

SPECIAL ARTICLE

FLUORIDE AND NUTRITIONAL OSTEOPOROSIS

by

P. A. Henrikson, L. Lutwak, L. Krook, F. Kallfelz, B. E. Sheffy;
R. Skogerboe; L. F. Belanger; J. R. Marier; B. Romanus and C. Hirsch.

SUMMARY: Osteoporosis was induced by feeding a low-Ca high-P diet for 41 weeks to Beagle dogs, and dietary fluoride supplements were given to obtain daily fluoride intakes of about 0, 25, 85, 300, and 1,000 ug/kg body weight. Bone radiography, specific gravity, bending and tension tests, and ash-per-volume revealed no effect of fluoride on the degree of osteoporosis. However, densitometry measurements showed that mineral mass decreased significantly with increased dietary fluoride, and this was accompanied by a marked increase in bone ash phosphorus and a slight decrease in ash calcium. Fluoride content of bone ash was proportional to dietary fluoride, and was higher in vertebrae than in long bones.

Osteoporosis can be readily induced in various mammalian species by feeding a diet high in phosphorus and low in calcium (1). Such diets induce secondary hyperparathyroidism, with consequent attrition of bone which is not necessarily mediated by osteoclastic activity, but can occur via the process of osteolysis (2). Studies of diets for various mammalian species have repeatedly shown that, to ensure proper bone integrity, the dietary Ca/P ratio must be in the range between 1.0/1 and 1.5/1 (1, 3).

In a survey of the intake of calcium and phosphorus in human populations throughout the world, Henrikson (3) has found that calcium intake can range from 1.33 g/day to 0.35 g/day. Data concerning phosphorus intake by humans is very scarce. The only value that Henrikson was able to find was for the United States, where a phosphorus intake of 2.94 g/day was indicated (3). Thus, with a calcium intake of 1.12 g/day, the Ca/P ratio in the U. S. diet appears to be 1.12/2.94, or 0.38. This is far below the Ca/P ratio of 1.0/1 to 1.5/1 required by other mammalian species.

From Cornell University, Ithaca, N. Y.; Colorado State University, Fort Collins, Colorado; University of Ottawa, Ottawa, Canada; National Research Council, Ottawa, Canada; Karolinska Institute, Stockholm, Sweden.

* * *

Presented at the Third Annual Conference of I. S. F. R., Vienna, 3/22-25/70
by J. R. Marier.

Method

It has often been suggested that fluoride can prevent osteoporosis (cf4). It was therefore decided to evaluate the possible influence of fluoride on the osteoporosis induced by a high phosphorus low calcium diet. For this study, our subjects were adult Beagle dogs. During growth, the dogs were fed a commercial pelleted food that contained 2.15% calcium and 1.40% phosphorus or Ca/P ratio of 1/5. This provides much more calcium and phosphorus than recommended by the U.S. National Research Council for this particular species (i. e., 0.54% calcium and 0.42% phosphorus), and therefore ensured that there was no deficiency (5).

The experimental diet was prepared from chemically pure ingredients, and analytical reagents were used in the mineral mixture. This experimental diet contained 0.12% calcium and 1.20% phosphorus, and represented conditions previously used to induce nutritional secondary hyperparathyroidism in Beagle dogs.

The fluoride levels were selected so as to provide the following intakes on a "mg F⁻ per kg body weight" basis:

.026 .087 .295 and .975 (mg/kg/day)

When expressed in relation to a 70 kg human, these fluoride levels are equivalent to:

1.82 6.09 20.65 and 68.25 mg/day.

The highest fluoride level is that recommended for "high fluoride therapy" of osteoporotic patients (4). The second-highest represents the approximate fluoride intake per dialysis, when patients are treated by hemodialysis using fluoridated water (6). A fluoride intake of 6 mg per day has been said to be helpful in avoiding osteoporosis in humans (7) while the lowest fluoride level is the approximate daily intake in communities where the drinking water contains essentially no fluoride (8). Non-fluoridated water was supplied ad-libitum. All dogs were vaccinated against distemper and infectious hepatitis. The experiment lasted 287 days.

Results

This report summarizes some of the physical and chemical properties of the bones of these dogs in this study. Details have been published elsewhere (9). Subsequent reports will deal with mineral metabolic balances, Ca⁴⁵ kinetics, and histochemical observations on the same dogs.

1. Pronounced osteoporosis had developed in all dogs, at the conclusion of the experiment, as revealed by pre- and post-experimental radiographic examination of canine and molar

teeth, and mandible bone. Laminae durae were no longer visible in mandible, and recession of interdental crests had occurred, along with a striking reduction in overall density. However, there were no differences due to the level of fluoride.

