

A study on branching pattern of branches of middle meningeal artery based on meningeal grooves present in the cranial cavity in south Indian dry skulls

Running title: Analysing the branching pattern of branches of middle meningeal artery based on meningeal grooves present in the cranial cavity

## Abstract:

### Aim:

To study the branching pattern of branches of the middle meningeal artery based on meningeal grooves present in the cranial cavity.

### Introduction:

Middle meningeal artery is the major human dural artery. It is a neurologically very important artery for treatment and study of various neural health problems. Its origin and course can vary a lot in relation with embryological development. Complex sequences of MMA gives many opportunities for variant anatomy. It is clinically very important.

**Comment [s1]:** Mention here that you will use MMA for it throughout in brackets

### Materials and methods:

In this study we decided to investigate the anatomical organisation of the MMA, its branching pattern by taking south indian human dry skulls (N=30). It can be easily traced next to foramen spinosum. The statistical analysis was performed using the t-test calculator.

**Comment [s2]:** Grammar (should be give and not gives)

### Result:

Most of the skulls had its middle branch of MMA from the anterior branch. There were many variations observed in the branching pattern.

### Conclusion;

The branching pattern had many anatomical variations, which differed from one skull to another. The future scope of this study is to analyse skulls of people from different ethnical groups, observe the variations and trace the correlations.

**Comment [s3]:** Why only this?

### Keywords:

Middle meningeal artery, variant anatomy, dry skull, neurological importance, foramen spinosum.

**Comment [s4]:** Please correct the grammar, punctuation, capitalization of proper nouns, etc.,

## Introduction:

The knowledge of the anatomical organisation of the middle meningeal artery (MMA) is of great importance in surgery and radiology.(1–4) This artery and its branches have implications in the pathophysiology of migraine by theories suggesting neurogenic information or cranial vasodilation(5,6) (7). Detailed information of MMA helps in surgeries like bypass(8) (9). MMA Originates from maxillary artery, predominantly periosteal, irrigating bone and dura matter(10)(11,12)(13–15).It enters the floor of middle cranial fossa through foramen spinosum, travels latterly through a middle fossa bony ridge and curves anteriorly over upper greater a wing of sphenoid where it divides into frontal and parietal branch.(16,17) Frontal branch is located in a Bonny tunnel and is susceptible to tearing during trauma and this can produce many neurological disorders (18,19). Awareness of these anatomic variations become important for surgeons to reduce risk of complication during surgical repair. Rupture of this artery at pterion leads to epidural haematoma(20) (21). The MMA plays some important role in treatment of many diseases and recurrent chronic subdural haematoma (CDSH) (22–25). In this research we will try to find various anatomical variations in the branching pattern of MMA.

## Materials and methods:

The present study analysed 30 adult dry skulls from a private dental College in Chennai. Only skulls that had bony tunnels and grooves formed from the MMA on either side were used. The statistical analysis was performed using the t-test calculator.

## Tracing of the MMA:

**Comment [s5]:** Please correct how you are putting in text citations. Full stop before or after? Follow journal instructions

**Comment [s6]:** So?

**Comment [s7]:** Citation format

**Comment [s8]:** How will you link migraine pathophysiology with all of this? Do you have evidence? Can you explain further and link?

**Comment [s9]:** Citation format

**Comment [s10]:** Why is this capitalized?

**Comment [s11]:** Citation format

**Comment [s12]:** Citation format

**Comment [s13]:** show this in figure/illustration format

**Comment [s14]:** only?

**Comment [s15]:** Citation format

**Comment [s16]:** Explain here why and specifically how your research is contributing to existing literature. Expand the scope a bit

**Comment [s17]:** Why is this capitalized?

**Comment [s18]:** Mention software name, model/year, etc. was it via graph pad?

**Comment [s19]:** Give proper method (s) of specimen/sample collection, procedure, mention approvals (overall process), exclusion and inclusion criteria should have more info

The MMA was first traced by finding out the foramen spinosum. From the foramen spinosum the anterior and posterior division of the artery divides, close observation of the traces gives us the arisal branch of MMA either from anterior or posterior branch.



