The paper discusses the development of a methodological framework for assessing bone mechanical quality in orthopaedics. The main objectives are to identify and develop techniques for ex vivo characterization of mechanical properties of bones, focusing on measuring bone characteristics that are relevant to orthopedic surgery. Both quasi-static and dynamic techniques are considered. The implemented methods will be used to measure patients' biopsies, leading to innovative experimental protocols and an increase of knowledge on the role of bone quality in orthopedic surgery.
Subject

CONTEXT
Each year, thousands of patients undergo surgery aiming at repairing joints (hip, knee, shoulder, etc.) or correcting spine's curvature. For instance, more than 100000 patients benefit in France, each year of hip surgery. Implant's design and surgical protocols are continuously being adapted to improve the patient's quality of life. As with the increase of life expectancy, patients live longer with an implant, the long term mechanical anchorage of the implant within bone is a major issue. For a successful surgery, the choice of a specific implant adapted to the patient's anatomy and bone quality, and the precise positioning of the implant during surgery, are of prime importance.

Modern surgery makes extensive use of three-dimensional imaging methods and image processing software to perform pre-operatively a planning of the surgery. This planning helps the surgeon selecting the correct implant size, surgical technique and also may help in the operating room to achieve a precise positioning of the implant. Use of planning software is not the norm but is increasing.

However, planning methods practically do not take into account the quality of the bone. Bone quality is defined as the sum of characteristics that affect the resistance of bone to fracture: bone mass, macro- and microarchitecture, tissue composition, and microdamage.

OBJECTIVE
The long term objective of the thesis work is to propose guidelines for the orthopedic surgeon to take into account the patient's bone quality. This objective contributes to the customization of health care to each patient, which is a major modern trend in medicine.

The specific objective of the thesis work is to identify and develop techniques for the characterization of mechanical properties of bone to document bone characteristics relevant to orthopedic surgery. Both quasi-static mechanical techniques and dynamic techniques (vibrational, ultrasonic wave propagation) will be considered. During the thesis, the implemented methods will be used to measure patient's biopsies.

PRELIMINARY WORKS
The PhD student will work in the Laboratoire d’Imagerie Biomédicale (LIB), in the research group (about 15 people including PhD students and post-doc) working at the mechanical characterization of bone. The group has an experience of more that 20 years in this area and is a world leader for the characterization of bone with ultrasound.

The group also conducts basic fundamental research aiming to understand the structure-function relationships in bone and the structural and compositional determinants of bone mechanical properties. The group has an established collaboration with Hopital de la Pitié Salpêtrière with ongoing works on the planning of hip surgery and spine surgery.

In the recent year, LIB have developed resonant ultrasound spectroscopy to measure bone stiffness. This is one the technique that will be further developed during the thesis.

WORK PROGRAM
Year 1-2
Training in image processing (CT, MRI). All mechanical analyzes will be coupled with imaging for surgical planning (in vivo) and high resolution imaging on biopsies.

- Design of a mechanical setup for bone biopsies to assess mechanical parameters. A universal testing machine will be adapted to conduct traction/compression/torsion/pull-out tests representative of in vivo loading of bone in the vicinity of implants.

- Developing resonant ultrasound spectroscopy to measure trabecular and cortical bone tissue properties. This technique will provide a unique means to assess the elastic quality of bone biopsies.

- Preliminary tests and validations of the developed techniques. Numerical simulation (finite elements) will be extensively used to aid the development of the setups.

**Year 3**

- Mechanical testing of the biopsies. The collection of bone biopsies will start during Year 1. They will be stored until testing in Year 3.

- Establishing a relationship between bone mechanical quality, planning information (essentially pre-operative bone mineral density) and clinical information (patient's characteristics and clinical outcome of surgery at 0.5-2 years). Both statistical and causal relationships will be investigated.

**EXPECTED RESULTS**

The work will lead to:

- Innovative experimental protocols to assess the mechanical quality of bone biopsies. These protocols may be patented and used in several laboratories.

- An increase of knowledge on the role of bone quality in orthopedic surgery. The work will establish a reference database documenting the inter-individual variations of bone mechanical properties for patients of various clinical backgrounds.

**CANDIDATE**

The ideal candidate has excellent academic records and a Master degree in Mechanics and/or Acoustics. The candidate should have a strong interest for the application of the laws of mechanics to solve biomechanical problems of clinical interest. He/she will have strong interactions with the surgeons.

**CONTACT**

For further information and application, contact Quentin Grimal (quentin.grimal@upmc.fr; 01 44 41 49 72). Applications should include a CV, a motivation letter, and a list of references.

**REFERENCES**


