

Original Research Article

Anatomical Observation of Different Shapes of Foramen Magnum and Its Clinical Implications: A Study in Dry Adult Human Skulls of Indian Population

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ABSTRACT

Background: Understanding of thoroughly explained anatomical basis is must for various surgical approaches at the craniovertebral junction. High mortality and morbidity are anticipated during the surgical procedures when undertaken without in depth anatomical knowledge. With so much clinical importance in this area, our study will present a thorough understanding in terms of skull.

Objectives: The aim of the present study is to evaluate the various shapes of foramen magnum in dry adult human skulls of Indian population and to find out their clinical correlation.

Materials and methods: 347 dried adult human skull base obtained from the Department of Anatomy, Geetanjali Medical College and Hospital, Udaipur, Rajasthan and other medical colleges were used in the present study. All the dry adult human skulls were observed from outer side at their base by naked eyes to determine the shape of foramen magnum. It was classified into one of the following shapes: - Oval, round, tetragonal, egg shaped, hexagonal, pentagonal and irregular.

Results: The shape of the foramen magnum in dry skulls were oval in 44.95%, round in 30.84%, hexagonal in 9.23%, irregular in 6.63%, pentagonal in 5.19%, tetragonal in 1.73 %, and egg shaped in 1.44%.

Conclusion: Inferences of the present study in the form of variations in the shapes of foramen magnum will be useful to the neurosurgeons, radiologists, orthopedics, anthropologists, forensic experts as well as anatomists. Further these data can be used as an anatomical reference for the researchers.

KEY WORDS: Human Skull, Shape, Foramen Magnum.

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Access this Article online	Journal Information	
Quick Response code  DOI: 10.16965/ijar.2022.189	International Journal of Anatomy and Research ISSN (E) 2321-4287 ISSN (P) 2321-8967 https://www.ijmhr.org/ijar.htm DOI-Prefix: https://dx.doi.org/10.16965/ijar	
	Article Information Received: 13 May 2022 Peer Review: 17 May 2022 Revised: 02 Jun 2022 Accepted: 27 Jul 2022 Published (O): 05 Sep 2022 Published (P): 05 Sep 2022	

INTRODUCTION

The English word "skull" is derived from "skulle" which means head [1]. Familiarity of

the detailed knowledge of the morphological variations in the foramina of skull base as well as their morphometrical values are vital to

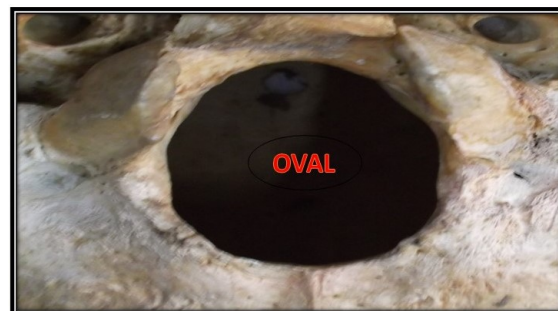
perform safe radical surgical procedures as well as interventional diagnostic procedures [2]. Vital structures passing through the foramen magnum are affected by the variations in shape of foramen magnum. Irregular shape of foramen magnum is featured by the formative cranial anomalies [3]. Occipital bone anterior to the foramen magnum develops from the basioccipital portion, posterior to the foramen magnum develops from supraoccipital portion and lateral to the foramen magnum develops from exoccipital portion of the chondrocranium. Development of a particular shape of the foramen magnum is explained on the basis of the embryologic data. It may be caused by ossification of primordial cranial residues, which join the endochondral ossification points in different locations, resulting in various shapes [4]. Irregular shape of foramen magnum is accentuated by the developmental anomalies of the bone and soft tissues at the craniovertebral junction [5]. Due to high chances of morbidity and mortality during various surgical procedures at the skull base, this area is having higher clinical importance. The present study was done to evaluate the various shapes of foramen magnum in dry adult human skulls of Indian population and to find out their clinical correlation.

