PRELIMINARY DESIGN OF AN X-RAY IMAGING SYSTEM FOR THE BONE STRUCTURAL INDEX EVALUATION

FRANCESCA COSMI[1], CAMILLA RAVALICO[1], MAGDALENA TOMANIK[2]

[1]University of Trieste, Department of Engineering and Architecture, Via A. Valerio 10, 34127, Trieste, Italy
e-mail: cosmi@units.it, camilla.ravalico@phd.units.it
[2]Wrocław University of Technology, Department of Biomedical Engineering, Mechatronics and Theory of Mechanisms, Faculty of Mechanical Engineering, Łukasiewicza 7/9, 50-371 Wrocław, Poland. e-mail: magdalena.tomanik@pwr.edu.pl

1. Introduction

Osteoporosis (OP) is a very common disease in which the bones become weak and are more likely to break. Despite the huge costs in the EU and worldwide [1-3], the majority of individuals who have sustained an osteoporosis-related fracture or who are at high risk of fracture are left untreated [4]. In effect, OP is a silent disease, with bones deteriorating without warning until fracture, and the current screening modalities are not significantly better than age alone [5,6], also because they consider only the bone quantity (bone mineral density, BMD) and the clinical risk factors, but disregard the bone quality, that is the structural soundness of the trabecular arrangement, which can be evaluated by simulations on virtual models. While 3D models can only be used in research because of high costs, an alternative approach based on the acquisition of planar hand radiograms for bone behaviour simulations, and the use of a Structural Index, SI, for bone quality ranking, have been developed at the University of Trieste [7-11].

In this work, we discuss the preliminary design of a portable low dose X-ray hand scanner to be used as a low cost, user-friendly device (Fig.1) for imaging the trabecular pattern in the proximal phalanges of the non-dominant hand and for providing a radiogram suitable for the SI evaluation.

2. Methods

In this work, two different approaches were investigated:

1. design of a dedicated prototype system for short low-dose scans in the specific hand ROI.
2. use of an already existing dental X-ray scanner and create an adequate measuring set-up.

Fig. 1. *An example of user and prototype.*

3. Results

In the first approach, the following components of a diagnostic x-ray systems must be assembled: tube housing, x-ray controls, x-ray high-voltage generators, x-ray tables, cradles, film changers, beam-limiting devices.

In the second solution, taking advantage of the wide range of different commercial systems available for dentistry allowed us to find cameras with adequate X-ray source parameters and detectors with a sufficient active area. Small portable low dose dental scanners of the last generation can be then integrated in a specially designed set-up.

Taking into account the hand anatomy and the established procedures for hand BMD, the Region Of Interest, ROI, to be used in the SI assessment includes the proximal epiphyses of the three central fingers. Measurements of different palms showed that the average width is in the 60-75 mm range, with a thickness between 10mm and 25mm, but the area actually investigated in each simulation is about 25x30mm^2.

With regards to the detector choice, again there are two possible approaches. The first solution, Fig.1 continuous line, captures all fingers at the same time with no need for a precise positioning of the palm, but the relatively large active area of the sensor can result in an increase in system dimensions and costs. In the second solution, Fig.1 dashed line, small detectors with a dimension limited to the ROI in the phalangeal epiphysis were considered. Similar detectors are also common in dental practice. The challenge here is the requirement of sensor/hand multiple positioning. Moreover, the system could be unsuitable for male patients with the biggest hands.

With regards to the final quality of the images, conventional X-ray systems have been shown suitable for the SI evaluation in [10, 11]. In a preliminary evaluation of the dental system adequacy, the obtained X-ray images were analyzed and showed that the images are also fit for the SI evaluation.

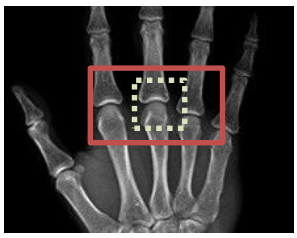

Fig. 2. *X-ray image of the ROI. Continuous line: big sensor, dashes: small sensor.*

Last, but not least, the portable dental systems already available on the market do no need to be certified.

Table 1 summarizes these findings.

Tab. 1. *Comparison of the two solutions.*

	X-ray tubes	**Dental cameras**
Tube Voltage	70-100 kV	60-70 kV
Target Angle	5°-19°	12°-20°
Focal Spot	0.5-1.8	0.3-0.8
Sensor active area [mm]	130x130* 25.5x25.5*	27x36
Price	~ 10-12 k$	~ 5-8 k$
Certification	Yes	No

*depending on approach

4. Conclusion

Along with increasing numbers of OP patients, new techniques for early and inexpensive diagnostic of disease are needed. In the present study we describe two possible solutions for the design of a portable system for bone quality evaluation, which can be placed for example in the doctor's office. Taking under consideration the pros and cons of each approach, there are good reasons for using existing portable dental systems that they are already assembled and FDA approved.

References

[1] X. Lin et al., JCIA, **10**, 2015, 1017-1033.
[2] B. R, Dawson-Hughes, et al., JBMR**,** **22**, 2007, 3, 465-475.
[3] A. Svedbom et al., Arch Osteoporos, **8**, 2013, 137.
[4] C.Fox et al., CRBMM, **13**, 2015, 1,53–60
[5] Xuezhi Jiang et al., Obstetrics & Gynecology, 2013, 1040-1046
[6] T.LN Järvinen et al., BMJ, 2015, 350:h2088
[7] F. Cosmi, 2008, USA patent No. 7,386,154B2
[8] F.Cosmi, et al., Acta Bioeng Biomech, **9**, 2007, 2, 35-39.
[9] F.Cosmi, et al., IV ICMOBT, Hawai'i, USA, 11-15.12.2011
[10] F.Cosmi, et al., JMBBM, **29**, 2014, 517-528
[11] F. Cosmi, MCB, accepted