Application of Fractal Dimension in Evaluation of Cranial Suture Complexity

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1. Introduction

Cranial sutures as the growth sites and articulations between bones of the skull resemble curve lines, which present vast range of morphological variation [7, 8]. Interparietal sutures vary distinctly among individuals and evaluation of their morphology has always been problematic, especially of those with intricate pattern. For a long time, scientists who studied sutural morphology used visual inspection to categorize appearance of cranial sutures and they tried to measure the length of cranial suture following the curves of the suture or simply to measure distance from the beginning to the end of the suture [1, 3]. These two parameters if divided by each other serve the index, which express sutural complexity. For the last decade fractal dimension has been also applied to measure complexity of cranial sutures as these structures can be treated as fractals because of their intricate contour, which if magnified reveals details in form of subtle projections [6].

Complexity of cranial sutures depends on the degree of interdigitations of the spicules, which are present on the edges of two opposing bones. These bony spicules are precisely interlocked and it provides for a solid connection between cranial bones but allowing small amount of movement.

The goal of this paper is to analyze frequency of the fractal dimension of the set of interparietal sutures, which in this case serve as example of biological fractal patterns.

Figure 1. Examples of the interparietal sutures as fractal curves

2. Material and method

We analyzed complexity of 40 interparietal sutures of the external surface of the cranial vault. The specimens were taken from the skulls which belong to the collection of the Anatomical Museum of the Jagiellonian University in Cracow. The images of these sutures were acquired in the following manner. A transparent tape had been placed on the external surface of the skull along the analyzed suture and its contour was traced with a marker that drew a thin line. Traced silhouettes of the sutures were scanned with a flat bat scanner and the digitized images were skeletonized to obtain a line wide of 1 pixel. Such obtained images of cranial sutures silhouettes were subjected to the HarFa software, which measured fractal dimension of the sutural images using the box-counting algorithm.

3. Results

The estimated fractal dimension of the contours of the interparietal sutures ranges from 1.1 to 1.59 and mean value equals 1.34 (std dev. = 0.114). Frequency of the fractal dimension in the analyzed sample is presented on *Figure 2*.

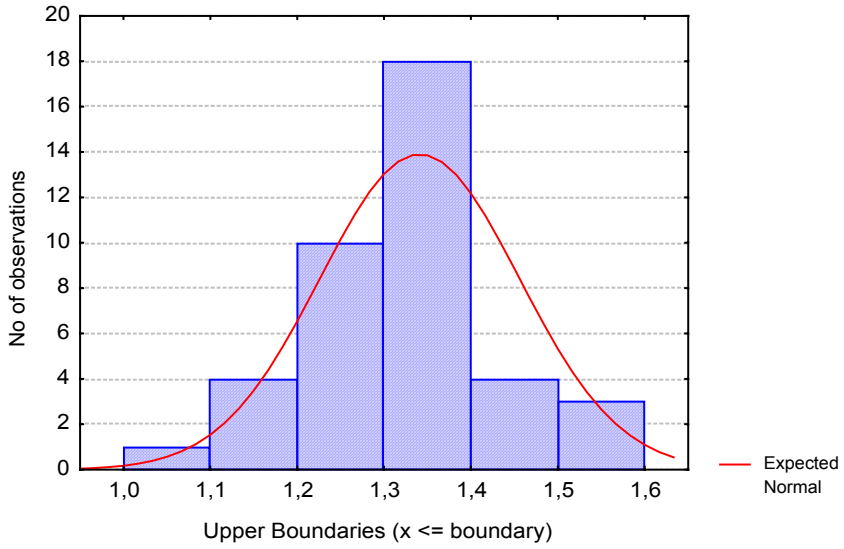

Figure 2. Frequency histogram of the fractal dimension of the analyzed interparietal sutures

Fractal dimension of the range 1.3 – 1.4 is the most representative for the studied sutures and it constitutes 45 %, whereas the lowest values (1.0 -1.1) are rare (2.5 %) and contrast to the highest values (1.5 – 1.6) of fractal dimension, which contribute three times more (7.5 %). More than half of the analyzed sutures yielded fractal dimension higher than median value (1.35) of the range of variation. It indicates that interparietal sutures appear more frequently as complicated patterns than simply convoluted lines.

4. Discussion

Fractal dimension seems to be a proper and objective descriptor of cranial suture complexity and it is more valid if the sutures are more intricate because than they show higher level of self-similarity. It proves that fractal geometry cope better with biological irregular patterns than classic methods of Euclidean geometry, which in this case would only approximate real features of the analyzed object [2]. There is considerable diversity in the patterns of cranial sutures; nevertheless they can be classified as curves which resemble fractals, eg. Koch's curve. Intricate interparietal suture shows 2-3 orders of scaling and yield fractal dimension about 1.3 - 1.4 [6].

Fractal dimension as a quantitative measure of sutural complexity enables to categorize sutural complexity. According to my previous studies, the analyzed set of interparietal sutures can be

regarded as considerably complicated [9]. Moreover fractal dimension becomes a helpful parameter which can be easily compared or correlated to other metrical characteristics of the skull or selected cranial bone. Sutural complexity is strictly related to amount of interdigitations of the edges of the linked bones. As it was reported by Jaslow increase energy absorption was correlated with increased sutural interdigitations [5]. The sutures between cranial bones provide for not only interstitial growth of the cranium, but they also alter the transmission of stress and strain through the skull [4].

Measurements of cranial suture complexity seem to be important in a case of considerations of mechanical properties of the articulations between cranial bones, their function and stability in the entire skull. Because of important role which sutures play in the skull a thorough investigation of these structures is essential for better understanding functional aspects of the skull. We presume that fractal approach to cranial suture morphology may be crucial in mentioned problems.

5. Literature

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