ASPECTS OF BONE TISSUE IN OSTEOPOROSIS

Rodica TÖRÖK-OANCE1, Liliana VASILE2

1Department of Biology-Chemistry, West University of Timisoara, 16 Pestalozzi, 300115, Timisoara, Romania
2Department of Microscopic Morphology, Victor Babeș University of Medicine and Pharmacy Timișoara, Piața E. Murgu 2, 300041, Timisoara, Romania
*Corresponding author’s e-mail address: rodica.torok@e-uvt.ro
Received 20 November 2014; accepted 12 December 2014

ABSTRACT
Osteoporosis is the most common bone disease and its prevalence is increasing as the population grows older. The aim of this study is to highlight changes of the bone tissue which occur in osteoporosis and which affect bone quality. We identified several aspects of the bone tissue in osteoporosis such as abundant cement lines, endosteal bone resorption, the presence of thinned bone trabeculae, the presence of trabecular microfractures, the disruption of intertrabecular connectivity and marked cortical porosity. These changes influence bone quality and may contribute to increased bone fragility in osteoporosis. We also revealed periosteal apposition, which in contrast with the aspects mentioned above, has a beneficial effect on bone strength due to the addition of bone material.

KEY WORDS: osteoporosis, bone tissue, bone quality

INTRODUCTION
Bone remodelling is a process that takes place continually throughout life. It starts with the bone resorption, followed by formation and deposition of new bone in the same place in which the resorption took place (Lerner, 2006). When more bone is destroyed than is formed, bone loss occurs and it can cause osteoporosis (Adami, 2006), in osteoporosis the regenerative capacity of the bone being compromised (Durao et al, 2012). Osteoporosis is the most common bone disease, affecting millions of people worldwide, and its prevalence is increasing as the population grows older (Werner, 2000). Osteoporosis remains often undiagnosed and untreated, partly because
it is not always clinically evident until a fracture occurs (De Gabriele, 2006). Nontraumatic fractures in osteoporosis are common, they occur in weakened bones under normal mechanical stress (Damilakis et al, 2007). Bone fragility can be defined briefly as the susceptibility to fracture (Turner, 2002). Fracture risk is not always accurately assessed by osteodensitometry, a high fracture risk could be caused by an abnormal bone quality (Compston, 2006). This paper aims to highlight some changes of the bone tissue which occur in osteoporosis and which affect the bone quality.

**MATERIALS AND METHOD**
The study material consists of bone fragments of ribs and iliac crests collected at the Institute of Forensic Medicine from Timisoara. In order to obtain the histological material on which the study was conducted, we used the histological technique of permanent preparation (Raica et al, 1996; Vasile et al, 2002). The fixation was made in 10% formalin. Decalcification was performed with a working solution consisting of equal quantities of 8% standard hydrochloric acid solution and 8% standard formic acid solution. The bone fragments were maintained in the decalcification solution until softening, when they could undergo embedding, sectioning and staining operations. The fragments were embedded in paraffin and the paraffin blocks were sectioned using the microtome, then the Haematoxylin and Eosin staining and Masson trichrome staining were performed. The analysis of histological samples was carried out under an optical microscope Nikon E200 and pictures were taken using the digital microscope camera.

**RESULTS AND DISCUSSIONS**
In the present study, we observed, both in the cancellous bone and compact bone, the presence of numerous cement lines (Fig. 1), which suggest an intense bone remodelling. Cement lines indicate the deepest penetration place of bone resorption, on top of which newly formed bone tissue is accumulating. Such a highly remodelled bone is structurally weaker than the primary lamellar bone of younger adult. The cement lines are places of minimum strength (Marcus, 1996).

We noticed on some samples aspects of endosteal bone resorption (Fig. 2). Concerning the remodelling at the endosteal surface, Brown et al (1987) stated that there is an increased bone turnover in this area, and underlined its significant contribution to bone loss in osteoporosis.

Some of the other changes highlighted on the analysed material are the presence of thinned bone trabeculae (Fig. 3), as well as of microfractures (Fig. 4). The thinning of the bone trabeculae contributes to weakening the mechanical strength of the osteoporotic bone. With respect to the bone microdamage, they are also likely to occur in healthy bone, but can be repaired by remodelling, which prevents their accumulation (Clarke, 2008). Mori and Burr (1993) showed that bone
remodelling is prevalent in regions with microdamage caused due to fatigue and is subject to a direct cause-effect relationship between the occurrence of the bone microdamage and its repair. The bone has an operational microdamage threshold. If bone stress and deformations are below this threshold, remodelling units can repair the microdamage, but the stress above this threshold creates a number of microdamages exceeding the restoring capacity of bone tissue, which will accumulate over time and cause the occurrence of nontraumatic fractures (Frost, 2003).

