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MICROWEAR AND STRIAE OF RETZIUS OF CANINES OF THE WILD JAPANESE MONKEYS (MACACA FUSCATA)

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Abstract

This is a description of microwear and striae of Retzius of canine teeth of wild-caught female Japanese monkeys (Macaca fuscata) from Oita Takasakiyama, Kyushu. Micrographs were taken of high resolution casts using a scanning electron microscope (SEM). Before the casts were made, the diet of the captive monkeys was water-softened for three or four days. This softened diet probably added little wear to the surfaces of the teeth. These animals are part of a sample used in a previous report published in this journal. Others have observed that wild Japanese monkeys eat hard foods (such as grasshoppers, cicads etc.) in the summer season. They also bite the hard bark of trees in order to obtain soft parts of buds in the winter season. The author previously reported that the wild female Japanese monkeys from Oita Takasakiyama showed many thick striations and large pits on the occlusal surfaces of the second mandibular molars, and noted that these microfeatures categorized these samples in the group of hard-object feeders as defined by Teaford. In this study canine teeth are examined. Three were heavily worn, exposing patterns related to the structure of the enamel. Two canines had prism relief on the heavily worn surfaces. Some of the relief seem to be related to the striae of Retzius. These features may be ascribed to excessive grinding (bruxism). These findings are presented as direct evidence of the effect feeding behavior has on the canine teeth of wild Japanese monkeys.

Key Words: Japanese monkey (Macaca fuscata), Oita Takasakiyama, canine tooth, heavy microwear and diet, striae of Retzius.

Introduction

Several authors have reported on the primate canine tooth wear, enamel prism, and striae of Retzius using the scanning electron microscope (SEM) (e.g., Beynon, 1987; Bromage and Dean, 1985; Dean, 1987; Ryan and Johanson, 1989). In these references high resolution casts of fractured teeth were examined using SEM. Recently Martin et al. (1988) noted prism patterns and striae of Retzius of Macaca mulatta. However, there are no references to canine wear on the wild Japanese monkeys (Macaca fuscata). There is one report dealing with the light microscopic structure of Hunter-Schreger bands on a molar of a Japanese monkey (Kawai, 1955). Zingeser (1969) noted that functional attrition of the canine teeth resulting from honing activity were largely distinct from that resulting from mastication. Moreover, behavioral aspects of honing activity were correlated with aggression, tension, and communication (e.g., Ryan and Johanson, 1989; Walker, 1984; Zingeser, 1969). However, they did not describe the dental microwear on the labial surfaces of the canine teeth.

The author previously reported SEM features on the second mandibular molars of wild female Japanese monkeys (Macaca fuscata) from Oita Takasakiyama. The results of these studies placed these animals in the category of hard-object feeders (Hojo, 1991a; 1991b). In this paper, using high resolution casts, dental wear features recorded on scanning electron micrographs of the labial surfaces of the mandibular canine teeth of wild female Japanese monkeys are analyzed with reference to feeding behavior.

Materials and Methods

Right mandibular canines of 6 wild-caught adult female Japanese monkeys from Oita Takasakiyama, Kyushu, Japan were examined in this study. During captivity their food was water-softened (CMK-1 made by CLEA Japan, Inc., Tokyo). To avoid damage to the teeth, high resolution positive casts were made using Araldite epoxy resin (Ciba-Geigy) in polysiloxane-impressions (Coltene, Light-Body) (Beynon, 1987; Hojo,
Figures 1-5. The first sample. Figure 1. A heavily worn canine with an incisor. Note the striae of Retzius on the heavily worn buccal surface. Bar = 1000 μm. Figure 2. Higher magnification of the canine tooth in Figure 1. Bar = 500 μm. Figure 3. Higher magnification of the labial surface of the canine tooth in Figure 2. Note more than 35 striae of Retzius on a heavily worn region of about 200 X 200 μm. Bar = 250 μm. Figure 4. Higher magnification of the area in the square in Figure 3. Note many enamel prism markings along and on the crenulations. Bar = 25 μm. Figure 5. Higher magnification of the striae of Retzius and the perikymata in the square in Figure 4. Note finer pores on the surfaces of enamel prisms and prism markings. Bar = 10 μm.

Figures 6-8. The second sample. Figure 6. A heavily worn canine tooth. Note three regions (arrows) where the striae of Retzius are exposed. Bar = 500 μm. Figure 7. Higher magnification of the distal and the middle part of the region in Figure 6 showing the striae of Retzius. Bar = 100 μm. Figure 8. Higher magnification of the mesial part of the region in Figure 6 showing striae of Retzius. Bar = 100 μm.

1989). These casts were sputter coated with gold and observed with an ABT SX-40A SEM (Akashi TOPCON, Tokyo, Japan). This SEM has a large working distance and can hold the whole set of mandibular teeth. The magnifications used ranged from X10 to X2,000 at acceleration voltages of 10 kV in Figures 4 and 5, 15 kV in Figure 16, 25 kV in rest of the figures.