**Fig 1**



**Fig 2**

**Fig 1 & 2: Shows the tracing procedure of the branching pattern of middle meningeal artery**

#### Statistical analysis:

The statistical analysis was performed using the t-test calculator. The comparison between the morphometric organisation of the right and left MMA from each skull were performed using a paired t test. The P value of 0.05 or less was considered significant in all statistical tests performed at 95% confidence interval.

#### Results:

The present study observed that by analysing the 30 skulls the branching pattern of each side was analysed and a table with the cumulative data is plotted below (Table 1). From this table the study inferred that the majority of middle branch of MMA has arisen from the anterior branch than the posterior one. In which figure 3, 4, 5 represent the exceptions or the rare anatomical

**Comment [s20]:** Why are figures in methodology? I don't see any captions of fig 1 and fig 2 in methods. Either add them or remove figures from this section

**Comment [s21]:** Observed what? Don't just write analyzing

**Comment [s22]:** Rephrase. Wrong English

**Comment [s23]:** Rephrase

variations among the 30 skulls analysed. Figure 3 represents a dry skull with 2 posterior branches on each side and figure 4 represents a dry skull with a very larger artery size than the normal ones. Figure 5 represents a dry skull which has two different branching patterns on either side of it. Figure 6, 7 represents a dry skull where the anterior branch has formed a bonny tunnel. A p value of 0.5 was obtained which shows there is no significance between the differences observed in the right and left sides for the 30 dry skulls.

**TABLE 1: Shows the number of the middle branches of MMA branching from anterior and posterior branches on each side.**

SIDE	ANTERIOR	POSTERIOR
RIGHT	19	11
LEFT	23	7





Fig4: Skull with large groove size



Fig 5: Skull with different branching pattern on both sides

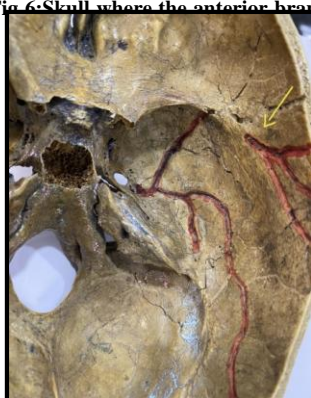
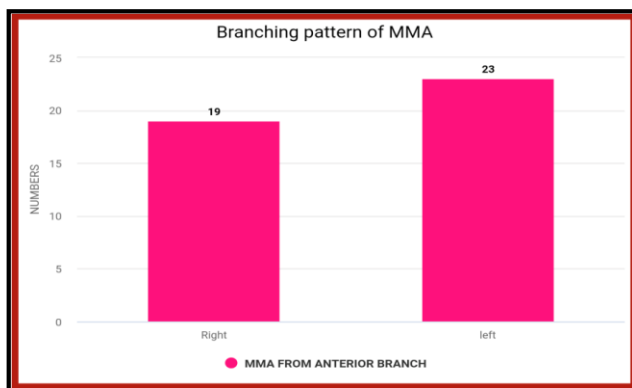
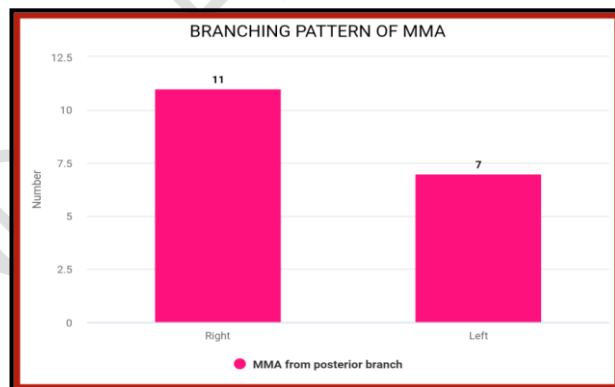


Fig 6: Skull where the anterior branch forms



Graph 1 shows the number of middle branches of MMA arising from the anterior branch on right and left sides. Y axis represents the number of skulls showing the mentioned pattern. X axis shows the respective sides whether left or right.



Graph 2 shows the number of middle branches of MMA arising from the posterior branch on right and left sides. Y axis represents the number of skulls showing the mentioned pattern. X axis shows the respective sides whether left or right.

