

# Biometric analysis of the area of the foramen magnum using the ImageJ software, and its correlation with the Radinsky and Teixeira formulas

## Abstract

**Introduction:** The knowledge of biometrics in the area of the foramen magnum is of importance in the pathophysiology of several disorders of the craniocervical junction, as well as for anthropology, anatomy and forensic medicine. The analysis of the area using image technology is still very scarce in the literature.

**Objective:** Determine the area of the foramen magnum using ImageJ and correlate it with the areas calculated by the formulas of Radinsky and Teixeira.

**Methodology:** 104 human dry skulls of adults were studied, 62 male and 42 female, belonging to the anatomy laboratories of the Universities: Tiradentes (UNIT) and Federal de Sergipe (UFS). To calculate the area of the foramen magnum, the ImageJ software was used, while the measures, length and width, were performed using a digital caliper. The areas calculated by ImageJ were compared to those calculated using the Radinsky and Teixeira formula.

**Results:** The area of the foramen magnum measured by ImageJ ranged from 532.14 to 1135.79mm<sup>2</sup>, with an overall average of 758.71mm<sup>2</sup>. According to Radinsky's formula, the area of the foramen magnum varied from 610.35 to 1233.09mm<sup>2</sup>, with an average of 828.25mm<sup>2</sup>; and in Teixeira, the area ranged from 633.67 to 1241.29mm<sup>2</sup>, with an average of 840.16mm<sup>2</sup>. The Cronbach's alpha correlating the three methods was equal to 0.950.

**Conclusion:** The calculation of the area of the foramen magnum, using the ImageJ software was significantly close to the area calculated by the formulas of Radinsky and Teixeira (Cronbach's alpha=0.950), proving to be useful for forensic practice. Sexual dimorphism can be found, varying its appearance in literature, but only in relation to its size, but not its shape. However some other authors seem to have not found any sexual dimorphism.

**Keywords:** sexual dimorphism, anatomy, anthropometry, foramen magnum, occipital bone, software validation, skull base, biometry, forensic medicine, ImageJ software

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**Abbreviations:** mm<sup>2</sup>, square millimeter; FMs, foramen magnum; M, male; F, female; %, percentage

## Introduction

The knowledge of the biometrics of the foramen magnum (FM) is of great importance in the pathophysiology of several conditions, as well as for anthropology, anatomy and forensic medicine. According to Muthukumar et al.<sup>1</sup> based on morphometric limits, it would be possible to report the possibility that the FM would be within a predetermined numerical variation or an anatomical malformation. In addition, the study of the FM region is important and is necessary in view of the increased transcondylar approach for ventral access of lesions at the craniocervical junction.

Smoker<sup>2</sup> stated that the configuration and size of the FM play an important role in the pathophysiology of several diseases of the craniocervical junction. Thus, it becomes important not only for the physician who diagnoses it, but also for the surgeon who operates on this region.

Teixeira<sup>3</sup> Günay & Altinkök<sup>4</sup> Gruber et al.,<sup>5</sup> Gapert et al.,<sup>6</sup> studied the biometry of the foramen magnum for gender identification and human biological characterization and evaluated its importance in

a criminal laboratory and in accidents, since this region remained unscathed due to being heavily protected by soft tissues.

Although the morphometric limits have already been detailed in some anatomical studies, the analysis of the dimensions of the foramen magnum using imaging technology is still scarce in the literature.<sup>7</sup> Our objective was to determine the area of the foramen magnum using the ImageJ software, and to correlate it with the formulas of Radinsky<sup>8</sup> and Teixeira<sup>3</sup>

## Materials and methods

104 foramina magna of dry human skulls were analyzed, belonging to the anatomical collection of Universidade Tiradentes (UNIT) and Universidade Federal de Sergipe (UFS). Of that total number 62 were male, 42 were female, with ages ranging from 11 to 91 years (average of 58.69 years old). Only skulls with intact occipital region were included in the sample and determined as to sex and age.

In each skull, the area of the foramen magnum (FM) was calculated using the ImageJ software (Figure 1), and using the formulas of Radinsky<sup>8</sup> and Teixeira<sup>3</sup> (Figure 2). To perform the calculation with the ImageJ software, the skull bases were photographed using a digital camera attached to a static support, positioned at a standard distance

of 20cm from the object. Subsequently, the photos were imported into the ImageJ software and the area of the foramen magnum was calculated.

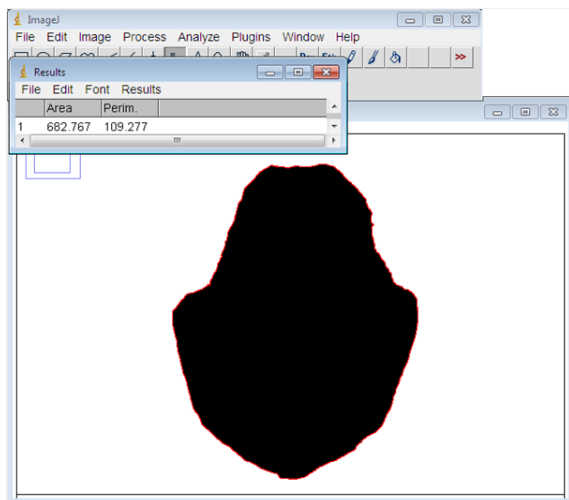


Figure 1 Foramen magnum area using ImageJ software.

