BDAT – a robust tool to examine bone fragility

- As the global population ages, there is an increased risk of fragility fractures, in particular hip fractures.
- Dual x-ray absorptiometry (DXA) is the current gold standard for detecting patients at risk of fragility, although many patients are left misdiagnosed.
- Is there another method to detect the risk of fragility with accuracy?
- Dr Jean-Gabriel Minonzio from the University of Valparaíso, Chile, and collaborators designed and tested a bi-directional axial transmission (BDAT) device, which uses ultrasonic guided waves to estimate the risk of fragility.
- This robust technique can be easily applied in every hospital.

BDAT measures the thickness and porosity of forearm and leg cortical bones in about five minutes.

Bone fragility remains a worldwide problem and is a huge burden in patients' lives, hospitals, and healthcare in general. Among the common bone fractures are hip fractures – a major consequence of osteoporosis, a health condition that weakens the bones, making them fragile and more likely to break. As the world's population gets older, osteoporosis rates are expected to double between 2018 and 2050. Consequently, researchers estimate that hip fractures will reach more than 10 million cases per year globally. Fortunately, many hip fractures are potentially preventable, although it is very crucial to identify osteoporosis as their cause.

Until today, dual x-ray absorptiometry (DXA) is most commonly used as the 'gold standard' to detect patients at risk of fragility fractures. However, it is not perfect: most patients suffering from fractures are not classified as osteoporotic, mainly because DXA doesn't capture the material and structural properties of the bones, which are crucial to distinguish osteoporotic bones from the non-osteoporotic. In particular, DXA cannot detect changes located at the cortical bone (the external hard layer of all bones, which is the main contributor to mechanical strength of the bones). That is why there is a huge need for another method to predict bone fracture risk by assessing different bone characteristics.

Dr Jean-Gabriel Minonzio from the University of Valparaíso, Chile, and colleagues designed a novel device, called BDAT (bi-directional axial transmission), which uses ultrasonic guided waves to estimate the risk of bone fragility. The team successfully tested this non-invasive method in a clinical setting.

Current limitations in hip fracture detection

DXA is a procedure that uses x-rays to measure the amount of calcium and other minerals found in the bone. It provides a parameter called bone mineral density (BMD) extracted from the calibrated grey level of the radiographic image. The amount

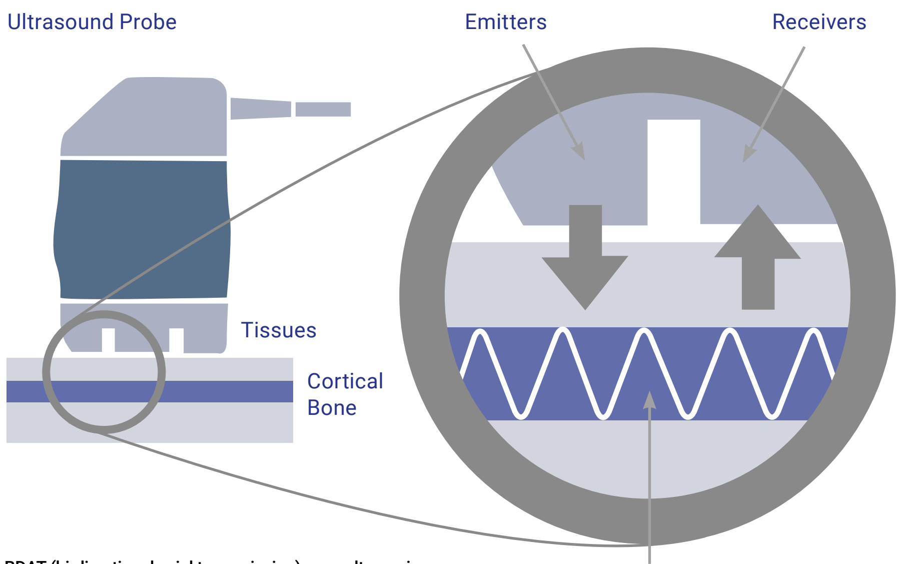
BDAT's failure rate was less than 10%.

of these minerals reflects on the quality of the bone – ie, how strong and thick it is – and the BMD value is used to diagnose if the patient suffers from osteoporosis or not. However, most patients with bone fractures are left misdiagnosed and are not classified as osteoporotic. Additionally, the accessibility to DXA is limited in many countries and often restricted to large cities. Minonzio and his team believe that among the DXA alternatives, quantitative ultrasound devices can be by far superior to DXA, mainly

due to their portability and lower price. Moreover, ultrasound being mechanical waves, they are naturally sensitive to both geometrical and mechanical properties of the inspected material. Quantitative ultrasound therefore has the potential to be used as a 'thermometer' of the bone quality.