MATERIALS AND METHODS

Present study was conducted on 347 dried adult human skull base obtained from the Department of Anatomy, Geetanjali Medical College and Hospital, Udaipur, Rajasthan and other medical colleges (GSVM medical college, Kanpur, Uttar Pradesh and King George's medical university, Lucknow, Uttar Pradesh) after taking necessary institutional ethical approval, during the year 2015 to 2018. Fractures or damaged skulls, skulls with congenital malformations or deformities or having previous trauma were excluded from the study. Fully ossified adult skulls were included in the present study. All the dry adult human skulls were observed from outer side at their base by naked eyes to determine the shape of foramen magnum. The shapes of foramen magnum were classified into one of the following: Oval, round, tetragonal, egg

shaped, hexagonal, pentagonal and irregular. The findings of the present study were tabulated and graphed by using Microsoft Office Excel 2019.

RESULTS



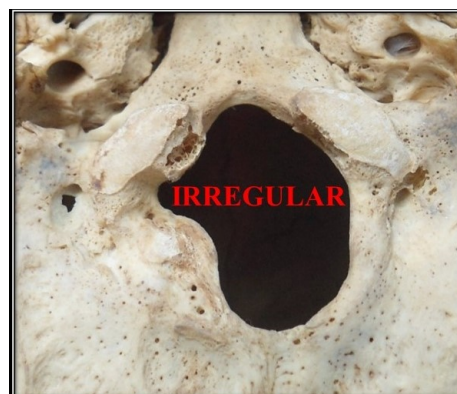
Photograph 1: Posterior part of base skull showing 'oval shape' of FM.



Photograph 2: Posterior part of base skull showing 'round shape' of FM.



Photograph 3: Posterior part of base skull showing 'hexagonal shape' of FM.



Photograph 4: Posterior part of base skull showing 'irregular shape' of FM.



Photograph 5: Posterior part of base skull showing 'pentagonal shape' of FM.



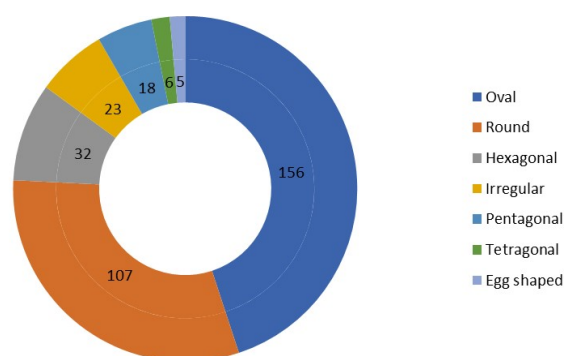
Photograph 6: Posterior part of base skull showing 'tetragonal shape' of FM.



Photograph 7: Posterior part of base skull showing 'egg shaped' of FM.

Table 1: Showing the frequency and percentages of various shapes of foramen magnum in the present study.

Sr No	Shapes of foramen magnum	Number of specimen (Out of total 347)	Percentage
1	Oval	156	44.95
2	Round	107	30.84
3	Hexagonal	32	9.22
4	Irregular	23	6.63
5	Pentagonal	18	5.19
6	Tetragonal	6	1.73
7	Egg shaped	5	1.44



Graph 1: Graph showing the frequency of various shapes of foramen magnum in the present study.

As shown in Table 1 and graph 1, various shapes of foramen magnum in 347 dry adult human skulls in the present study were as follows:

The most common shape of foramen magnum was oval in 156 out of 347 skulls (44.95%) (Photograph 1). The least common shape of foramen magnum was egg shaped in 5 out of 347 skulls (1.44%) (Photograph 7). The round shape of foramen magnum was observed in 107 out of 347 skulls (30.84%) (Photograph 2). The hexagonal shape of foramen magnum was observed in 32 out of 347 skulls (9.22%) (Photograph 3). The irregular shape of foramen magnum was observed in 23 out of 347 skulls (6.63%) (Photograph 4). The pentagonal shape of foramen magnum was observed in 18 out of 347 skulls (5.19%) (Photograph 5). The tetragonal shape of foramen magnum was observed in 6 out of 347 skulls (1.73 %) (Photograph 6).

DISCUSSION

The foramen magnum is the largest foramen of the skull, which is located in the most inferior portion of the cranial fossa and it is a part of the occipital bone [6]. Several anatomical parameters such as shape, size and orientation of the foramen magnum should be taken into consideration during surgery involving the posterior and lateral craniovertebral junctions. The quantitative data may be useful in planning the degree of bone work required for optimum exposure of the surgical field and minimization of the risks of morbidity [4].