2. Microradiographic examination of various bones revealed that, regardless of dietary fluoride, osteoporosis was most severe in alveolar bone, then in vertebrae, and least in the long bones. Again, fluoride did not influence loss of bone.

3. Densitometry of mandibular bone was determined by measuring the transmission of a monoenergetic I^{125} photon beam as it was moved across the first molar and the ramus of the mandible. As the level of dietary fluoride increased, the mineral content of both the molar tooth and mandible decreased. This trend was statistically significant at the 2 1/2% level. The two lower fluoride conditions caused a loss of about 9% in mineral density; the 2 higher fluoride levels resulted in a loss of approximately 28% in density, when compared with the bone density in the control dogs which had not received fluoride supplementation.

4. Specific gravity and "ash content" of various bones revealed no significant differences caused by fluoride, although osteoporosis was again seen to be more severe in vertebrae than in long bones. This apparent conflict with densitometry results suggested a change in composition, but not in weight, of bone ash components.

5. Ashed bones were dissolved in 4% HCl and analyzed for calcium by atomic absorption, for phosphorus by auto-analyzer, and for fluoride by means of the fluoride electrode. As the dietary fluoride increased, the fluoride content of vertebral ash increased by factors of 1.5, 2, 4, and 6-fold. In the ash from long bones, the fluoride increment was only about one-half of this.

The ash calcium and phosphorus revealed what Schatz (10) might term a "paradoxical" effect. As the level of dietary fluoride increased, the ash calcium increased by 3%, then decreased to values 2 to 5% lower than in controls. In contrast, ash phosphorus at first decreased by 10%, then became 10 to 15% higher than in controls. Thus, as dietary fluoride was increased, the Ca/P ratio in bone ash increased by 15%, then dropped to values 10 to 15% below that of controls.

6. Beary (11) has described an experiment with rats, in which increasing dietary fluoride reduced the strength of rat femurs, although they gained in elasticity. We conducted similar tests on the dog bones, but bending and tensile strength measurements were not influenced by the level of dietary fluoride. One might conclude that, in comparison to dog bone, the rat bone is a much younger bone chronologically, and thus, its greater pliability might make it more responsive in terms of such parameters.

Conclusion

The above data warrant the conclusion that the proper prophylaxis and therapy of the bone disease with which we are dealing and which is reminiscent of human osteoporotic conditions are correct calcium and phosphorus nutrition -- not fluoride supplementation.

Bibliography

1. Krook, L.: Metabolic Bone Diseases of Endocrine Origin. In: "Ernst Joests Handbuch der speziellen pathologischen Anatomie der Haustiere", G. Pallaske, ed. Springer, Hamburg and Berlin, 1968.
2. Belanger, L. F.: Osteolysis: An Outlook on its Mechanism and Causation. In: "The Parathyroid Glands: Ultrastructure, Secretion, and Function", ed. by P. J. Gaillard, R. V. Talmadge, and A. M. Budy, Univ. Chicago Press, 1965.
3. Henrikson, P. A.: Peridontal Disease and Calcium Deficiency. Acta Odontol. Scand., Suppl. 50, 26:1, 1968.
4. Faccini, J. M.: Fluoride and Bone. Calc. Tiss. Res. 3:1, 1969.
5. National Research Council: Nutrient Requirements of Dogs, Nat. Acad. Sci. Nat. Res. Council, Washington, D. C. publ. 8, 1962.
6. Taves, D. R., et al.: Hemodialysis with Fluoridated Dialysate. Trans. Amer. Soc. Artif. Int. Organs 14:412, 1968.
7. Bernstein, D. S., et al.: Prevalence of Osteoporosis in High- and Low-Fluoride Areas in North Dakota. J. Amer. Med. Assoc. 198:499, 1966.
8. Hodge, H. C. and Smith, F. A.: Fluorine Chemistry. Vol. IV Edit. J. H. Simons Academic Press, New York, 1965, page 155.
9. Henrikson, P. A., et al.: Fluoride and Nutritional Osteoporosis: Physico-chemical Data on Bones from an Experimental Study in Dogs. The Journal of Nutrition 100:631-42, 1970.
10. Schatz, A. and Martin, J. J.: The Importance of Paradoxical Effects of Fluoride. Pakistan Dent. Rev. 14:113, 1964.
11. Beary, D. F.: The Effects of Fluoride and Low Calcium on the Physical Properties of the Rat Femur. Anat. Rec. 164:305, 1969.