**Comment [s24]:** Change how you are showing this result. Make a table instead

## Discussion:

In the present study we investigated the branching pattern of MMA either from anterior or posterior branch, a similar study where morphological and histological features of the bony canal through which the MMA passes was examined. The study observed that the middle meningeal grooves were deepened and gradually enveloped the MMA. The collagen tissues of the outer dural layer continued into the bony canal with the MMA and was seen in histological study (26). A similar morphometric analysis of the bony canal in the human skull which measured the lengths of frontal and parietal branches of the bony canal to view the anatomical variations (27)).

**Comment [s25]:** Reference?

**Comment [s26]:** How does this relate to what you found? Can you make a logical collection?

One more study of the functional and morphological pattern of MMA, its embryological differences were done to observe variations (28). The artery which surrounds the middle meningeal artery is the auriculo temporal artery, it arises from a complex embryological origin which is the reason for many anatomical variations (29). The importance of MMA in surgical revascularization. MMA can be injured easily if it passes through the bony canal, its morphological and histological features were studied to improve surgical results (26).

**Comment [s27]:** Rephrase

**Comment [s28]:** How does it fit within your scope? Please relate and make a logical flow

Chronic subdural hematoma (cSDH) is caused due to trauma which results in the injury of pterion which is right behind the temple, it is the thinnest part of the skull, where 4 types of bones come in contact. Underneath this lies the anterior region of MMA, thus it is often injured leading to cSDH (30). This disease is said to be more common among the elderly people. MMA embolization offers the potential for a minimally invasive less morbid treatment in this age group (31). The frontal branch of the MMA embedded in bony canal is currently omitted both in anatomical nomenclature, in this study we observed bony canal formation in few skulls out of the total similar to the study done by (32), where they studied the incidence and morphometry of the MMA bony canal and grooves on the skull base. In the present study we obtained the anatomical variations of the MMA, it's different branching patterns.

**Comment [s29]:** It doesn't connect with your results at all. Wrong choice of studies and not properly detailed

However the limitation of this present study should be acknowledged, first the age, race, gender etc of the 30 dry skulls is unknown, therefore correlation of the branching pattern with age, gender etc cannot be done. The future scope of this study is to collect dry skulls from different

parts of the world, from people belonging to different ethnical groups and also analyse the correlation of the branching pattern with age, gender, descendants, etc.

**Comment [s30]:** Don't abruptly jump to limitation. Why are you using however here?

### Conclusion:

The branching pattern of MMA shows variations in the region of branching, point of branching, thus the study concludes by saying there is anatomical variation in the branching pattern of MMA from person to person. Thus the present study concluded that studying branching patterns of MMA in the cranial cavity is an important parameter in anatomical studies, anthropometric studies, etc.

**Comment [s31]:** Weak conclusion. Not insightful

### REFERENCES:

1. Sekar D, Lakshmanan G, Mani P, Biruntha M. Methylation-dependent circulating microRNA 510 in preeclampsia patients. *Hypertens Res*. 2019 Oct;42(10):1647–8.
2. Princeton B, Santhakumar P, Prathap L. Awareness on Preventive Measures taken by Health Care Professionals Attending COVID-19 Patients among Dental Students. *Eur J Dent*. 2020 Dec;14(S 01):S105–9.
3. Barma MD, Muthupandiyar I, Samuel SR, Amaechi BT. Inhibition of Streptococcus mutans, antioxidant property and cytotoxicity of novel nano-zinc oxide varnish. *Arch Oral Biol*. 2021 Jun;126:105132.
4. Vijayashree Priyadharsini J. In silico validation of the non-antibiotic drugs acetaminophen and ibuprofen as antibacterial agents against red complex pathogens. *J Periodontol*. 2019 Dec;90(12):1441–8.
5. Logeshwari R, Rama Parvathy L. Generating logistic chaotic sequence using geometric pattern to decompose and recombine the pixel values [Internet]. Vol. 79, *Multimedia Tools and Applications*. 2020. p. 22375–88. Available from: <http://dx.doi.org/10.1007/s11042-020-08957-9>
6. Priyadharsini JV, Vijayashree Priyadharsini J, Smiline Girija AS, Paramasivam A. In silico analysis of virulence genes in an emerging dental pathogen *A. baumannii* and related species [Internet]. Vol. 94, *Archives of Oral Biology*. 2018. p. 93–8. Available from: <http://dx.doi.org/10.1016/j.archoralbio.2018.07.001>
7. Dian J, Linton J, Shankar JJ. Risk of recurrence of subdural hematoma after EMMA vs surgical drainage - Systematic review and meta-analysis. *Interv Neuroradiol*. 2021 Feb 1;1591019921990962.