In the present study, the most common shape of FM in Indian population was oval (156 out

Table 2: Showing comparison of percentage (%) of different shapes of foramen magnum (Indian Authors).

Sr No	Authors	Sample size	Round	Oval	Irregular	Tetragonal	Hexagonal	Pentagonal	Egg shaped
1	Muthukumar N et al [25]	50	54	46	NA	NA	NA	NA	NA
2	Chethan P et al [5]	53	22.6	15.1	15.1	18.9	5.6	3.8	18.6
3	Radhikrishna SK et al [32]	100	28	39	NA	19	NA	14	NA
4	Radhika PM et al [27]	150	20	40	16	6	6	2	10
6	Ganapathy A et al [28]	100	9	52	22	17	9	NA	NA
7	Ajay R et al [26]	210	35	60	33	22	10	5	25
8	GopalaKrishana K et al [29]	55	25	41	20	14	NA	NA	NA
9	Saini K [8]	98	19	44	14	21	NA	NA	NA
10	Riyaz ZH et al [13]	61	29.5	31.14	11.47	18.03	8.19	1.63	NA
11	Sharma S et al [30]	50	22	16	18	12	8	8	16
12	Krishna K et al [10]	34	8.82	58.8	2.94	17.6	11.8	NA	NA
13	Fathima F et al [31]	53	13	26	NA	NA	21	4	NA
14	Singh K C [14]	50	20	34	8	16	18	4	NA
15	Chandekar K S et al [24]	80	30.43	41.3	28.26	NA	NA	NA	NA
16	Devadas P et a [7]	100	29	45	NA	14	NA	12	NA
17	Remya K et al [9]	50	16	46	2	20	2	NA	NA
18	Bhaskar R et al [11]	50	16	48	NA	30	6	NA	NA
19	Sampada P K et al [12]	100	9	58	10	8	3	1	11
20	Veeramani R et al [15]	100	15	6	32	11	21	3	12
21	Revankar S et al [21]	40	17.5	22.5	12.5	12.5	10	12.5	12.5
22	Sharma DK et al [22]	75	14.67	22.67	10.67	14.67	16	9.33	12
23	Sharma A et al [23]	50	3.9	15.7	5.9	17.6	45.1	3.9	5.9
24	Present study	347	30.84	44.95	6.63	1.73	9.22	5.19	1.44

Table 3: Showing comparison of percentage (%) of different shapes of foramen magnum (International Authors).

Sr No	Authors	Population	Sample size	Round	Oval	Irregular	Tetragonal	Hexagonal	Pentagonal	Egg shaped
1	Natsis K et al [18]	Greek	143	1.4	14.7	0.7	NA	NA	NA	21
2	Aragão JA et al [19]	Brazil	110	15.5	5.5	6.4	10.9	9.1	2.7	NA
3	Kumar A et al [16]	Oman	36	20	50	16	6	8	NA	NA
4	Pires LA et al [17]	Brazil	77	24.67	53.24	16.88	16.88	1.29	1.29	2.36
5	Ilhan P et a [20]	Turkey	100	6	10	22	24	21	2	12
6	Present study	Indian	347	30.84	44.95	6.63	1.73	9.22	5.19	1.44

[*NA- Not applicable]

of 347 skulls- 44.95%), which is almost similar to the findings obtained by Devadas Pet al[7](2017) in 45%, Saini K[8](2015) in 44% and Remya K et al[9](2017) in 46% cases; lower than the findings of Krishna K et al[10] (2016) in 58.8%, Bhaskar R et al[11](2017) in 48%, SampadaP.K et al[12] (2017) in 58%, Kumar A et al[16] (2015) in 50% and Pires LAet al[17](2016) in 53.24% cases; higher than the findings of Riyaz ZHet al[13](2015) in 31.14%, Singh KC et al[14](2017) in 34%, Veeramani Ret al[15](2018) in 6%, Natsis K. et al[18](2013) in 14.7%, Aragão JA et al[19](2014) in 5.5%, Ilhan Pet al[20](2017) in 10 %, Revankar S et al[21] in 22.5%, Sharma DK et al[22] in 22.67% and Sharma A et al[23] in 15.7% cases (Table 1 & 2). These differences may be due to racial variations, genetic differences or individual variations in recording the shape of foramen magnum.