Employing ultrasound devices

Minonzio and colleagues used BDAT to estimate the thickness and porosity of cortical bones at the forearm (radius) and leg (tibia) in about five minutes per body part. This custom-made guided wave technology includes two specialised probes for forearm



BDAT (bi-directional axial transmission) uses ultrasonic guided waves to estimate the risk of bone fragility.

Fracture risk assessment could be performed in a robust, quick, and reproducible way.

and leg measurements, an electronic device for signal transmission and reception, and a human-machine interface for real-time guided display and operator guidance. Minonzio successfully used BDAT in a clinical setting in a pilot study considering two groups of postmenopausal women, with or without history of fragility fractures. 201 postmenopausal women were included in the study taking place in Cochin Hospital, Paris, France, between April 2014 and November 2015, where Minonzio and coworkers gathered information regarding two important parameters: cortical thickness (Ct.Th) and porosity (Ct.Po). Among their findings, Ct.Po was the most important parameter which could help the researchers discriminate patients with any types of fragility fractures from the control group (patients without fragility fractures) with a classification ability similar to the gold standard DXA. In addition, cortical thickness was found to be a good predictor for the subgroup of patients with hip fragility fractures.

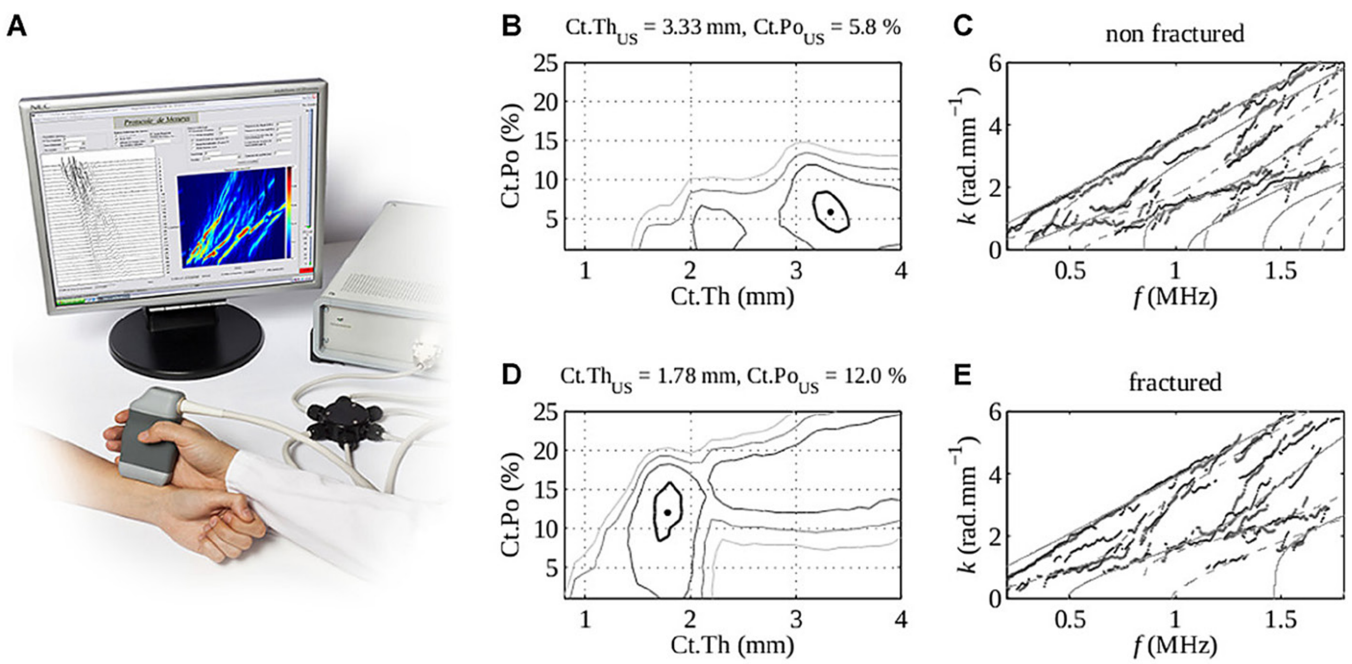
In a second cross-sectional study published in 2022, the group examined whether the device could be used in a clinical environment, studying 106 patients in Marien Hospital and St. Anna Hospital in Herne, Germany. In the first study, the device was used by laboratory staff, whereas in the second study, the device was used by nurses, after a two-day training session. The device's failure rate was less than 10% – this was significantly lower than their previous study (20%), mainly due to the improvements of the guiding interface associated with real-time monitoring of the measurement quality. This study confirmed that the device could be easily used in a clinical environment and that the ultrasonic parameters were particularly helpful to detect non-vertebral fragility fractures, which include hip fractures. In this case, the BDAT classification ability was slightly better than the gold standard DXA.

