Integrated project Engineering Technology 2024-2025

DESIGN OF A MACHINE FOR SAFE ADMINISTRATION OF BONE CEMENT IN VERTEBROPLASTY

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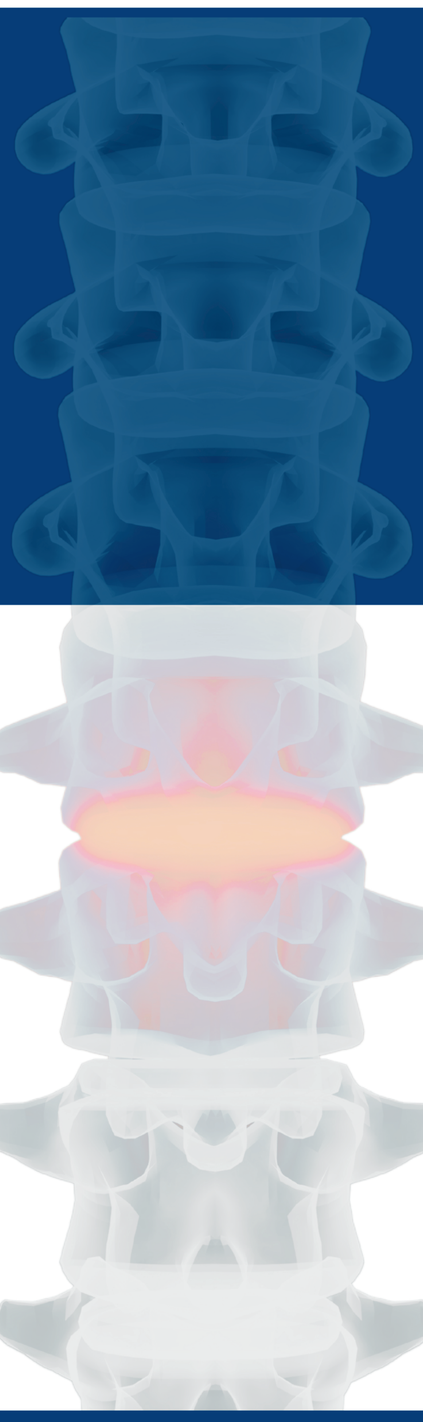
Bridging programme for Master of Electromechanical Engineering Technology

Background

Ziekenhuis Oost-Limburg and prof. dr. Jan Vandevenne

This bachelor thesis is conducted in collaboration with prof. dr. Jan Vandevenne, an interventional radiologist at Ziekenhuis Oost-Limburg (ZOL). As part of his clinical work, Prof. Vandevenne frequently performs **vertebroplasty** procedures, which are the central focus of this project.

ZOL is the largest hospital in the Limburg region and is recognized for its advanced care in neuroradiology and musculoskeletal imaging.



Vertebroplasty

Vertebroplasty is a medical procedure used to treat painful vertebral compression fractures.(1) It requires continuous internal imaging through ionizing radiation, which cannot be avoided during the procedure. Even with protective equipment, current techniques still lead to direct exposure of the physician's hands and forearms to radiation.
At ZOL, vertebroplasty is performed on a regular basis. Because of this, the radiologist is exposed to radiation repeatedly over time. This ongoing exposure increases the risk of health problems, such as changes in DNA that could eventually lead to cancer.(2)

Problem definition / objective

Problem

The current working method in vertebroplasty causes repeated and direct radiation exposure to the physician. This creates serious safety concerns for healthcare workers involved in these procedures.

Objective

- Design a device that enables **safe and effective** vertebroplasty
- Ensure **full control** over all critical procedural parameters
- Allow **continuous fluoroscopic imaging** during the procedure
- Eliminate or **minimize radiation exposure** for the physician to near zero

