Promotors & advisory committee

Prof. Dr. Emmanuel Audenaert
BioCAT, Department of Human Structure And Repair, Ghent University
Prof. Dr. ir. Gunther Steenackers
InViLab, Department of Electromechanics, University of Antwerp
Prof. Dr. Arne Burssens
Department of Orthopaedic Surgery and Traumatology, Ghent University Hospital
Prof. Dr. ir. Amélie Chevalier
Cosys-Lab, Department of Electromechanical Engineering, University of Antwerp
Prof. Dr. Jan Victor
Department of Orthopaedic Surgery and Traumatology, Ghent University Hospital

Examination Members

Prof. Dr. Patrick Calders (Chair)
Department of Rehabilitation Sciences and Physiotherapy, Ghent University
Dr. Claudio Belvedere
Laboratorio di analisi del movimento e valutazione funzionale protesi, IRCCS Istituto Ortopedico Rizzoli, Bologna (Italy)
Prof. Dr. ir. Stijn Derammelaere
Cosys-Lab, Department of Electromechanical Engineering, University of Antwerp
Prof. Dr. Gwen Sys
Department of Human Structure and Repair, Ghent University
Prof. Dr. Luc Vanden Bossche
Department of Rehabilitation Sciences and Physiotherapy, Ghent University
Prof. Dr. Stijn Verwulgen
Department of Product Development, University of Antwerp
Prof. Dr. Erik Witvrouw
Department of Rehabilitation Sciences and Physiotherapy, Ghent University

Contact

Aline Van Oevelen

Human Structure And Repair

aline.vanoevelen@ugent.be

ORCID: 0000-0002-2389-0080

Curriculum Vitae

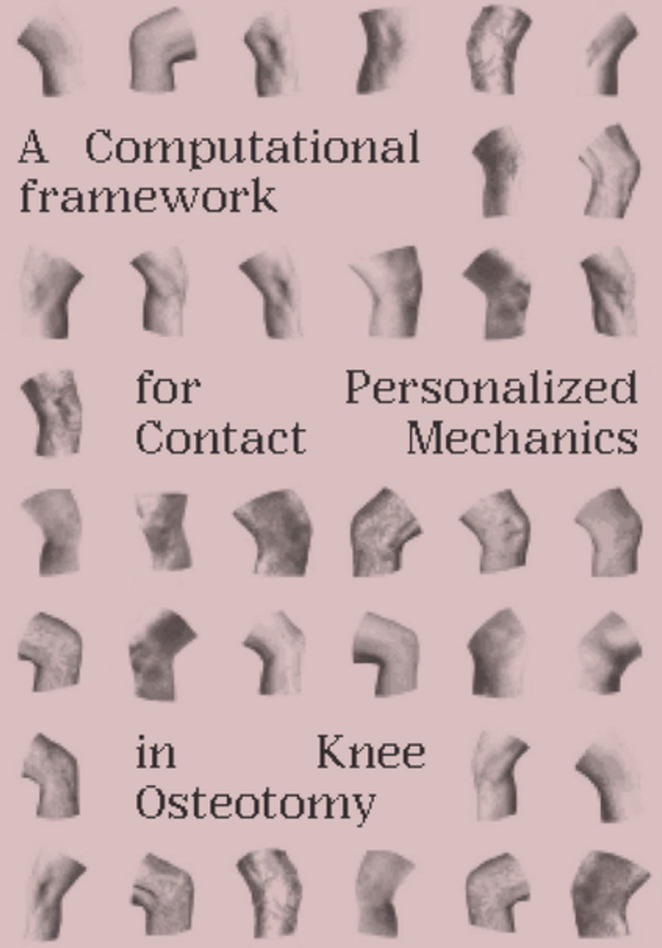
2021-2026	PhD Candidate Ghent University & University of Antwerp
2020-2023	Master of Medicine in Specialist Medicine (Orthopaedic Surgery) Ghent University
2017-2020	Master of Medicine in Medicine Ghent University
2019-2020	Sports Medicine Ghent University
2014-2017	Bachelor of Science in Medicine Ghent University

