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DENTAL WEAR EVALUATION BY IMAGE ANALYSIS METHODS

ABSTRACT: Image analysis techniques are useful for depicting and enhancing morphological features which are not usually easy to see and evaluate with the naked eye alone.
But a digital work-station for image analysis usually requires operator expertise, involving a long training, and does not allow the direct observation of the multi-tonal images. We therefore used an analogic Video Assistance Unit (V. A. U. 101) to observe dental wear in an Italian paleolithic skull. The treatment and observation in real-time was carried out using electronic filters.
After electronic shading correction, we applied the following functions:
- "Casting" effect for edge finding and enhancement.
- Interferential filter.
- Grey level classification with or without tonal inversion. In the first case we could add or subtract the areas with the same grey level, while in the second all the areas were visualized but with a progressive tonal inversion.
The above-mentioned functions enabled us to find three wear-levels with a different mechanical significance.

KEY WORDS: Dental wear – Analogical image processor – Electronic filters.

The problem of dental microwear has been studied by various authors using scanner electronic microscopy (SEM) (Bulter and Joysey 1978, Moggi Cecchi et al. 1989) for the study of surface details which cannot be evidenced in any other way.

However, these techniques have considerable limits as they require the availability of the instrument, the preparation of microduplicates, the observation of very small fragments only and finally there is the impossibility of using the tooth in situ.

We have examined a different method of evaluating dental wear (Pesce Delfino and Lettini 1990), which ensures visual results and employs measurement techniques whose results compare well with those of scanner electronic microscopy, and whose facilities are beyond the limits of optical microscopy.

Our aim was to facilitate fast, simple surveys of wear patterns: an undoubtedly relevant need in systematics.

MATERIALS AND METHODS

In the last decade the technical solutions available for morphological investigations have made use of image producing instruments, based on various technologies and with a greater or lesser degree of complexity. The observation of the object in its original form in visible light is only possible in a small number of cases (necessarily by means of optical media observation, especially microscopy), in most cases we obtain an image which provides information to be evaluated according to the technical solution of the given image releasing apparatus.

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This information refers mainly to three characteristics: dimensions, shape and optical density of the examined structure.

The possibility of obtaining image elaborations based on densitometric characteristics is undoubtedly useful from the point of view of legibility and to highlight structural details which were poorly visible in the original image. It is, however, necessary to define standards for an exact evaluation of information which is considered banal, in the observation of a normal image, e. g. a photograph. Particular examples of this kind of information are the relationship between light and shade and transparency and opacity, the position of the source of light, the characteristics of the surface, etc.

For this reason instruments are required which can provide the observer with solutions facilitating the analysis and the interpretation of the images themselves.

The classification of the grey levels is the first step in the strategy of image analysis based mainly on the use of computers. The discrimination of the grey levels attained by these computers can be very high, so that a reclassification is useful for varying the limits and range of the classes. As the image to be observed is obtained through the interaction of the examined object with the source of light, it is necessary to allow for some important details. In fact the reliefs of a tridimensional object are easily evaluable only if the source of light is very distant and can be considered punctiform (e. g. the images obtained by satellite), but this only seldom occurs in the observation of biological objects, like dental surfaces.

Moreover, it is necessary to allow for the fact that elaboration based on densitometric analysis and carried out by image digitization involves transforming the image itself into very large tridimensional numerical arrays. This is very burdensome for the operators and also requires a large memory and processing speed.

The densitometric exploration of an image is considered useful as means of obtaining equalization, shadowing, contrast enhancement, pseudo 3D, grey slicing and classification, false color, contour detection, level curve etc., with the corresponding numerical evaluation. More advantageous solutions like processing speed (real time) and flexibility and facility of use can be obtained using high-technology analysers based on analogical filter net techniques, which ensure high-reliability performances.

We used an analogical image processor „V. A. U. 101" (Video Assistance Unit – produced by Metamorphosis s. r. l.) which takes a video image, elaborates it by combining different functions and returns it in real time. Dental microwear observation carried out by scanner electronic microscopy proceeds through phases which are notoriously complicated and expensive. For our research we used an optical microscope in epiillumination with a coaxial prism illumination system, which provides high magnification and, in comparison with SEM, operates on enormous surfaces (if necessary a whole molar) and with long distances (2–3 cm) between the frontal lens and the examined object. The use of very narrow diaphragms allows a remarkable field depth to be attained. Observation was not carried out directly, the video image was returned on the monitor and video-printer.

The surface to be examined was uneven because in epiillumination there are a lot of shades projected in all directions. Moreover, observation was made more difficult because of the light reflections on the surface. These disadvantages were overcome by using an equalization function. Was then applied a Laplace filter on the equalized image to reduce contrast and enhance slope. Thus in some cases, the reflections were even useful, as they allowed the details to be enhanced without dazzling. The possible elaborations are as follows:

- affixing a reference variable step electronic net,
- grey level classifications,
- Laplace filter for lateral shading,
- false colour and surface measurements,
- extraction of level curves,
- continuous tonal inversion,
- interferential filter.

These techniques were applied on the masticatory surfaces of the teeth of the Palaeolithic skull found in „Riparo Villabruna" near Belluno (Italy) in 1988, which was kindly lent to us by Prof. Broglio and his collaborators.

RESULTS

Figures 1–6 show examples of image treatments which can be obtained with this processor.

Figure 1 shows the lateral incisor and the canine of the right mandibular half arch. On the canine we can see a wide area of marginal wear, with a head-ring circumscribing it on the lingual versant. The epiillumination causes a lot of reflections on the observed surface.

Figure 1. Lateral incisor and canine of the right mandibular half-arch.

Figure 2 shows the same image after equalization and using a Laplace filter which highlights slope and allows easier interpretation of the uneven surface. The details are emphasized owing to the lateral shading effect. In particular, we can appreciate the detail of reliefs constituting the bottom of the three depressions brought about by wear.

