotomy through the maxillary tuberosity as recommended by Trimble et al[12], the distance from the PPF then becomes 25.6 mm as found in the present study. This procedure, therefore, would increase the safety margin on average to15.6 mm if a conventional 10 mm straight osteotome is used in the tuberosity dysjunction.

The present results found in Table 2, showed that mean heights of maxillary tuberosity and posterior maxilla were longer in the group with upper molar teeth than in the group without upper molar teeth. This data suggested that the mean heights of these structures were influenced by the presence of upper molar teeth.

Although the trunk of MA as it enters the PPF is safe during pterygomaxillary dysjunction, the posterior superior alveolar artery and the descending palatine artery are prone to be severed during Le Fort I osteotomies because of their positions[1,6]. As found in the present study, the posterior superior alveolar artery arises from the third portion of the MA before the MA enters the PMF and then lies on the posterolateral wall of the maxilla before entering the posterior superior alveolar foramen. Severing the posterior superior alveolar artery usually does not result in marked hemorrhage unless it is a large-diameter vessel [1,6]. The descending palatine artery is the most vulnerable source of bleeding during the pterygomaxillary dysjunction and the downfracture procedure due to its location in the posteromedial wall of the maxillary air sinus[1,6]. The descending palatine artery arises from the third portion of the MA in the PPF and descends in the greater palatine (pterygopalatine) canal. The descending palatine artery is usually a more important source of bleeding[1,6]. Care should be taken not to damage this vessel with an osteotome when separating the lateral wall of the nose posteriorly and the posterior wall of the maxilla medially. Even after the maxilla has been successfully downfractured, this vessel can still be injured if the maxilla is advanced to a significant degree, if the maxilla is intruded posteriorly, and particularly if the maxilla is retruded[6].

In conclusion, the present results from a study of Thais demonstrate that pterygomaxillary dysjunction can be conducted safely and without damage to the MA and causing hemorrhage. To avoid damage to the MA, the osteotome should be placed inferiorly in the PMJ and directed medially and anteriorly. Directing the osteotome superiorly should be avoided. When properly placed, the margin of safety from the superior cutting edge of an osteotome with a 15-mm cutting edge to the MA is approximately 8 mm in Thai adults.

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การศึกษาทางกายวิภาคของหลอดเลือดแดงขากรรไกรบนที่รอยแยกเทอริโกแมกซิลลาในคนไทยกลุ่มหนึ่ง: ความสัมพันธ์กับการตัดกระดูกขากรรไกรบน

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ภูมิหลัง *: หลอดเลือดแดงขากรรไกรบน (MA) และแขนงของหลอดเลือดนี้มักได้รับอันตรายขณะทำการตัดกระดูกขากรรไกรบน โดยเฉพาะในขณะแยกรอยต่อเทอริโกแมกซิลลา (PMJ)*

วัตถุประสงค์ *: เพื่อศึกษาความสัมพันธ์ระหว่าง MA ที่รอยแยกเทอริโกแมกซิลลา (PMF) และ PMJ ในคนไทย อีกทั้งทำการวัดเส้นผ่าศูนย์กลางของ MA ขณะทอดเข้าแอ่งเทอริโกแพลาทีน (PPF) และวัดความสูงของ PMJ ปุ่มขากรรไกรบนและขากรรไกรบนส่วนหลัง*

กลุ่มตัวอย่างและวิธีการวิจัย *: ทำการศึกษาในทั้งสองด้านของร่างอาจารย์ใหญ่คนไทยจำนวน 100 คน (เพศชาย 50 คนและเพศหญิง 50 คน) ที่มีอายุเฉลี่ย 64.5 $\pm$ 12.8 ปี ทำการชำแหละโดยเข้าจากด้านข้างของแอ่งใต้ขมับเพื่อหาแขนงของส่วนที่สามของ MA, PMJ และส่วนหลังของด้านข้างของขากรรไกรบน จากนั้นทำการวัด 1) ระยะระหว่างจุดล่างสุดของ PMJ ไปยังตำแหน่งล่างสุดของ MA ขณะทอดเข้า PPF 2) วัดเส้นผ่าศูนย์กลางภายนอกของ MA ขณะทอดเข้า PPF และ 3) วัดความสูงของ PMJ ปุ่มขากรรไกรบน และขากรรไกรบนส่วนหลัง*

ผลการวิจัย *: MA ทอดเข้า PPF โดยอยู่เหนือต่อตำแหน่งล่างสุดของ PMJ เป็นระยะทางเฉลี่ยเท่ากับ 23.5 $\pm$ 2.5 มม. ค่าเฉลี่ยของเส้นผ่าศูนย์กลางภายนอกของ MA ขณะทอดเข้า PPF เท่ากับ 2.8 $\pm$ 0.6 มม. ความสูงเฉลี่ยของ PMJ ปุ่มขากรรไกรบน และขากรรไกรบนส่วนหลังมีค่าเท่ากับ 19.5 $\pm$ 2.3 มม. 6.1 $\pm$ 2.7 มม. และ 25.6 $\pm$ 3.3 มม. ตามลำดับ ไม่พบความแตกต่างกันอย่างมีนัยสำคัญทางสถิติทั้งในระหว่างด้านและเพศ ยกเว้นระยะระหว่างจุดล่างสุดของ PMJ และตำแหน่งล่างสุดของ MA ขณะทอดเข้า PPF ที่พบในเพศชายยาวกว่าในเพศหญิง ($p < 0.05$)*

สรุป *: MA ทอดเข้า PPF โดยอยู่เหนือต่อขอบล่างของ PMJ เป็นระยะทางเฉลี่ยเท่ากับ 23.5 มม. ดังนั้นการผ่าตัดแยก PMJ สามารถกระทำได้อย่างปลอดภัยและไม่ทำอันตรายต่อ MA โดยใช้มีดตัดกระดูกที่มีคมมีดยาว 15 มม. ซึ่งเมื่อวางมีดอย่างถูกต้อง ขอบบนของคมมีดจะอยู่ห่างจาก MA ประมาณ 8 มม. ในผู้ใหญ่*