Results

Some samples showed heavily worn labial surfaces exposing what I interpret as striae of Retzius (Figures 1-8). The first sample had an area of about 2000 X 2000 μm, that showed these striae. The striae were more than 35 in number, about 10 μm wide and the distance between them was about 30-40 μm (Figures 1-5). There were many cross-sectional enamel rods with fine pores on perikymata, and many prism markings (see Figures 4 and 5) similar to those noted by Martin et al. (1988).

The second sample had three small areas showing striae of Retzius on the labial surface: distal, middle and mesial (Figures 6-8). The number of striae was about 9 in each of the three parts, and the distance between them was almost the same as in the former sample. The third sample also showed a heavily worn labial surface that exposed many large striations (Figures 9-10).

The fourth sample was worn flat on both the labial and occlusal surfaces with large striations on the occlusal surface (Figures 11-15).

The fifth sample had prism relief (decussation) attributed to excessive grinding (bruxism) on the occlusal surfaces as described by Hojo (1991b) and Teaford (1985) (Figure 16).

The sixth sample (not shown) had a little wear on the labial surface and had a pointed tip.

A previous report (Hojo, 1991b) showed prism relief on the enamel occlusal surfaces of the mandibular second molars in these wild female Japanese monkeys. In this study prism relief (decussation) was observed on one of the canine teeth in this sample (Figure 16). This prism relief is attributed to excessive grinding (bruxism). This finding is presented as additional evidence to support the previous view of the author that wild female Japanese monkeys are bruxists (Hojo, 1991b).

Discussion and Conclusion

There have been some reports on diet and enamel structure of molars, canines and incisors in cercopithecidae and other mammals (e.g., Boyde and Martin, 1984; Martin et al., 1988; Rensberger, 1978; Ryan and Johanson, 1989; Teaford, 1988; 1991; Walker, 1984), but no report concerning the striae of Retzius on heavily worn labial surfaces of canine teeth.

In this paper, two canine teeth showed striae of Retzius on heavily worn labial surfaces. The third sample, without striae, also had heavily worn labial surfaces where many thick and long striations were exposed. Finally a fourth sample was worn flat on the labial surface, which sloped towards the lip.

The striae of Retzius are visible as perikymata on the tooth surface, and are observed on micrographs using high resolution casts of naturally fractured tooth surfaces (Bromage and Dean, 1985; Dean, 1987). Perikymata are often visible on human and hominid permanent incisors and premolars (e.g., Bromage and Dean, 1985; Dean, 1987; Weber and Ashrafi, 1979). However, in this study the micrographs showed striae of Retzius on the worn labial surfaces of the canine teeth, but not on the worn surfaces of the incisors.

Striae of Retzius are distinct from Hunter-Schreger bands in spaces between crenulations. That is, the former, which are spaced about 30-40 μm on wild Japanese monkeys in this study, were different from the latter, which on a molar of a Japanese monkey, are spaced about 0.12 mm (Kawai, 1955; calculated from one of his micrographs). The adjacent crenulations in Hunter-Schreger bands are spaced about 0.2 mm in front and cheek teeth of early *Australopithecus* from Laetoli, Garusi and Hadar (Puech et al., 1986), and about 0.13 mm in a *Homo sapiens* canine (Martin et al., 1988; calculated from one of their micrographs by the present author).
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**Figures 9-10.** The third sample. **Figure 9.** A heavily worn labial surface of the canine tooth. Bar = 100 µm. **Figure 10.** Higher magnification of the squared area in Figure 9 showing many large and thick striations. Bar = 20 µm.

**Figures 11-15.** The fourth sample. **Figure 11.** A canine tooth with an incisor. Bar = 100 µm. **Figure 12.** Higher magnification around the top of the canine tooth. Note the slope and the flat top with thick and thin striations. Bar = 250 µm. **Figure 13.** Higher magnification of the large rectangular area in Figure 12. Bar = 100 µm. **Figure 14.** Higher magnification of the squared area in Figure 13. Bar = 20 µm. **Figure 15.** Higher magnification of the small squared area in Figure 12. Bar = 50 µm.

**Figure 16.** Worn labial surface of the fifth sample. Note the prism relief (diazone and parazone). This is attributed to excessive grinding (bruxism). Bar = 5 µm.

The maxillary canine and lateral incisor tend to overbite the mandibular canine. A mouthful of hard food between the maxillary and the mandibular canine may wear the labial surface of the canine tooth during to-and-fro sliding movements. In any event, the labial surface was worn, exposing a heavily worn flat plane, striae of Retzius and many thick striations.

The results of this study give additional direct evidence in support of previous reports of Itani (1956), Kawai et al. (1968), and Nishida (1976) that wild Japanese monkeys are hard-object feeders.