In the present study, round shape foramen magnum was found in 30.84% cases (107 out of 347 skulls). The value of this study was almost similar to the values of studies done by Riyaz ZH et al[13](2015) in 29.50% and Chandekar KS et al[24](2017) in 30.43 % cases; lower than the findings of Muthukumar N et al[25](2005) in 54% and Ajay R et al[26] (2015) in 35% cases; higher than the findings of Chethan P et al[5](2012) in 22.6%, Radhika PM et al[27] (2014) in 20%, Ganapathy A et al[28](2014) in 9%, Gopalkrishana K et al[29] (2015) in 25%, Saini K[8](2015) in 19%, Bhaskar R et al[11] (2017) in 16%, Veeramani R et al[15] (2018) in 15%, Aragão JA et al[19](2014) in 15.5%, Kumar A et al[16](2015) in 20%, Pires LA et al[17] (2016) in 24.67%, Revankar S et al[21] in 17.5%, Sharma DK et al[22] in 14.67% and Sharma A et al[23] in 3.9% cases. (Table1 & 2) This difference may be due to population variation.

In the present study, hexagonal shape of foramen magnum was in 9.22% cases (32 out of 347 skulls). The finding of the present study is almost similar to the studies done by Ganapathy A et al[28] (2014) in 9%, Riyaz ZH et al[13] (2015) in 8.19%, Sharma Set al[30](2015) in 8%, Ajay Ret al[26](2015) in 10%, Aragão JA et al[19](2014) in 9.1%, Revankar S et al[21] in 10% and Kumar A et al[16] (2015) in 8 % cases; lower than the finding of Krishna K et al[10](2016) in 11.8 %, Fathima F et al[31] (2016) in 21%, Veeramani R et al[15](2018) in 21%, Ilhan P et al[20] (2017) in 21%, Sharma DK et al[22] in 16% and Sharma A et al[23] in 45.1% cases; higher than the finding of Pires LA et al[17](2016) in 1.29% cases. (Table 1 & 2) These differences could be due to inter observer variation.

In the present study, irregular shape foramen magnum was found in 6.63% cases (23 out of 347 skulls) in Indian population. This value is almost similar to the study done by Singh KC et al[14] (2017) in 8%, Aragão JA et al[19](2014) in 6.4% and Sharma A et al[23] in 5.9% cases; lower than the findings of Chethan P et al[5](2012) in 15.1%, Sampada PK et al[12](2017) in 10%, Ganapathy A et al[28] (2014) in 22%, Riyaz ZH et al[13](2015) in 11.47%, Veeramani R et al[15] (2018) in 32%, Kumar A et al[16](2015) in 16%, Pires LA et al[17](2016) in 16.88%, Ilhan P et al[20](2017) in 22%, Revankar S et al[21] in 12.5% and Sharma DK et al[22] in 10.67% cases; higher than the values of Krishna K et al[10](2016) in 2.94%, Remya K et al[9](2017) in 2% and Natsis K et al[18](2013) in 0.7% cases. (Table 1 & 2) This is because in their studies, all the foramen magnum which could not be classified into any shape was grouped as irregular shaped foramen magnum. Hence, they have a higher percentage of irregular shape compared to present study.

In the present study, pentagonal shape of foramen magnum was in 5.19% cases (18 out of 347 skulls). The finding of the present study is almost similar to the studies done by Ajay Ret al[26] (2015) in 5% cases; higher than the finding of Fathima F et al[31](2016) in 4%, Chethan P et al[5](2012) in 3.8%, Radhika PM et al[27](2014) in 2%, Sampada PK et al[12]

(2017) in 1%, Pires LA et al[17](2016) in 1.29%, Aragão JA et al[19](2014) in 2.7%, Ilhan P et al[20](2017) in 2% and Sharma A et al[23] in 3.9% cases; lower than the finding of Radhikrishna SK et al[32](2012) in 14%, Sharma Set al[30](2015) in 8%, Devadas P et al[7](2017) in 12%, Revankar S et al[21] in 12.5% and Sharma DK et al[22] in 9.33% cases (Table 1 & 2).