Funding

fwo **PhD fellowship fundamental research**

FACULTY OF MEDICINE AND HEALTH SCIENCES

Universiteit Antwerpen
Faculteit Toegepaste Ingenieurswetenschappen



A Computational framework for Personalized Contact Mechanics in Knee Osteotomy

Aline Van Oevelen
2025 - 2026

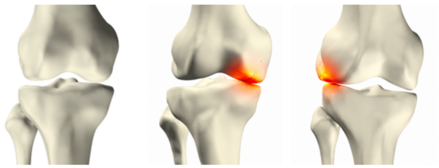
Dissertation submitted to obtain the degree of Doctor of Health Sciences (Ghent University) and
Doctor of Philosophy in Applied Engineering (University of Antwerp)

GHENT UNIVERSITY

University of Antwerp

Background

Knee osteoarthritis (OA) is a leading cause of global disability. Frontal-plane malalignment (X- or O-legs) contributes to OA onset and progression, shifting excessive load to one side of the joint, accelerating cartilage breakdown.



Neutral *O-legs* *X-legs*

Joint-preserving osteotomies realign the leg to unload the diseased compartment. However, standard surgical planning relies on static 2D X-rays and surgeon intuition. While 3D Finite Element Analysis (FEA) can model cartilage stresses, its high computational cost and reliance on non-weight-bearing imaging limit clinical use.
To bridge this gap, this PhD research introduces inverse Discrete Element Analysis (iDEA): a fast computational framework calculating personalized knee contact stresses from 3D Weight-Bearing Computed Tomography (WBCT).

Why iDEA Matters?

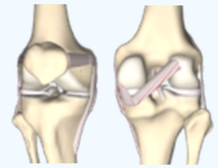
- **1 in 5 patients are dissatisfied** with total knee replacements making early, joint-preserving intervention critical
- iDEA leverages **WBCT** to assess the joint in its natural, weight-bearing state
- It replaces complex FEA with **spring-based** Discrete Element Analysis (DEA) for fast, personalized contact stress analysis

Objectives

This PhD research aimed to develop an inverse Discrete Element Analysis (iDEA) framework for estimating knee joint contact stresses from WBCT data in knee osteotomy patients by addressing three challenges:

I: Healthy Knee

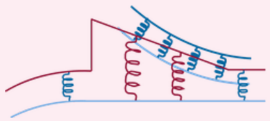
1 Personalized Soft Tissue Model



Predict the soft tissue anatomy from WBCT data, using Statistical Shape Modeling (SSMg)

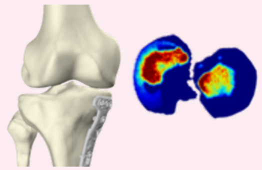
II: Osteoarthritic Knee

2 inverse Discrete Element Analysis (iDEA)



Replace soft tissue structures by springs to calculate knee contact stresses based on spring compression

3 Clinical Translation



Use iDEA to compare pre- and post-osteotomy contact stresses with control data

Key findings

I: Healthy Knee

1 Personalized Soft Tissue Model

Sub-millimeter precision was achieved for cartilage and ligament inclusion. Consistent meniscus modeling across all tested knee bending angles was observed.

II: Osteoarthritic Knee

2 inverse Discrete Element Analysis (iDEA)

The iDEA model quantified personalized mean and peak contact stresses, as well as the contact area under load.

3 Clinical Translation

Using iDEA, a trend towards normalization in contact stresses and contact area was observed comparing pre- and post- osteotomy cases with control subjects.

Conclusions

The personalized iDEA workflow enables fast estimation of knee cartilage stress, addressing gaps in conventional orthopedic planning. Its design supports clinical translation by enabling patient-specific assessment to inform surgical decision-making.

Full Dissertation