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IMPLEMENTATION OF CORRECTNESS CRITERIA FOR THE BONE STRUCTURE ANALYSIS BY MEANS OF A HAND-HELD X-RAY SYSTEM

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1. Introduction

The social costs of osteoporosis are huge and keep growing because of increased life expectancy. Densitometry represents the current gold standard for osteoporosis diagnosis and a low bone mineral density is considered to be associated with a higher risk of fracture. However, densitometry alone has been shown to be inadequate to predict fractures in 40-50% of cases, since these occur in people who do not have a significant reduction in bone density.

In fact, trabecular bone tissue is extremely complex (Fig.1) and its shape and function are influenced by the constant physiological or pathological modifications that occur during lifetime. In particular, its mechanical properties – and consequently its resistance – are strongly influenced not only by the composition (mineralization and density but also, to a large extent, by the trabecular microarchitecture, that is by the spatial arrangement of the internal structure of bones.

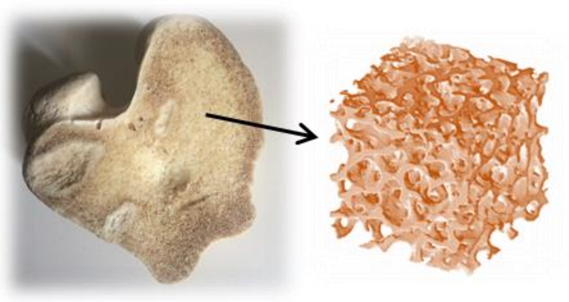

Fig. 1. Trabecular bone and micro-CT 3D reconstruction of its architecture.

Although trabecular bone accounts for only 20% of our skeleton, the quality of bone structure is an additional key factor responsible for its resistance. Measuring bone density alone, therefore, is insufficient to assess the bone's load-bearing capacity, and the spatial arrangement of the trabecular structure should be assessed, too.

Hence the need to develop innovative and low-cost diagnostic methods that can be used together with the consolidated systems.

2. The BESTEST®

The BESTEST®, Bone Elastic Structure Test, applies a patented technique [1] to virtually simulate the application of compressive loads on the trabecular architecture's reconstructions obtained from digital radiographs of the patient. Thus, the bone structure alterations due to osteoporosis can be detected and quantified, providing a low cost complement to the tools currently in use and assuring a better management of the patient [2].

Specifically, the BESTEST® processes the radiographic images of first proximal epiphyses of the non-dominant hand. The radiograms are acquired by a hand-held portable x-ray system equipped with a digital sensor like, for example, the NOMAD2PRO®, a lightweight (2.5 kg) device originally developed for intraoral radiography and the Gendex GXS-700 (Fig.2).

Fig. 2. Hand-held system (A) and digital sensor (B).

3. Hand-held radiology implications.

The recent introduction of handheld portable X-ray devices has brought new concerns in order to avoid any additional risk to the operator, patient or third party, compared with conventional radiography [3, 4]. While in certain cases these systems have been proved to present risks that are no greater than with standard systems [5], and despite the use of a digital sensor ensuring that the required dose is minimized according to the ALARA (As Low As Reasonably Achievable) principle, the following issues must still be addressed in order to ensure a complete safety and repeatability of the exam:

1. the position of the handheld X-ray device relative to the operator has a significant effect on the overall radiation exposure received by the operator and it is crucial that the operator is positioned within the conical protective area, shown in Fig.3, created by the antiscatter shield with the beam in horizontal position [5];
2. with hand-held devices there is always a risk of misalignment and of displacing the X-ray units during exposure, that must be avoided;
3. patient protection requires the use of the smallest possible field size, besides the already mentioned choice of the sensor.
4. last but not least, the acquired image quality depends on the interaction among the X-ray device, exposure time, exposure geometry and image receptor. Given the fixed exposure time prescribed by the BESTEST® protocol, caution must be used to ensure a correct positioning of the sensor, which may affect the results of the subsequent image elaborations.

4. Results

A special stand and a customized sensor holder have been designed in order to solve the aforementioned issues, as shown in Fig.3.

Fig. 3. Configuration of stand and sensor holder during the radiographic procedure.

The BESTEST® protocol requires the use of a rectangular collimator to further limit radiation exposure and to ensure the correct positioning of the beam with respect to the proximal epiphysis, that must appear at the center of the radiogram.

In Fig.4, two radiographic images of the same proximal epiphysis acquired respectively before (a) and after (b) implementation of the correctness criteria are depicted.

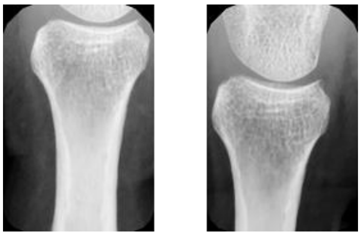

Fig. 4. Radiographic images before (a) and after (b) implementation of the correctness criteria.

5. Remarks

- The stand correctly positions the operator with respect to the beam and behind the conical protective area, while allowing an easy operation of the equipment.
- By completely supporting the weight of the equipment, the stand also ensure stability of the equipment during acquisition.
- The customized holder minimizes patient's discomfort, while ensuring a correct positioning of the finger with respect to the sensor, and at the same time minimizing patient's discomfort.
- Safety for patient and operator and repeatability of the exam have been improved.

References

[1] Cosmi F. USA Patent 7,386,154B2, 2008.

[2] Cosmi F., Numerical Evaluation of Trabecular Bone Alterations: A Cell Method Application, MCB,12 (2), 2015, pp.87-105.

[3] Berkhout W.E.R. et al. Justification and good practice in using handheld portable dental X-ray equipment: a position paper prepared by the European Academy of DentoMaxilloFacial Radiology, Dentomaxillofac Radiol, 44, 2015.

[4] Makdissi J. et al. The effects of device position on the operator's radiation dose when using a handheld portable X-ray device, Dentomaxillofac Radiol, 45, 2016.

[5] Goren A.D. et al., Radiation exposure with the NOMAD portable X-ray system, Dentomaxillofac Radiol, 37(2), 2008, pp.109-112