Fluoride and its Relation to Bone and Tooth

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Interest in the reaction of fluoride with the mineralizing tissues has increased because of proposals to fluoridate water supplies in the interests of dental prophylaxis and because of the hope that fluoride administration might help with the treatment of certain bone diseases. Such intentions necessitate a comprehensive knowledge of the uptake and distribution of fluoride in the mineralizing tissues and of possible hazards associated with its ingestion.

I. Occurrence, Absorption and Accumulation of Fluoride

All diets and most water supplies contain fluoride but the amount ingested varies considerably (WALDBOTT, 1963), depending upon local geography and dietary habits. In Britain, a major contribution is made by tea, an average infusion containing about 1 ppm (HARRISON, 1949). Tinned fish is a rich source of fluoride and it has been claimed that in some countries fish and sea-salt constitute a large proportion of the total fluoride intake (ELLIOTT and SMITH, 1960; HADJIMARKOS, 1962).

Unless the ingested fluoride is in an insoluble form (ERICSSON, 1958; WEDDLE and MUHLER, 1957) it is quickly absorbed (HODGE, 1956) and although excretion via the kidney is very efficient, up to half the absorbed fluoride is incorporated into the skeleton, where it accumulates with time (LARGENT and HEYROTH, 1949). In many experimental studies using relatively large dosage of fluoride, it was found that the initial rapid rate of incorporation into the skeleton gradually decreased, presumably due to saturation of the sites of skeletal uptake (ZIPKIN and McClURE, 1952; WEATHERELL, 1969). At the restricted concentrations present in human diets, this does not occur and throughout life the concentration of fluoride in bone progressively increases (WEATHERELL, 1966). The bone of older individuals therefore contains a relatively high concentration of fluoride. Even in Leeds, where the concentration in the water supply is low (<0.1 ppm), the cortical bone in femora from elderly individuals can contain almost 3,000 ppm F on an ash basis. (Fig. 1.)

II. Concentration and Distribution of Fluoride within the Hard Tissues

The fluoride concentration is not the same in all parts of the skeleton and in general is highest at bone surfaces. This is perhaps the principal reason why cancellous bone, which has a very high surface/mass ratio contains 2-3 times as much fluoride as compact cortical bone (WEIDMANN and WEATHERELL, 1959; SINGER and ARMSTRONG, 1962). In the compact cortical bone itself, the surfaces usually contain the highest fluoride concentration and, in the human femur, the periosteal surface usually contains more fluoride than the endosteal surface (WEATHERELL,
Fig. 1. Fluoride concentration in bone ash from the femoral diaphysis of males and females living in a district where the fluoride concentration in the water supply was <0.1 ppm.

1969). This is probably because the amount of fluoride present in the surface region depends partly on the amount of bone formation at that surface and upon the amount of resorption taking place. In the femur, while bone formation occurs predominantly on the periosteal surface the endosteal surface is preferentially resorbed. With increasing age, this resorption gradually removes the relatively low-fluoride endosteal bone. Thus, although the femoral cortex undoubtedly accumulates fluoride with age, the rate at which the average concentration in the bone increases will be influenced by the pattern of resorption. This effect will be greater as the cortex becomes thinner with age. Resorption can also lower the average fluoride concentration of a tissue. In deciduous dentine, for instance, the average fluoride concentration increases as the tooth forms and decreases prior to shedding; because the resorption associated with the process of exfoliation removes the high-fluoride pulpal dentine (HARGREAVES and WEATHERELL, 1965) (Fig. 2a). It would be interesting to know whether all the fluoride removed during such resorptive processes finds its way into the general circulation or whether some of it is picked up locally by adjacent hard tissues. Local transfer of fluoride from one part of a bone to another has been reported from animal experiments (LIKINS et al., 1959). In the case of deciduous dentine, some of this fluoride lost by resorption from the pulpal surface might be taken up by the still mineralizing surface enamel of the underlying permanent teeth. Such fluoride transfer could make a significant contribution to the relatively high fluoride concentration of permanent enamel and the higher incidence of dental fluorosis found in permanent teeth, most of which are situated directly beneath a deciduous precursor and all of which, during eruption, come into close proximity with the overlying resorbing bone (Fig. 2b).

As in bone and dentine, the fluoride concentration in enamel is invariably highest in its surface region (JENKINS and SPEIRS, 1953; BRUDEVOLD et al., 1959). Most of this fluoride in the tooth surface