Monitoring of Bone Health

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Changing lifestyle and food habits are responsible for health problems, especially those related to bone in an aging population. Poor bone health has now become a serious matter of concern for many of us. In order to avoid serious consequences, the early prediction of symptoms and diagnosis of bone diseases have become the need of the hour. From this inspiration, the evolution of different bone health monitoring techniques and measurement methods practiced by researchers and healthcare companies has been discussed. This paper focuses on various types of bone diseases along with the modeling and remodeling phenomena of bones. The evolution of various diagnosis tests for bone health monitoring has been also discussed. Various types of bone turnover markers, their assessment techniques, and recent developments for the monitoring of biochemical markers to diagnose the bone conditions are highlighted. Then, the paper focuses on the potential assessment of the recent sensing techniques (physical sensors and biosensors) that are currently available for bone health monitoring. Considering the importance of electrochemical biosensors in terms of high sensitivity and reliability, specific attention has been given to the recent development of electrochemical biosensors and significance in real-time monitoring of bone health.

bone | bone remodeling | bone biomarkers | bone diseases | osteoporosis | biosensors

1. Introduction

Growing and living bone tissue forms part of the vertebrate skeleton. Bone is basically a combination of organic matrix, inorganic minerals (calcium phosphate), and vitamins that makes the structural framework. Type I collagen forms approximately 94% of the organic bone matrix. During development of skeleton, modeling and remodeling of bone occur simultaneously [1]. Bone modeling is a slow and continuous formation of bones by connective tissues until the age of adolescence, as bones are not fully developed at the time of birth. Bone remodeling is also a continuous process by which mature bone tissues are removed and replaced with newly synthesized bone. This process is also known as bone turnover. Osteogenic cells, osteoblasts, osteoclasts, and osteocytes are four different type of bone cells involved in progression of bone modeling and remodeling [2]. Osteoblasts are responsible for bone formation; osteoclasts enable the bone resorption. Bone lining cells cover bone surfaces that take minerals directly and release them in bone and osteocytes behave as natural mechanosensors [3]. During osteoblastic bone formation, procollagen I aminioterminal propeptide (PINP) and osteocalcin (non-collagenous protein) are either found in the cavities of bone matrix or in the blood circulation [4][5]. In osteoclastic resorption, collagen is degraded, and small peptide fragments are released in the blood. In addition, bone resorption markers such as cross-linked N-terminal and C-terminal telopeptides of type I collagen are released in urine. The degraded

collagen and peptides behave as biochemical markers [6]. The identification of bone biomarkers is important in the timely diagnosis of diseases such as osteoporosis, bone cancer, and infections, with their underlying processes involved. Biomarkers for bone health can be specific cells, enzymes or hormones, and gene products. The accurate recognition and appearance of specific bone biomarkers can be supportive in staging the diagnosis and effective treatment of bone diseases [7]. An electronic device is needed to process this biological information into readable output. However, it is quite challenging to connect such a device to a biological environment due to the complexity of attaching the device and processing the electronic signals. Besides, such devices are costly, require expertise, and can detect bone health only after large amounts of degradation of bone.

2. History and Development

In this regard, several studies have reported that more sensitive and real-time assessment tools are required. Research has been continuously going on in the field of biosensors for the assessment of bone health by using biochemical markers present in biological samples such as blood or urine [8]. Biosensors collect information from biofluid and convert it into an electronic signal. In recent years, literature regarding biosensor technology has shown its potential as a tool for the prognostic monitoring of abnormal changes in bone mineral density. The development of bone biosensors is one of the rapidly emerging fields of biosensors. Researchers started exploring this area in the mid-1980s and only after 2005 did work on bone biosensors started gearing up. Later on, a significant rise in publication can be observed (Figure 1), demonstrating the increasing need and importance of working on bone biosensors.

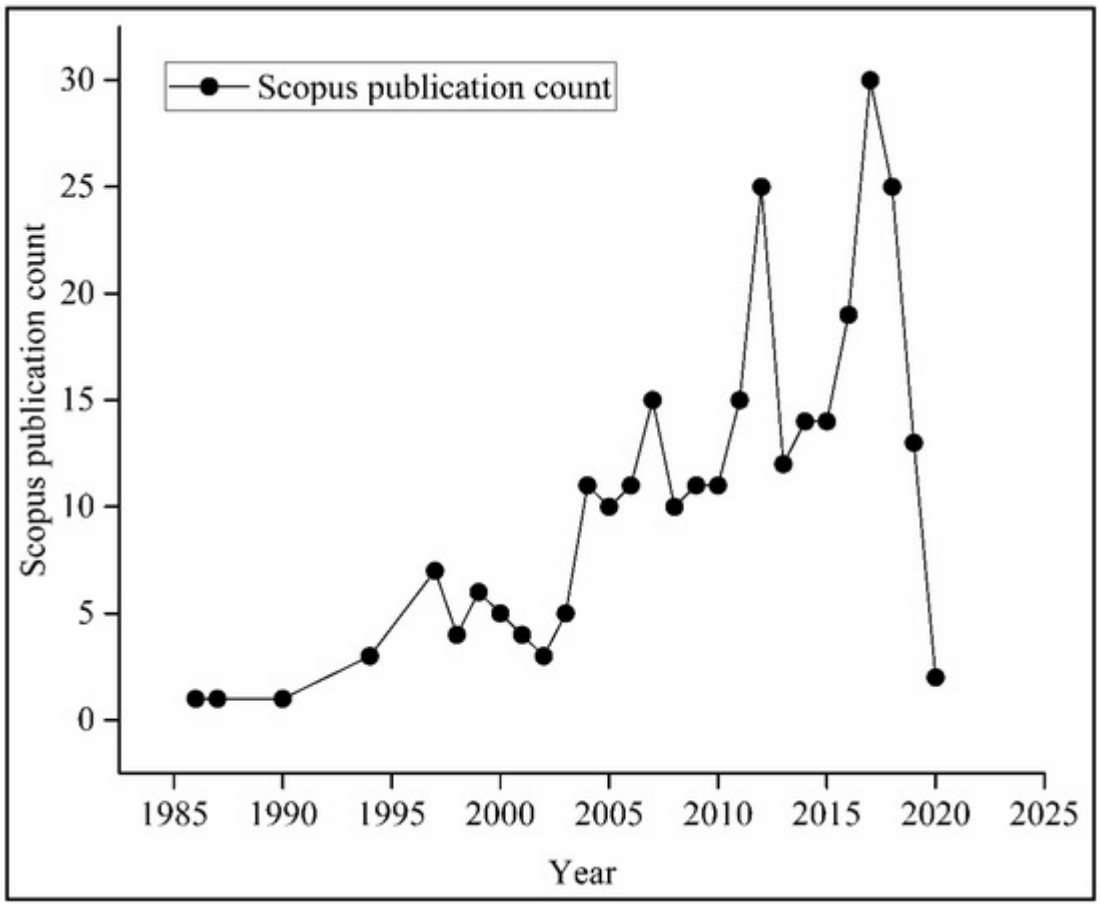

Figure 1. Research documents published on bone biosensors by year (Scopus data up to 15 January 2020).

Against the above background, this paper reviews and provides a potential assessment of recent bone biosensing techniques based on biochemical marker-based sensors. Biosensors for the detection of biomarkers to indicate bone health are increasingly becoming popular, since biomarkers are readily available in serum or urine carrying bone health information. In the following section, various methods for diagnosis based on biochemical changes associated with bone formation and resorption along with the analytical techniques for their measurements have also been reported. Finally, reports of traditional and emerging technologies on the development of biosensors for the assessment of bone health have been discussed.

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