EFFECT OF HIGH FLUORIDE AND LOW PROTEIN ON TOOTH MATRIX DEVELOPMENT IN GOATS

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SUMMARY: An optical and scanning electron microscopy study was made of the effect of high fluoride and low protein intake on tooth matrix development in goats in an industrially polluted region of Baotou, China, during the dry grass season. The enamel and the dentine were severely damaged, and the boundary lines between them and between the cementum and the dentine were obscure and uneven. The fluorosed dentine had loose and crooked rows of collagen with non-uniform staining, in contrast to dense and neat rows of collagen in controls with uniform staining.

INTRODUCTION

The Baotou region in Inner Mongolia of China has a rainy season (total annual rainfall 250-300 mm) from July to September. During the remainder of the year, with little rainfall, goats pastured in this region develop sawteeth that are brittle and show excessive wear, whereas teeth developed in the green grass season are comparatively hard and normal in appearance. When teeth are uneven, pasturing and mastication are impaired, and the life span of the animal is curtailed. In severely polluted areas livestock can survive only 2-3 years, thereby limiting reproduction and reducing the success of animal husbandry.1,2 Various efforts to solve these problems have been investigated, e.g., removal of goats from high to low fluoride areas, transfer of adult nanny goats from low to high fluoride areas,3 use of stored green grass in the dry season as fodder,4 mechanical trimming of sawteeth,5 and dietary supplementation with minerals.6-8 Over the years we have experimented with methods to reduce fluoride exposure and have been able to show that supplying protein-rich feed is the best way to prevent wearing down of teeth in goats being pastured in high-fluoride areas.9,10

How does fluoride affect the development of teeth in goats? Do various nutritional factors play a role, or do they indirectly modify the toxicity of fluoride? Focusing on these questions, we conducted the following investigation.

MATERIALS AND METHODS

Twenty native goats, aged 6 months, were sent to pasture in Baotou for 12 months in a severely fluoride-contaminated area. When the first pair of incisors (developed in the high fluoride period) had grown out and had worn for half a year, and the second pair of incisors (developed in the green grass pe-
iod) had also breached and were used, the first and second pairs of incisors were collected as specimens. Incisors of control goats, which did not have any symptoms of fluorosis, were selected from a safe low-fluoride zone.

The teeth were fixed in neutral formalin for about 1 week. They were then transferred to methanoic acid-formalin solution (methanoic acid 5 mL, formalin 5 mL, distilled water 90 mL) for decalcification until calcium could no longer be detected chemically. For histo-pathological study the teeth were dehydrated, embedded in paraffin, sectioned, stained by the Van-Gieson method, and photographed. For scanning electron microscopy (SEM: Japan EMASIC-40) the decalcified teeth were dehydrated, gilded, and photographed following Zhan Chongwan’s method.

RESULTS

Clinical appearance: The sampled F incisors were mottled and appeared worn. The first pair of incisors were even more affected than the second pair. The control teeth had no fluorosis symptoms.

Histo-pathology: Under an optical microscope, teeth of control goats presented clear and even boundary lines between enamel and dentine and between cementum and dentine. Moreover, the dentine and the cementum were thick and compact (Figure 1). In the F groups, the boundary lines between cementum and dentine were diffuse, the density of cementum and dentine was poorly-distributed, boundaries between enamel and dentine were uneven or crooked, and part of the enamel was damaged (Figure 2). The second incisors had distinct boundary lines between the cementum and dentine, and textures were comparatively compact. In contrast to the control

Figure 1. Tooth cementum of control goats: clear and even boundary lines between tooth enamel and dentine. Van-Gieson staining (×100).

Figure 2. Fluorosed tooth enamel: damaged tooth enamel and uneven boundary line between cementum and dentine. Van-Gieson staining (×100).
High fluoride and low protein effect on goat teeth

Teeth (Figure 3), collagen of fluorosed dentine showed loose and crooked rows and non-uniform staining (Figure 4).

Under SEM, dentinal tubes of transverse section of the control tooth showed regular shapes and neat rows with uniform brightness of dentinal matrix (Figure 5), while the F dentinal tube section had irregular shape and unequal size, showing bright wall tubes but with darkness between them (Figure 6).
DISCUSSION

In the industrially fluoride-polluted areas of Baotou, goat teeth developed in the dry grass seasons were worn very rapidly, while the teeth developed in the green grass seasons were worn relatively slowly. According to our earlier study, the fluoride content of herbage was high (soluble F 30-80 mg/kg) in the dry grass seasons (dust fluoride was dominant), while it was relatively low in green grass seasons (herbage grew rapidly, and therefore suffered less fluoride pollution). Moreover, the dust on herbage is frequently washed away by rain in the rainy seasons (soluble F 10-30 mg/kg).1

In terms of nutrition, herbage in the dry grass seasons was notably deficient and lacked coarse protein (5.3%), compared with that in green grass (average protein 15%). In addition, it had more coarse fiber which resulted in poor digestion and evacuation in rumen, and less food intake by rumenal animals, causing them to be seriously undernourished in the dry grass seasons. Accordingly, we suggested that besides the effects of high fluoride on tooth quality in the dry grass seasons, perhaps malnutrition (especially protein deficiency) also had a negative influence on the development of teeth or enhanced the toxic effect of fluoride. To confirm this, we conducted a study and found that supplying protein-enriched bean feed during a dry green season relieved the excessive wear of teeth developed in this period.9

Other epidemiological surveys support these ideas. A 1995 New Zealand Health Ministry survey on the developmental quality of children’s teeth in different cities and towns concluded that the health level of children's teeth was related to the income of their parents, i.e., the poorer the region, the lower the quality of the children's teeth.13 In India, Kodali also found that undernourishment and high-fluoride water affect tooth development.14 A comparative survey on tea-drinking fluorosis of teeth in pasture and non-pasture areas of the Xinjiang Uygur Autonomous Region and the Inner Mongolia Autonomous Region in China revealed that herdsmen ingested a high level of fluoride, but their teeth were only slightly damaged. These phenomena suggest that other nutrient factors may be involved, and although the herdsmen lack diversity in their diet, their main food is protein-rich milk and meat, which help prevent the toxic effects of fluoride.15

All the above evidence indicates that, in the developmental phase, malnourishment has a negative influence on tooth development, and high fluoride combined with malnourishment affects the development of teeth matrix. The result is that larger quantities of imperfect collagen matrix are produced, and thus the quality of teeth is decreased, which results in extreme wear.

CONCLUSION

In dry and industrial fluoride-polluted areas, high fluoride (especially polluting dust fluoride) and malnourishment in the dry grass seasons cause...
underdevelopment of the tooth matrix, subsequently affects its calcification and finally impairs the quality of the teeth.

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