Figure 3 shows a more highly magnified detail (100×) of the left lateral upper maxillary incisor. We can very clearly see a dense net of microengravings characterizing the examined surface.

Figure 4 is an elaboration of the previous one. The equalization and restitution in pseudo 3D, exaggerated by the superimposition of an interferential filter on the Laplace one, eliminated the reflection and highlighted the microengravings and allowed the exact reading.

Figure 2. Elaboration of the image shown in Figure 1, with application of an equalization function and a Laplace filter. The details are highlighted by the lateral shadowing effect.

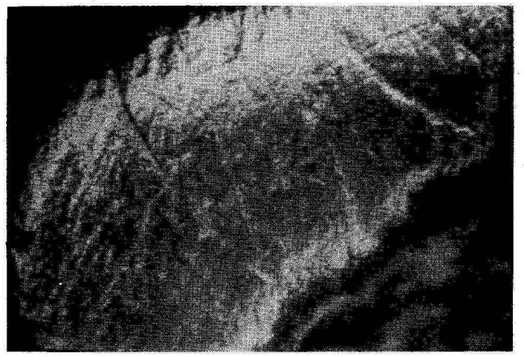

Figure 3. Highly magnified detail (100×) of the left lateral superior maxillary incisor. The surface appears to be crossed by a dense net of microengravings.

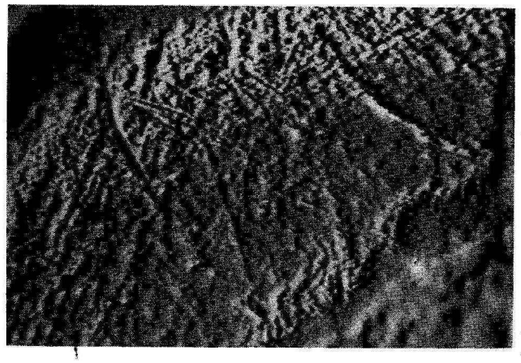

Figure 4. Elaboration of the previous image. Apart from equalization, the functions applied in this elaboration are a Laplace filter and an interferential filter. After eliminating the reflections, the microengravings were highlighted, enabling exact reading of the direction and the three different wear levels.

Three surface modification orders can be distinguished.

The first one is represented by deep engravings with arch-shaped trends, oriented toward the vestibular margin of dental surface, which represent the result of strong, hard abrasive mechanical stresses.

The second modification order is represented by linear microstrias with various trends and with transversely oriented components.

The third is represented by very thin, short strias in relief, some of which are punctiform, with irregular trends and tend to meet in polygonal fields.

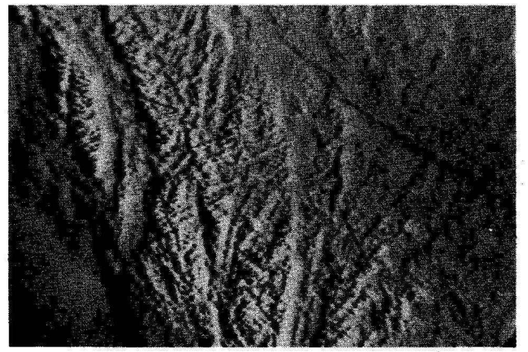

Figure 5. Greatly magnified detail of the incisor shown in Figure 1. An interferential filter was applied in addition to the Laplace one. A group of second-level strias can be observed.

Figure 5 shows the elaboration, with an interferential filter added to the Laplace one, of the lateral incisor field shown in *Figure 1.* The second level strias are grouped in systems separated from each other by deep, large engravings.

Three modification orders of the masticatory surface can easily be seen in *Figure 6* also, which

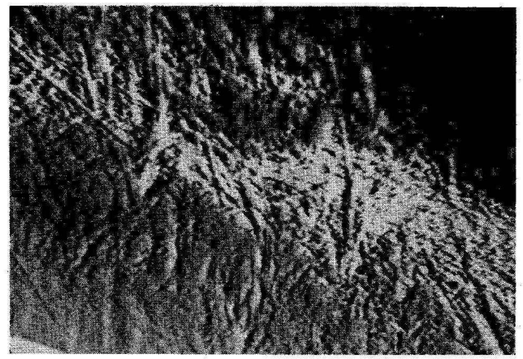

Figure 6. Elaboration of another field of the same tooth. The three modification orders of the masticatory surface are evident.

represents another field of the same tooth. Deep, isolated and curvilinear engravings are well evident. The subcircular, elliptical component, which may depend on tooth architectural aspects, stands out well.

CONCLUSIONS

In conclusion, by means of the electronic instrument with an analogical filter net V. A. U. 101, it was possible to obtain useful highly magnified image elaborations, in epiillumination, of the masticatory surface, which had to be examinated in situ owing to the unique character of the find.

We consider these elaborations, obtained in real time to be the most advantageous solution for studies of this kind.

We consider the three wear patterns found (first order: deep engravings, second order: microstrias, third order: very thin engravings) to be the result of different mechanisms, and make the following suggestions:

Starting from the third level, the thin engravings could be considered directly connected with the fundamental bite, which caused a smoothing of the surface. This smoothing seems to be old and related to repetitive and not traumatic facts.

The engravings of the second level are rougher and seem to be more recent: they may also be related to masticatory mechanisms, but in the presence of substances producing greater friction.

The engravings of the first level, on the other hand, do not seem to be related to food intake, also in view of their non-homogeneous distribution. The problem appears subtle and must be approached with a comparative method. This requires the availability of easy-to-use instruments both for the preparation, in practice not required, of the material, and for the elaboration processing speed (real time), which are all performances easily obtained with this instrument.

NOTE

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