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The ammonoid suture problem readdressed: a discrete wavelet analysis

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One of the most amazing structures of organism in the Earth's history is ammonoid septum, which is a partition subdividing the interior of shell into chambers. The periphery of the septum is folded and frilled to form a complex suture line where the septum intersects the external shell wall. The complex septa had been conventionally thought to have helped reinforce the shell with its fluted structure against hydrostatic pressure. In recent years, however, their function is debated: the 'strength paradigm' is often criticized because any clear relationship between sutural complexity and external shell morphology has not been demonstrated. Nevertheless, the failure of finding the relationship may be attributed to ambiguity of complexity measures of suture line hitherto been available: disparate suture forms are often represented by near-identical values of such measures as fractal dimension. To solve the 'ammonoid suture problem' requires a rigorous description of suture form itself rather than proxies of complexity. One of promising approaches may be a Fourier-based method in which a series of morphometric data transformed into a periodic function is decomposed into sine and cosine functions with various frequencies. However, predominant frequency often changes with position along the suture line, and Fourier-based methods are not powerful enough to analyze signals with non-stationary frequency even if a windowed short-time Fourier transform is adopted. Here I introduce an alternative method based on a discrete wavelet transform for comparison of suture forms with external shell morphology of ammonoids.

At the beginning of measurements, a figure of a suture line was installed in an x-y coordinate system by putting the point of ventral extreme onto the origin of the coordinate and placing the straight line traced from venter to umbilical seam along the x-axis. A series of y coordinate data along the suture line was measured, and was used as periodic function of the cumulative chordal length of the suture line. Wavelet transform is defined as a kind of correlation of the periodic function with a short and localized function called mother wavelet. Wavelet transforms were calculated for individual mother wavelets with various wavelengths and positions. A power spectrum was obtained for each mother wavelet as a square of the wavelet transform. An average power spectrum was calculated for each portion of the shell which is represented by x-coordinate value. Series of average spectra with position were used for a kind of principal component analysis of outlines, or eigenshape analysis, to summarize the greatest portion of variance on the fewest number of variables. The principal components of suture forms were compared with those of the cross-sectional shape of the whorl by use of multiple regression analyses. The results successfully demonstrated significant relationships between suture form and cross-sectional shape of whorl.