In a study taking place in the UK, published in the same year, Minonzio and colleagues tried using the device in patients undergoing hip arthroplasty – in other words, hip replacement – where the damaged bone and cartilage are removed and replaced with prosthetic components. This study suggests that the BDAT device could help the surgeon to choose the best prothesis adapted to each patient depending on their bone quality.

Furthermore, in a recent study – soon to be published and presented at conferences – the group examined patients from Chile aged over 50 years old with and without hip fragility fractures. The device's robustness and user friendliness have been improved once again, confirming that the fracture risk assessment clearly suggests the benefit of the affordable and transportable device for routine use, with performance similar or better than the gold standard.

Minonzio and his group now want to take a step further and use the BDAT device on a larger scale in a clinical environment, in particular in countries where DXA is not widely used. In that way, the fracture risk assessment could be performed in a robust, quick, and reproducible way giving a full image of the clinical status of the bones, especially in people suffering from osteoporosis and fragility fractures.

Photo credit: Minonzio, et al, (2019), doi.org/10.1002/jbmr.3733



(A) Illustration of the BDAT prototype device. (B-E) Examples of guided wave measurements for a nonfractured patient (B, C) and a patient with a nontraumatic shoulder fracture (D, E).

Personal response

What inspired you to conduct this research?

I did my PhD in physical acoustics, studying the ultrasonic scattering of controlled objects such as cylinders or spheres, without application in mind. I was interested in finding an application to the analysis tools developed during the thesis. Measuring guided waves in bone and then extracting robust parameters of clinical interest was a major challenge. It took more than a decade to be successfully solved.

What other bones could be examined using the BDAT device?

The BDAT device in its current form has been designed to be used on long bones without too much surrounding soft tissues, ie, for the two main sites, the forearm and lower leg. One can imagine that the device could be adapted to bone surrounded by more soft tissue, such as midshaft humerus (upper arm) or femur (thigh bone).

Could the BDAT device be used to detect bone infections?

I am not sure. One has to study if the infection could modify the geometrical or elastic properties of the cortical bone. But usually, infections appear rapidly compared to bone changes, which take more time. However, this may be an interesting direction of investigation.

How do you intend to progress this research?

The device could be even more portable using the latest progress in electronics. It could be integrated in a tablet, making it possible to measure patients with low mobility or in remote locations. Progress in telemedicine could also be used to link a specialist to different mobile devices and operators. Latest methods in explainable artificial intelligence (XAI) are currently being tested. It would potentially help to find novel discriminative parameters, without the need for physical modelling, learning from the measured data. The biggest challenge is to measure more patients in different populations to convince even more of the interest of the device.

Can you identify all the possible fragility fractures of the bone using the BDAT device?

The BDAT device is meant to measure cortical bones. Thus, it is not expected to be sensitive to fragility fractures usually associated with trabecular bone tissue (interior part of the extremities of long bones such as radius or tibia, and inside the vertebra and heel), such as vertebral fracture. This has been confirmed during the clinical studies.

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Bio

Jean-Gabriel Minonzio received his PhD in physical acoustics from the University Denis Diderot, Paris (2006). He has been involved in the clinical measurement of guided waves in cortical bones with the Laboratoire d'Imagerie Biomédicale (LIB) associated with Sorbonne Université, CNRS, and INSERM, and is co-founder of the startup Azalée, Paris. He is a Full Professor at the School of Informatics Engineering, Universidad de Valparaíso. Minonzio is also head of the PhD programme in Applied Informatics and member of the Center for Research and Development in Health Engineering (CINGS-UV) and of the PhD programme Sciences and Engineering for Health.

Further reading

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