**References**


See page 790 for Discussion with Reviewers.
Microwear and Striae of Canines of Japanese Monkeys
Discussion with Reviewers

M. Fortelius: There is a major problem of interpretation. The author has attributed the wear relief observed on the labial side of the canine to striae of Retzius. Is it not more likely that the relief observed is due to Hunter-Schreger bands (prism decussation), and not to striae of Retzius? And if so, that it appears when wear has exposed the inner, decussating enamel, no matter what level of occlusal stress is involved?

I do not believe the argument about markedly different spacing. Dr. Lawrence Martin (personal communication) tells me that Macaca HSB are spaced about 30-50 µm, S of R about 25-40 µm, depending on many factors. Calculating them from micrographs is risky if the plane of section is not known exactly.

J.M. Rensberger: The "striae of Retzius" may be Hunter-Schreger bands (HSB). Retzius lines do not seem to produce differential wear, but HSB do produce differentially worn grooves and ridges on enamel that has been worn deeply enough to expose them (they almost always occur in the deeper part of the enamel). HSB differentially wear where the plane of decussation is perpendicular or oblique to the wear surface. If the HSB planes are parallel to the wear surface no ridges are produced [See: Rensberger JM, Koenigswald Wv (1980) Functional and phylogenetic interpretation of enamel microstructure in rhinoceroses, Paleobiology 6: 477-495]. It would also be a good idea to look at these structures in Macaca under the SEM in enamel rather than in epoxy casts, because the resolution in the latter is limited and identifying HSB requires good resolution. This would help verify whether prisms are decussating or striae of Retzius are indicated.

Author: As noted in this paper, I believe that the crenulations on the labial surfaces of enamel are striae of Retzius which are different from HSB because these crenulations were almost regularly spaced about 20-30 µm and 35 in number in a sample. The spaces of the striae of Retzius of Japanese monkeys have been measured for the first time by this study; other Macaca data you mention, may be from different species. In comparison, HSB were measured to be about 120 µm on a molar of Japanese monkey by Kawai (1955); about 200 µm in front and cheek teeth of early Australopithecus from Laetoli, Garusi and Hadar by Puech et al. (1986); and about 130 µm in a Homo sapiens canine by Martin et al. (1988). I think that the spacing of HSB on a molar of Japanese monkey is almost the same as that of a Homo sapiens, and that the spacing from my data is very different from those of other three. This large difference is very significant in my determining whether the crenulations are striae of Retzius or Hunter-Schreger bands.

The canine teeth in this study had heavily worn labial surfaces showing many parallel and almost regular crenulations in these two samples. Especially, in one of them the striae were more than 35 in number, about 10 µm in width, and the distance between adjacent striations was about 30-40 µm. Since the 10 µm wide striae were harder than the finer enamel prism areas between the striae, these remained after even heavy dental-wear behavior of some Japanese monkeys. The fine microstructure of these enamel prism areas on naturally fractured or worn labial surfaces may not be so clear as those on artificially fractured surfaces. The finer enamel prism between striae of Retzius may be weaker and worn faster than striae of Retzius during eating hard food by wild Japanese monkeys. I think that in some areas the fine prism pattern may be found on many other naturally worn surfaces. These striae of Retzius are coarse regular lines that pass obliquely from the enamel-dentine junction to the surface of enamel where they become visible as perikymata, and thought to be the incremental growth markings (Bromage and Dean, 1985). The surfaces where these striae were observed, were labial and these striae were almost perpendicular to the labial surfaces. These features of these striae are thought to be striae of Retzius. Furthermore, the dental-wear pattern of the Japanese monkeys are very different among different teeth, even different cusps, and are more variable than those of other herbivorous mammals.

J.M. Rensberger: It would be useful to include a comparison of a sample of Macaca which have been eating a different diet for an extended period of time (long enough to make its effects the dominant wear pattern on the teeth). If cheek tooth and canine wear in this control sample differs substantially from what you found in your wild sample, then that would be evidence that the different diet is producing a difference in wear.

Author: Thank you for your suggestion; I shall perform these experiments and report the results later.

J.M. Rensberger: I am unconvinced that bruxism is a factor that produces prism relief. I have only seen prism relief in areas of enamel that do not come into direct contact with the opposing enamel surface. This would seem to be contrary to the hypothesis that this relief is produced by bruxism. More evidence is needed. This could be acquired by comparing observed bruxists with animals known not to practice bruxism.

Author: Japanese monkeys were often observed to keep frequent contact and grinding between the upper and lower teeth; which means "bruxism" and may cause heavy wear showing prism patterns (decussation). This is confirmed in the present study by the observation of more transversely sectioned prisms (diazone) and the more longitudinally sectioned prisms (parazone) in the fifth sample of this study (Figure 16).