Trabecular fractures lead to disruption of trabecular connectivity (Fig. 4B). The decrease of trabecular connectivity has consequences on the strength of the trabecular system. It has been shown that an equivalent amount of bone mass distributed in thick trabeculae, distant from each other and with reduced connection is, from a biomechanical perspective, less competent than if it were structured in several thinner and more intensely interconnected trabeculae (Davison et al, 2006).

FIG. 1. Marked bone loss by osteolysis. Multiple cement lines present within bone tissue suggesting a reactive bone response to the load of forces acting upon the bone (Masson trichrome staining, x400).

FIG. 2. Endosteal bone resorption in cancellous bone with adaptive remodelling, trabecular microfracture (HE staining, x200)
We have also noticed on certain sections aspects that suggest the destruction of some connecting trabeculae, associated with an irregularity of the remaining bone trabeculae (Fig. 5). We try to explain the presence of this trabeculae dimensional variety by a compensating mechanism, initiated as the attempt of the bone to supplement the decrease in strength due to the resorption of the connecting trabeculae. As the connecting trabecular elements disappear, the mechanical load shall rest upon the remaining trabeculae, which can become thicker as a compensating measure.

We have also highlighted some changes at bone marrow level of the cancellous bone. In this case, we have found aspects of its adipose degeneration (Fig. 6A). Our findings are similar to those of Verma et al (2002), who showed that the decrease of cancellous bone is associated with the decrease of bone marrow cellularity, while the adiposity at medullar level increases. In some cases we also noticed the presence of enlarged areolar spaces with reduced myeloid content (Fig. 6B). In other cases we observed necrobiosis of the myeloid tissue (Fig. 6C). This modifications could be explained based on the changes in the blood infusion at bone level.
Increased cortical porosity is another aspect noticed in some of the analysed histological samples (Fig. 7). Porosity refers to the prevalence and the dimensions of intracortical cavities. It has been shown that intracortical porosity undergoes a sudden increase in women after menopause, becoming significantly different from young
adults at around sixty years, while in men the increase is slower, and the difference becomes significant at about eighty years (Davison et al, 2006). Increasing porosity that occurs with age is reflected in the changes of the properties of bone material, which also occur with age, and thus the high incidence of fractures (Stein et al, 1999).

Another aspect that we have observed on some sections is that of periosteal apposition (Fig. 8). There are at least two reasons which can explain the existence of periosteal apposition. Since the estrogen has an inhibiting effect over bone formation at periosteum level, the decrease of estrogen after menopause will be followed by periosteal bone apposition. Another explanation is the fact that bone loss at endosteal level leads to increased stress within the bone tissue, which will enhance the number and / or activity of bone forming cells on the periosteal surface of the cortex, driving bone formation (Ahlborg et al, 2003). This modelling phenomenon does not occur in bone regions which lack periosteum (Bonjour et al, 1994). Periosteal apposition is regarded as an adaptive response for the purpose of conserving bone strength.
throughout ageing and endocortical bone resorption (Jepsen & Andarawis-Puri, 2012). On the other hand, there are studies that show that periosteal apposition is reduced after menopause onset (Szulc et al, 2006).

CONCLUSIONS
On the analysed histological material we identified several aspects of the bone tissue under osteoporotic conditions, which are abundant cement lines, endosteal bone resorption, the presence of thinned bone trabeculae, the presence of trabecular microfractures, the disruption of intertrabecular connectivity and marked cortical porosity. These changes influence bone quality and may contribute to increased bone fragility in osteoporosis. As more of these changes are present simultaneously, by cumulative effect, so it increases the impact on bone strength and the bone fragility. Conversely with the other aspects mentioned above, the periosteal apposition, also highlighted herein, due to the addition of bone material, has a beneficial effect on bone strength.

REFERENCES
- Jepsen, K.J., Andarawis-Puri N. 2012. The amount of periosteal apposition required to maintain bone strength during aging depends on adult bone morphology and tissue-modulus degradation rate, J Bone Miner Res, 27(9): 1916–1926.


