Schreger lines as support in the Elephantinae identification

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SUMMARY: The tusk of Elephantidae representatives is constituted by a serial of cones of dentine, which are formed progressively during the ontogenetic development and have been radials crossed by tubule bundle, carrying blood. Every transversal cross-section of tusk, cutting the tubules, generates a pattern of two set of lines curving clockwise and counterclockwise that form a typical. Different tubule trends can be observed starting from initial stage (apex) to final stage (rings with maximal radius) of tusk. Consequently, the wideness of rhomboid-shaped figure angles increases from central to peripheral area of the tusk; the different increasing rates allow to discriminate the Elephantinae taxa. This research should like to establish the range of variation in *Loxodonta, Elephas* and *Mammuthus* representatives and the main differences among Schreger patterns of the three genera.

1. Foreword

The "Schreger lines", described for the first time by time by Bernhard Gottlob Schreger in the 1800 (Obermayer 1881) are a peculiar character of the Proboscidean dentine. They are evident in transversal cross-section of tusk and are due to sinusoid trend of dentinal tubules: when the waves, formed from these tubules, have intercepted by the cut-surface on the transversal section, the interception point sequences form two different sets of lines that curve clockwise and counterclockwise. The crossing of these lines form several outer and inter angles here called Schreger angles. According to the different calibre of tubules, we can distinguish more evident Schreger lines, near dental-cement surface and less clear ones, near pulp cavity (Espinoza *et al.* 1990).

Our research has as main object to study the trend of Schreger lines in the subfamily Elephantinae, try to test their taxonomic value and to establish the range of variation in *Loxodonta, Elephas* and *Mammuthus* representatives and the main differences among Schreger patterns of the three genera.

Furthermore, we have made a preliminary comparison with other genera, no closely to subfamily Elephantinae, like *Anancus* and *Stegodon* (Palombo & Villa 2000).

2. Materials and Methods

We have collected and examined 480 specimens of tusks, but it was possible to get reliable measurement of Schreger angles in only 238 specimens, belonging to the following species: *Loxodonta africana* (72 specimens); *Elephas maximus* (17); *Mammuthus primigenius* (49); *Mammuthus meridionalis* (20); *Mammuthus trogontherii* (10); *Mammuthus* sp. (6); *Elephas (Palaeoloxodon) antiquus* (28); *Elephas falconeri* (4); *Anancus arvernensis* (31); *Stegodon* (9). The specimens belonging to extant species are both tusk and miniature sculptures or souvenir in ivory.

The 70% of samples were examined using a video camera and then all of tusks were listed in a computer. Each image was studied with the software CV9000. This software allow to measure almost Schreger angles, with precision of 93%-95%.

Then, five concave angles and five convex angles were measured for each specimen, both in proximity to dentine-cement surface and to pulp cavity.

3. Discussion

The first step of analysis allow to better understand the factors, which affect both Schreger line trends and, consequently, angle width. Schreger lines with wide bending radius correspond to sets of dentinal tubules with the distance between two adjacent nodes that increases in each cone, from more recent one to older generation. Schreger lines with short bending radius correspond to sets of dentinal tubules with the distance between two adjacent nodes decreases (Fig. 1).

Two major Schreger patterns can be detected: one is characterised of genera *Loxodonta* and *Elephas*; the other one is characterised of genus *Mammuthus* (Fig. 2).

In *Loxodonta africana*, it is possible to show two types of sections: one correspond the last generation cones, where the Schreger inter angles (in proximity to pulp cavity) are narrow (48°-88°), and the Schreger outer angles (in proximity to dentine-cement surface) are wide (118°-145°). The other one corresponds to the first generation cones, where the bending radius is kept constant and the Schreger angles are wide in the sub-central area of tusk, yet.

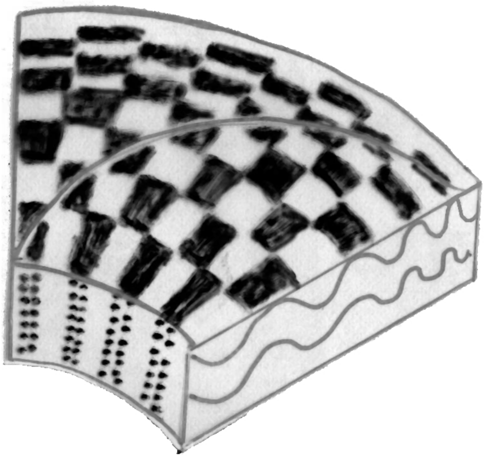

Fig.1 - Cross section with lines drawn through the dark areas (section of tubules nodes) to emphasise the curved natura of Schreger lines and radial section showing undulated curvatures of the dentinal tubules.

