A QUANTITATIVE MEASUREMENT OF CHANGES APPEARING UNDER THE INFLUENCE OF FLUORIDE IN CORTICAL AND TRABECULAR BONE

HABILITATION DISSERTATION

SUMMARY

CRACOW 1993
Industrialised nations frequently encounter environmental pollution and a profession-related risk associated with chronic poisoning by fluoride compounds. Severest pollution is caused by aluminium foundries, phosphate fertiliser manufacturers, steel and glass works, brick producers and cryolite mines. Fluoride is characterised by a specific affinity for hydroxyapatite formation in bone tissue, accumulating throughout a person's lifetime. Excessive fluoride intake leads to an industrial flourosis that is characterised by, among others, pain and restricted motion in joints and the spine. Radiographs reveal ossification of muscle insertions, interosseous membranes and osteosclerosis, representing the most typical change associated with fluoride's actions. At present, the diagnosis of flourosis is a difficult one in as much only its initial stages are evidenced in clinical practice.

The aim of the study was a quantitative evaluation of changes in long bones and their diagnostic implications. I based my research on the radiographic evaluation of the forearm which exposes cortical and trabecular bone with precision. I evaluated changes in cortical bone by morphometric measurements taken at three different levels on both bones of the forearm. Due to a lack of available objective criteria for evaluating the constitution of trabecular bone, I developed my own method of computer analysis.

I studied a group of 1578 employees of the Skawina Aluminum Works. Their average age was 46.5 years (s=10.4) while average tenure of employment at the mill was 17.6 years (s=7.6). Orthopaedic physical examinations and radiographs of the forearm, tibia, lumbar spine and pelvis were performed on the entire group. Based on the examination's performed I evaluated the presence of flourosis according to established stages as well as degenerative changes in joints and the spine. Morphometric measurements were performed on the entire group. Additionally, in 211 workers I executed a computerised analysis of bone structure images of the distal radius. I introduced radiographic images to the memory of a high-tech image analyser, the Quantimet 570, subjecting each image to analysis by two independent software programs.

The Quantitrab program was based on the Quantimet 570 and unco-veroed non-trabecular zones on the radiograph after initial image transfor-mation. Furthermore, the program determined parameters in structures detected as their number, field, circumference, anizotropia and length. The Trabecula Program is IBM PC compatible. Work on the program began in 1981 and, with the assistance of several
researchers at Jagiellonian University, I developed an algorithm for uni-dimensional analysis based on microdensitometric measurements. That algorithm became the foundation for the presently developed program incorporating two-dimensional analysis. The Trabecula Program analyses fields of 128 x 128 pixels (0.096 resolution) and locates trabecula found in a given field according to a preprogrammed definition. It then generates a trabecular map and determines trabecular characteristics according to the following parameters: total number; width; height; area; circumference and density. Together, both programs permitted me to quantitatively evaluate radiographic bone structures and accompanying changes under the influence of fluoride.

Additionally, I performed autopsies on 57 individuals who died suddenly which constituted the control group. Radiographs in this group were taken in an identical manner as with the foundry-worker group. Bone specimens destined for further analysis were divided into two symmetrical halves for mineral contents and morphometric tests. This enabled me to describe the dependency between the radiographic bone structure image and mineral contents as well as histological morphology.

Results of morphometric measurements together with the computerised structure analysis (Quantitrab and Trabecula Programs) were compared with the control and foundry-worker group. In the latter, I measured the (relationship) dependency between analysis results from time of fluoride exposure, age, work area in the Skawina Aluminum Works as well as the type of work the employee was engaged in.

Taking into account the possibility of concomitant exposure to fluoride by foundry workers, I analysed for the appearance of flourosis and degenerative changes while also taking quantitative measurements of cortical and trabecular bone from their place of residence.

In foundry workers a total of 19.3% cases of flourosis was found: Stage O (suspected) - 13.5%; Stage OI (initial changes) - 4.8%. Advanced stages were rarely found: 15 patients (1%) with changes in Stage I and 1 patient with Stage II disease. Degenerative changes appeared with the following frequency: spondylosis 29.1%; discopathy 18.1%; osteoarthritis of the hip 9.5%; gonarthrosis 9.9% and osteoarthrosis of the elbow 3.4%.

Morphometric measurements in the control group exhibited a reduction of cortical indicators with age, being a natural consequence of widening of the bone marrow cavity with age. Foundry workers experience a cessation of this process resulting in an increase of
cortical indices. These indices were higher in individuals with diagnosed fluorosis compared to the control group.

The computerised analysis of radiographic bone structure images with the Trabecula Program in individuals with fluorosis revealed fewer and wider trabeculae. An analysis of non-trabecular spaces with the Quantitrab Program in the group with fluorosis revealed a higher number of non-trabecular spaces and a decrease in total area.

I also ascertained a relation between domicile and the appearance of fluorosis, degenerative changes as well as pathology of bone structures on radiographs. In workers with a higher exposure to fluoride contamination, a greater prevalence of fluorosis and degenerative changes is noted together with more advanced changes in bone structure (as seen on) on radiographs.

Based on results of clinical trials, experimental investigations, morphometric measurements and computer image analysis, the following conclusions can be drawn:

1. Trabecula and Quantitrab programmes for computerised image analysis enables a quantitative assessment of the bone structure on radiographs.

2. A significant relationship has been found between the bone structure parameters on the radiograph, obtained as a result of the quantitative analysis of the X-ray image, and the histomorphometric features as well as the mineral content of specimens of bones subjected to radiographic investigation.

3. Typical changes of fluorosis in trabecular bone structure on the radiograph include: increased trabecular width and decreased total amount as well as decreased trabecular density.

4. Typical changes of fluorosis structure of non-trabecular zones an increased number of non-trabecular spaces and a decrease of their area.

5. Fluoride's effects on both cortical and trabecular bone are dose-dependent. Chronic poisoning with moderate doses leads to inhibition of endosteal resorption as well as an increase in trabecular bone mass. Cortical indices are higher in individuals with advanced fluorosis compared to individuals without fluorosis.

6. Flourishes and degenerative changes occurred more frequently in workers employed in zones with higher fluoride concentration. The occurrence of changes in bone and joint of aluminium workers was due not only to their exposure in the plant but also to the contamination of the environment of place of living.
The study contains 149, 31 tables, 34 diagrams, 29 figures and 180 references.

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