In the present study, tetragonal shape of foramen magnum was in 1.73% cases (06 out of 347 skulls). The finding of the present study is lower than the findings of Radhika PM et al[27](2014) in 6%, Bhaskar R et al[11](2017) in 30%, Veeramani R et al[15](2018) in 11%, Kumar A et al[16](2015) in 6 %, Aragão JA et al[19](2014) in 10.9%, Pires LA et al[17](2016) in 16.88%, Ilhan P et al[20](2017) in 24% and Revankar S et al[21] in 12.5%, Sharma DK et al[22] in 14.67% and Sharma A et al[23] in 17.6% cases. (Table 1 & 2) These higher percentages may be due to racial differences as the population in the above studies differs from population of the present study.

In the present study, egg shaped foramen magnum was in 1.44 % cases (05 out of 347 skulls). The value of the present study is lower than the finding of Chethana P et al[5](2012), in 18.6 %, Radhika PM et al[27](2014) in 10%, Sampada PK et al[12](2017) in 11%, Veeramani R et al[15](2018) in 12%, Natsis K et al[18](2013) in 21%, Ilhan P et al[20](2017) in 12%, Pires LA et al[17](2016) in 2.36%, Revankar S et al[21] in 12.5%, Sharma DK et al[22] in 12% and Sharma A et al[23] in 5.9% cases. (Table 1 & 2) As explained earlier these higher values of egg shape of foramen magnum could be due to interobserver variation or due to classification of foramen magnum into 6 shapes only.

CONCLUSION

As the various surgical approaches and the radiological diagnostic procedures have their own limitations, the analysis of various shapes of foramen magnum is utmost important. This study will become a useful guide for the surgeons, radiologists, orthopedics, anthropologists as well as forensic experts. As the present study enhances the knowledge about

various shapes of foramen magnum at the base of skulls in Indian population, the data of the present study may serve as an anatomical reference for researchers.

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Conflicts of Interests: None