In *Elephas maximus, Elephas (Palaeoloxodon) antiquus* and *Elephas falconeri* the distribution pattern of Schreger angles is comparable to *Loxodonta africana* (Fig. 3).

In *Mammuthus primigenius, Mammuthus meridionalis* and *Mammuthus trogontherii* the Schreger lines diverge from section radius not so much, both the first generation and last generation cones. Therefore, the Schreger angles are narrower than in genus *Loxodonta*, especially in the peripheral area of tusk (in proximity to dentine-cement surface) (Fig. 3).

Moreover, the Schreger lines network can change during the ontogenetic grow, so different section of a given tusk might be quite different.

For example, the study of transversal serial sections of *Loxodonta africana* has allowed to show that the part of tusk corresponding to young stage (distal part) is characterised from very curved Schreger lines, with almost constant bending radius. The sections of last formed part of the tusk (proximal part), instead, exhibit important differences of bending radius from central part to circumference. All this is explained by different trend of dentinal tubules due to a change of different distances between adjacency nodes along the same tubule as well as in different parts of every cone. In fact, each dentinal tubule is characterised from a wave of nodes and antinodes alternated long tubule. The more nodes are near each other, the more virtual lines, formed from all of sections, will trend to curve; and in this way, these lines will go away radius of tusk sections and will have a trend almost parallel to circumference. After the analysis of serial sections of *Loxodonta africana*, in the last generation cones the distance between adjacency nodes, called wavelength, is relatively width at the apex and then it strongly decreases, in proximity to dentine-cement interface. In the first generation cones,

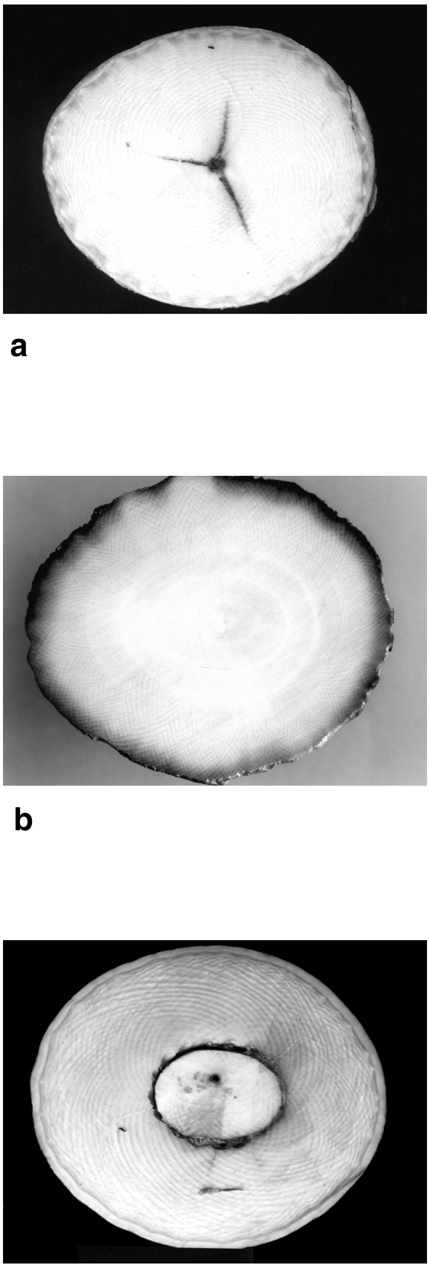

Fig.2 - Cross section of tusks. a) *Loxodonta africana*, b) *Mammuthus primigenius*, c) *Elephas maximus*.

the wavelength is already short from apex of cone. Therefore, in transversal section the optical effect form the Schreger lines is different in the nearest sections to apex and the bending radius is almost constant; with lines that progressively move away from radius of sections. On the contrary, in the proximal sections, the Schreger lines are less curved at last, and they are formed a rhomboid pattern with maximal diagonal in according to the radius of tusk.

In transversal sections of *Mammuthus primigenius*, the wavelength of dentinal tubules, independently by their generation, undergoes a lower decrease as to *Loxodonta africana*. Consequently, the high bending radius of Schreger lines in all species of *Mammuthus* studied (*Mammuthus primigenius; Mammuthus meridionalis; Mammuthus trogontherii*) could be the cause of narrow Schreger outer angles.