8. Johnson J, Lakshmanan G, M B, R M V, Kalimuthu K, Sekar D. Computational identification of MiRNA-7110 from pulmonary arterial hypertension (PAH) ESTs: a new microRNA that links diabetes and PAH. *Hypertens Res.* 2020 Apr;43(4):360–2.
9. Fiorella D, Hirsch JA, Arthur AS. Embolization of the middle meningeal artery for the treatment of chronic subdural hematoma: considerations for pragmatic trial design. *J Neurointerv Surg* [Internet]. 2021 Mar 5; Available from: <http://dx.doi.org/10.1136/neurintsurg-2021-017458>
10. Paramasivam A, Priyadharsini JV, Raghunandhakumar S, Elumalai P. A novel COVID-19 and its effects on cardiovascular disease. *Hypertens Res.* 2020 Jul;43(7):729–30.
11. Pujari GRS, Subramanian V, Rao SR. Effects of *Celastrus paniculatus* Willd. and *Sida cordifolia* Linn. in Kainic Acid Induced Hippocampus Damage in Rats [Internet]. Vol. 53, *Indian Journal of Pharmaceutical Education and Research.* 2019. p. 537–44. Available from: <http://dx.doi.org/10.5530/ijper.53.3.86>
12. Rajkumar KV, Lakshmanan G, Sekar D. Identification of miR-802-5p and its involvement in type 2 diabetes mellitus. *World J Diabetes.* 2020 Dec 15;11(12):567–71.
13. Uma Maheswari TN, Nivedhitha MS, Ramani P. Expression profile of salivary micro RNA-21 and 31 in oral potentially malignant disorders. *Braz Oral Res.* 2020 Feb 10;34:e002.
14. Gudipani RK, Alam MK, Patil SR, Karobari MI. Measurement of the Maximum Occlusal Bite Force and its Relation to the Caries Spectrum of First Permanent Molars in Early Permanent Dentition. *J Clin Pediatr Dent.* 2020 Dec 1;44(6):423–8.
15. Chaturvedula BB, Muthukrishnan A, Bhuvaraghan A, Sandler J, Thiruvenkatachari B. *Dens invaginatus*: a review and orthodontic implications. *Br Dent J.* 2021 Mar;230(6):345–50.
16. Ravisankar R, Jayaprakash P, Eswaran P, Mohanraj K, Vinitha G, Pichumani M. Synthesis, growth, optical and third-order nonlinear optical properties of glycine sodium nitrate single crystal for photonic device applications [Internet]. Vol. 31, *Journal of Materials Science: Materials in Electronics.* 2020. p. 17320–31. Available from: <http://dx.doi.org/10.1007/s10854-020-04288-5>
17. Wu S, Rajeshkumar S, Madasamy M, Mahendran V. Green synthesis of copper nanoparticles using *Cissus vitifolia* and its antioxidant and antibacterial activity against urinary tract infection pathogens [Internet]. Vol. 48, *Artificial Cells, Nanomedicine, and Biotechnology.* 2020. p. 1153–8. Available from: <http://dx.doi.org/10.1080/21691401.2020.1817053>
18. Shotar E, Premat K, Lenck S, Degos V, Marijon P, Pouvelle A, et al. Angiographic Anatomy of the Middle Meningeal Artery in Relation to Chronic Subdural Hematoma Embolization. *Clin Neuroradiol* [Internet]. 2021 Feb 24; Available from: <http://dx.doi.org/10.1007/s00062-021-00996-5>
19. Vikneshan M, Saravanakumar R, Mangaiyarkarasi R, Rajeshkumar S, Samuel SR, Suganya

M, et al. Algal biomass as a source for novel oral nano-antimicrobial agent. *Saudi J Biol Sci*. 2020 Dec;27(12):3753–8.