REFERENCES

- [1]. White TD, Black MT, Folkens PA. Human osteology. Academic press; 2011 Jan 21.
- [2]. Keskil S, Gözil R, Çalgüner E. Common surgical pitfalls in the skull. Surgical neurology. 2003 Mar 1;59(3):228-31.
- [3]. Furtado SV, Thakre DJ, Venkatesh PK et al. Morphometric analysis of foramen magnum dimensions and intracranial volume in pediatric Chiari I malformation. Acta neurochirurgica. 2010 Feb;152(2):221-7.
- [4]. Govsa F, Ozer MA, Celik S et al. Three-dimensional anatomic landmarks of the foramen magnum for the craniovertebral junction. Journal of Craniofacial Surgery. 2011 May 1;22(3):1073-6.
- [5]. Chethan P, Prakash KG, Murlimanju BV et al. Morphological analysis and morphometry of the foramen magnum: an anatomical investigation. Turkish neurosurgery. 2012 Jan 1;22(4).
- [6]. Ficke J, Varacallo M. Anatomy, head and neck, foramen magnum. InStatPearls [Internet] 2021 Jul 31. StatPearls Publishing.
- [7]. Devadas P, Rao MJ, Yesender M et al. Study on the morphometric analysis of the foramen magnum as an indicator for sex determination. Int J Anat Res. 2017;5(3.1):4163-67.
- [8]. Saini K. A morphometric study of foramen magnum in dry adult human skull. International Journal of Current Research and Review. 2015 Feb 15;7(4):14.
- [9]. Remya K, Rathnakar P. Swathi. Evaluation of foramen magnum in dry human skulls of dakshinakannada district. Int J Anat Res. 2017;5(4):4488-91.
- [10]. Krishna K, Nag AR, Prasad R. Morphometric study of foramen magnum and variation in its shape. IOSR J. Dent. Med. Sci. 2016;15(8):120-3.
- [11]. Bhaskar R, Anjana S, Satheesha KS et al. Morphometric Analysis of Foramen Magnum in Adult Dry Skulls in Dakshina Kannada. Int J Heal Sci Pharm. 2017 Jun 30;1(1):46-52.
- [12]. Sampada PK, Poornima B, Mallikarjun M et al. Morphometric and morphological study of foramen magnum in dried human skull bones. Int J Anat Res. 2017;5(2.1):3682-86.
- [13]. Riyaz ZH, Siddiqui AA. Morphometric study of foramen magnum in human skulls. International Journal of Recent Trends in Science and Technology. October to December 2015; 5(4): 28-31
- [14]. Singh KC, Rai G, Rai R. Morphological Variations of the Foramen Magnum in Adult Human Dry Skull in Eastern UP (India) Population. Int J Med Res Prof. 2017;3(2):205-8.
- [15]. Veeramani R, Manjunath KY, Amirthalingam U. Morphological and morphometric study of variations in the shape and size of the foramen magnum of human skulls. International Journal of Anatomy Radiology and Surgery. 2018;7(2):1-8.
- [16]. Kumar A, Dave M, Anwar S. Morphometric evaluation of foramen magnum in dry human skulls. Int J Anat Res. 2015;3(2):1015-23.
- [17]. Pires LA, Teixeira ÁR, Leite TF et al. Morphometric aspects of the foramen magnum and the orbit in Brazilian dry skulls. International Journal of Medical Research & Health Sciences. 2016;5(4):34-42.
- [18]. Natsis K, Piagkou M, Skotsimara G et al. A morphometric anatomical and comparative study of the foramen magnum region in a Greek population. Surgical and Radiologic Anatomy. 2013 Dec;35(10):925-34.
- [19]. Aragão JA, de Oliveira Pereira R, de Moraes RZ et al. Morphological types of foramen magnum. Annual Research & Review in Biology. 2014 Jan 10:1372-8.
- [20]. İlhan P, Kayhan B, Ertuk M et al. Morphologic analysis of occipital condyles and foramen magnum as a guide for lateral surgical approaches. MOJ Anat Physiol. 2017;3:188-94.
- [21]. Revankar S, Naik SC, Chabbra PK, Tandon R, Sharma MD. Morphometric Analysis of Foramen Magnum Region in Adult Indian Population. European Journal of Molecular & Clinical Medicine.;7(10):2020.
- [22]. Sharma DK, Mehra S. Foramen Magnum: A Morphological and Morphometric Study in Dried Human Skull Bones of Rajasthan Population and its Surgical Importance. Journal of Mahatma Gandhi University of Medical Sciences and Technology. 2018 May;3(2):41-9.
- [23]. Sharma A, Ramandeep K, Sharma Kumar M. Foramen Magnum: morphometry, possible variation in the shape and its clinical implication. Int J Scientific Study. 2019;6(10):13-6.
- [24]. Chandekar KS, Jiwane NN. Morphometric study of foramen magnum of human skull in Vidarbha region. International Journal of Research and Review. 2017; 4(5):157-160
- [25]. Muthukumar N, Swaminathan R, Venkatesh G et al. A morphometric analysis of the foramen magnum region as it relates to the transcondylar approach. Acta neurochirurgica. 2005 Aug;147(8):889-95.
- [26]. Ajay R, Kalindi S, Bhavika P et al. Morphometry and sexual dimorphism of human skull foramen magnum. Int J Rec trend sci tech. 2015;15(2):379-86.

- [27]. Radhika PM, Shailaja S, Prathap KJ et al. Morphometric study of the foramen magnum in adult human skulls in Indian population. Asian Journal of Medical and Clinical Science. 2014;3(2):62-72.
- [28]. Ganapathy A, Sadeesh T, Rao S. Morphometric analysis of foramen magnum in adult human skulls and CT images. International Journal of Current Research and Review. 2014 Oct 15;6(20):11.
- [29]. Gopalkrishana K, Rathna BS. The craniometric study of foramen magnum of Indian population and variations in its dimensions. Int. J. of Allied Med. Sci. and Clin. Research. 2015:205-11.
- [30]. Sharma S, Sharma AK, Modi BS et al. Morphometric evaluation of the foramen magnum and variation in its shape and size: a study on human dried skull. Int J Anat Res. 2015;3(3):1399-03.
- [31]. Fathima F, Babu KY. Evaluating the shape of foramen magnum and overlapping of occipital condyle on the foramen. Int J Sci Res. 2016;5(9).
- [32]. Radhakrishna SK, Shivarama CH, Ramakrishna A et al. Morphometric analysis of foramen magnum for sex determination in South Indian population. Journal of Health and Allied Sciences NU. 2012 Mar;2(01):20-2.

How to cite this article:

R. Kumar, M. Javia, D. Agrawal, P. Manik. Anatomical Observation of Different Shapes of Foramen Magnum and Its Clinical Implications: A Study in Dry Adult Human Skulls of Indian Population. Int J Anat Res 2022;10(3):8445-8451. DOI: 10.16965/ijar.2022.189