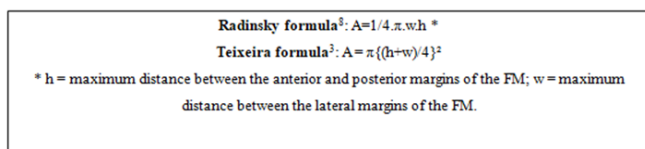


Figure 2 Radinsky and Teixeira formulas.

For the calculation using the formulas of Radinsky<sup>8</sup> and Teixeira<sup>3</sup> the maximum longitudinal distance - h (between the anterior and posterior margins) and the maximum transverse distance - w (between the lateral margins) of the foramen magnum, were measured using a 0.01mm precision digital caliper, and after collection, the dimensions were applied to the formulas.

## Results

Determining the area of the foramen magnum using the ImageJ software, the average found was 758.71mm<sup>2</sup>, using the Radinsky formula,<sup>8</sup> the average found was 828.25mm<sup>2</sup>; and the Teixeira's<sup>3</sup> formula was 840.16mm<sup>2</sup> (Table 1).

Table 1 Foramen magnum areas calculated using ImageJ software, and Radinsky and Teixeira formulas

	FMs areas (mm <sup>2</sup> )			
	Minimum	Maximum	Mean	Standard deviation
ImageJ software	532.14	1135.79	758.71	±118.60
Radinsky formula <sup>8</sup>	633.67	1241.29	840.16	±110.81
Teixeira formula <sup>3</sup>	610.35	1233.09	828.25	±110.75

mm<sup>2</sup>, square millimeter; FMs, foramen magnum

## Discussion

The values of the areas found by the 3 methods were statistically correlated by Cronbach's Alpha, showing significance (Cronbach's alpha=0,950).

The areas and lengths of the FMs were extensively studied. Authors such as Gabert et al.,<sup>9</sup> Macaluso,<sup>10</sup> Raghavendra et al.,<sup>11</sup> Singh & Talwar<sup>12</sup> and Kazi et al.<sup>13</sup> performed biometric studies of the FMs, using the formulas of Radinsky<sup>8</sup> and Teixeira<sup>3</sup> as a model (Table 2).

Table 2 The FMs areas in averages, calculated by the Radinsky and Teixeira formulas

Authors	Sex	Radinsky formula <sup>8</sup>	Teixeira formula <sup>3</sup>
		FMs areas (mm <sup>2</sup> )	
Teixeira <sup>3</sup>	M	-	963
	F	-	805
Radinsky <sup>8</sup>	M	819	-
	F	771	-
Gabert et al. <sup>6</sup>	M	862	868
	F	801	808
Macaluso <sup>10</sup>	M	854	860
	F	807	815
Raghavendra et al. <sup>11</sup>	M	811	821
	F	722	727
Singh & Talwar <sup>12</sup>	M	733	741
	F	692	699
Kazi et al. <sup>13</sup>	M	777	-
	F	728	-
Present study	M	839	834
	F	811	824

M, male; F, female; mm<sup>2</sup>, square millimeter; FMs, foramen magnum

The Radinsky<sup>8</sup> and Teixeira<sup>3</sup> formulas are based on the mathematical formula of a circle ( $A=\pi r^2$ , "r" being the radius). The first formula makes the product of two distinct radius (half the longest length - h - times half the longest width - w), while the second uses a single radius, corresponding to the average between the length and the width.

Many studies on the morphological types of the foramen magnum show that, in most cases, this structure does not have a round shape, making it difficult to determine a radius (Table 3). Therefore, the use of a software that delimits exactly the shape of the FM is more advantageous. In addition, with the ImageJ software, it is not necessary to measure the dimensions of each skull with the digital caliper, making this method more practical.

Table 3 Predominance of the FMs morphological types

Authors	Types (%)
Zaidi & Dayal <sup>14</sup>	Oval (64%)
Sindel et al. <sup>15</sup>	Tetragonal (49%)
Murshed et al. <sup>16</sup>	Round (22%)
Espinoza et al. <sup>17</sup>	Oval (45%)
Chethan et al. <sup>18</sup>	Round (23%)
Radhakrishna et al. <sup>19</sup>	Oval (39%)
Aragão et al. <sup>20</sup>	Pear shaped (37%)

FMs, foramen magnum; %, percentage

## Conclusion

The calculation of the area of the foramen magnum using the ImageJ software showed a high correlation with the calculation of the area using the formulas of Radinsky and Teixeira (Cronbach's alpha=0.950), proving to be useful for the practice of forensic medicine.

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## Conflicts of interest

The authors declare there are no conflicts of interest.

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