20. Alharbi KS, Fuloria NK, Fuloria S, Rahman SB, Al-Malki WH, Javed Shaikh MA, et al. Nuclear factor-kappa B and its role in inflammatory lung disease. *Chem Biol Interact*. 2021 Aug 25;345:109568.
21. Natali AL, Reddy V, Leo JT. Neuroanatomy, Middle Meningeal Arteries. In: StatPearls. Treasure Island (FL): StatPearls Publishing; 2020.
22. Okuma Y, Hirotsune N, Sotome Y, Kegoya Y, Matsuda Y, Sato Y, et al. Middle meningeal artery embolization for chronic subdural hematoma with cerebrospinal fluid hypovolemia: a report of 2 cases. *Neurochirurgie* [Internet]. 2021 Mar 2; Available from: <http://dx.doi.org/10.1016/j.neuchi.2021.02.008>
23. Rao SK, Kalai Priya A, Manjunath Kamath S, Karthick P, Renganathan B, Anuraj S, et al. Unequivocal evidence of enhanced room temperature sensing properties of clad modified Nd doped mullite Bi<sub>2</sub>Fe<sub>4</sub>O<sub>9</sub> in fiber optic gas sensor [Internet]. Vol. 838, *Journal of Alloys and Compounds*. 2020. p. 155603. Available from: <http://dx.doi.org/10.1016/j.jallcom.2020.155603>
24. Bhavikatti SK, Karobari MI, Zainuddin SLA, Marya A, Nadaf SJ, Sawant VJ, et al. Investigating the Antioxidant and Cytocompatibility of Linn Extract over Human Gingival Fibroblast Cells. *Int J Environ Res Public Health* [Internet]. 2021 Jul 4;18(13). Available from: <http://dx.doi.org/10.3390/ijerph18137162>
25. Marya A, Karobari MI, Selvaraj S, Adil AH, Assiry AA, Rabaan AA, et al. Risk Perception of SARS-CoV-2 Infection and Implementation of Various Protective Measures by Dentists Across Various Countries. *Int J Environ Res Public Health* [Internet]. 2021 May 29;18(11). Available from: <http://dx.doi.org/10.3390/ijerph18115848>
26. Fujimoto M, Otsuka N, Ezure H, Moriyama H, Inoue Y, Mori R. Intracranial Bony Canal of the Middle Meningeal Artery - Morphological and Histological Analysis. *Okajimas Folia Anat Jpn*. 2017;93(4):119–25.
27. Honnegowda TM, Dineshan V, Kumar A. Morphometry of organization of middle meningeal artery through the analysis of bony canal in human's skull: A clinico-anatomical and embryological insight. *J Craniovertebr Junction Spine*. 2019 Apr;10(2):127–30.
28. Bonasia S, Smajda S, Ciccio G, Robert T. Middle Meningeal Artery: Anatomy and Variations. *AJNR Am J Neuroradiol*. 2020 Oct;41(10):1777–85.
29. Kulkarni N. Middle Meningeal Artery [Internet]. *Clinical Anatomy for Students: Problem Solving Approach*. 2006. p. 369–369. Available from: [http://dx.doi.org/10.5005/jp/books/10116\\_86](http://dx.doi.org/10.5005/jp/books/10116_86)
30. Moshayedi P, Liebeskind DS. Middle Meningeal Artery Embolization in Chronic Subdural Hematoma: Implications of Pathophysiology in Trial Design. *Front Neurol*. 2020 Aug

27;11:923.

31. Joyce E, Bounajem MT, Scoville J, Thomas AJ, Ogilvy CS, Riina HA, et al. Middle meningeal artery embolization treatment of nonacute subdural hematomas in the elderly: a multiinstitutional experience of 151 cases. *Neurosurg Focus*. 2020 Oct;49(4):E5.
32. Eberlova L, Pisova S, Papezova L, Mirka H, Hosek P, Steflova M, et al. Bony canal and grooves of the middle meningeal artery: mythic structures in anatomy and neurosurgery? *Folia Morphol* . 2020;79(3):450–61.