The complete separation of two different variability ranges of Schreger angles measured near the dentine-cement surface, one for *Loxodonta africana* (118°-145°), the other for *Mammuthus primigenius* (65°-90°), is due to Schreger lines trend (Fig. 3).

In fact, in *Loxodonta africana* the Schreger lines follow the section radius only for short distance, and then they diverge and have a parallel trend to tusk circumference. In *Mammuthus primigenius* the Schreger lines follow the section radius for long distance, and they diverge from it in the peripheral part only. This different Schreger lines trends explains the evident difference between the width of *Loxodonta africana* Schreger outer angles and width of *Mammuthus primigenius* Schreger outer angles (Fig. 1).

Moreover, excluding the apex of tusk, the degrees of Schreger inter (in proximity to pulp cavity) angles of *Loxodonta africana* are similar to degrees of Schreger outer (in proximity to dentine-cement surface) in *Mammuthus primigenius*. This would make very difficult to distinguish two types of ivory between them on the basis of Shreger angles only, therefore the rhomboidal figures resulting by Schreger line crossing is quite different.

A preliminary comparison have been made among the species of subfamily Elephantinae

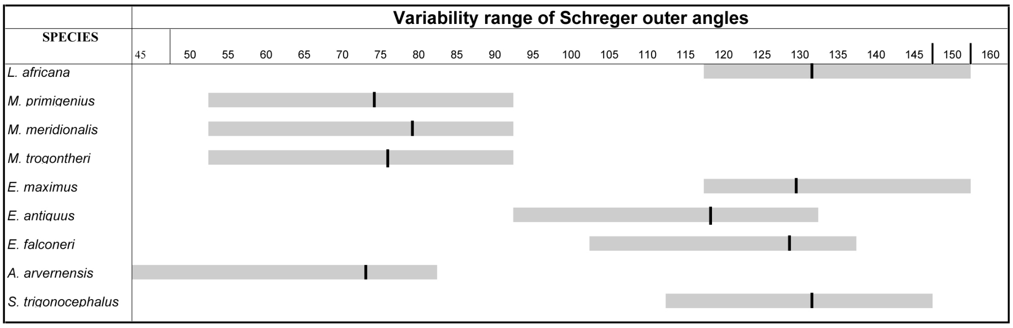

Fig.3 - Variability ranges of Schreger outer angles.

and two other species of different subfamily like *Anancus arvernensis* and *Stegodon trigonocephalus*. Even if with the caution due to the scanty number of samples, it seems that the averages wideness of Schreger angles in *Anancus arvernensis* is very close to genus *Mammuthus*. In fact, the bending radius of Schreger lines in *Anancus* is constant, independently from different generations, long all tusk sections. In *Anancus arvernensis*, therefore, the mean of Schreger outer (in proximity to dentine-cement surface) angles is the same to mean of Schreger inter (in proximity to pulp cavity) angles. On the contrary, the means of Schreger angles in *Stegodon trigonocephalus* are similar to means of Schreger angles in *Loxodonta africana* (Fig. 3).

4. Conclusive remarks

The analysis of Schreger lines trend can constitute a valid support to Elephantinae genera identification especially when other identifiable osteological samples are not available; although the possibility of identification widely change according to dimension, growing stage, anatomical position of the investigated section, fossilisation of tusk fragment et cetera.

Moreover, the data collected show that the Schreger angles and lines are not sexual characters. The observation on tusks of different individuals, both old and young, shows that especially in *Loxodonta africana* the degree of Schreger angles depend of age.

Furthermore, to examine specimens of both extant and extinct taxa coming from different geographic area, remarks that the environmental factor is not influence on the Schreger angles and trend of lines

The study of dentinal tubules trim and, consequently, of Schreger lines trend and Schreger angles width allow to distinguish two Schreger patterns: one is characterised of genera *Loxodonta* and *Elephas*; the other one is characterised of genus *Mammuthus*.

In fact, the comparison between *Loxodonta africana* and *Mammuthus primigenius*, two guide species, and other species studied has showed as: the widths of Schreger angles, in *Elephas maximus, Elephas (Palaeoloxodon) antiquus* are like widths of Schreger angles measured in *Loxodonta africana*. This should emphasise that genus *Loxodonta* is closer to genus *Elephas* as regard as this character considered.

The Schreger patterns can be a valid basis for taxonomic identification of Elephantinae genus, especially when the molars and other important parts of skeleton (skull) are incomplete or is very difficult to ascribe them. An increase in analysis and in data could be a valid help for taxonomic and phylogenetic studies about Proboscideans.

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