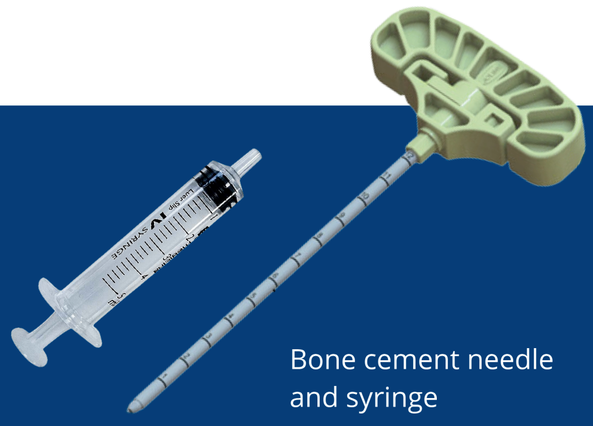
Key design requirements

- **Safe distance from radiation source**
  The physician must operate the system from a minimum distance of 3 meters, in accordance with the inverse square law to significantly reduce radiation exposure.
- **Mechanical feedback**
  The system must provide tactile (force) feedback, allowing the operator to feel the resistance during cement injection for precise and safe control.
- **Efficient cement loading**
  The cement delivery system must be designed to allow full loading of a bone cement syringe within 1 minute to meet clinical workflow demands.

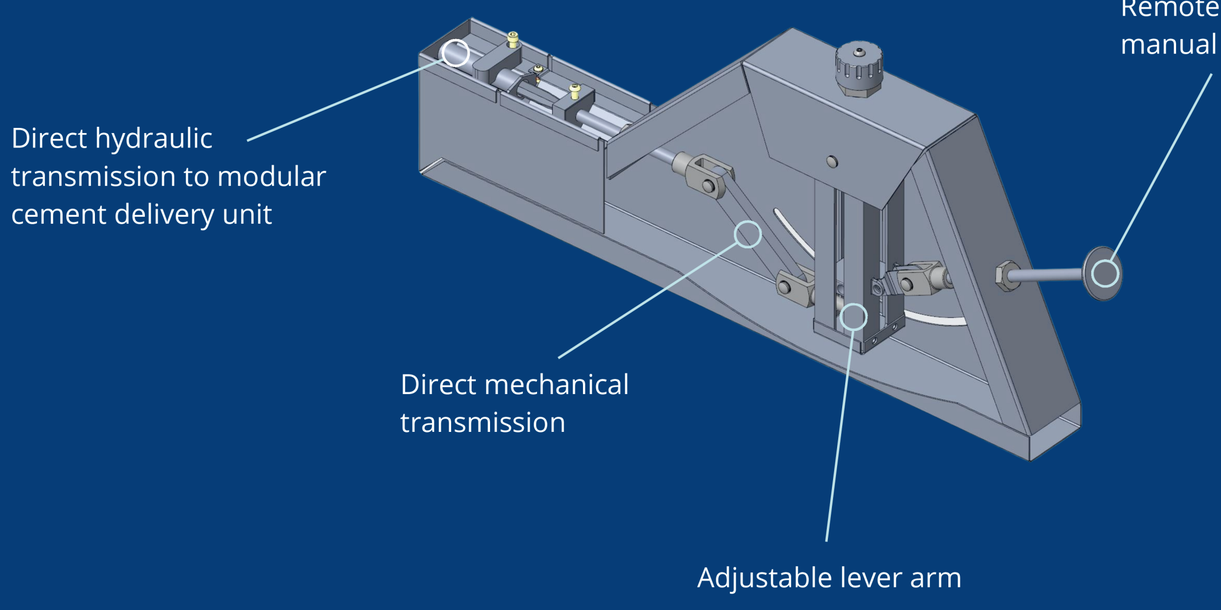
Technical development

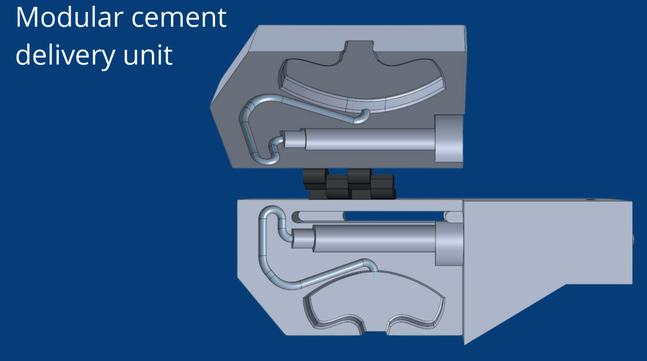
To meet the design requirements in a cost-effective manner, a custom machine was developed with the following features:

- The physician operates the system from a safe distance using a manually driven input mechanism.
- The machine uses continuous mechanical and hydraulic linkages to transmit force and feedback without electronic components.
- An adjustable lever system is integrated to fine-tune the required input force, enhancing ergonomic control during injection.
- The system includes a dedicated module that holds the bone cement syringe, allowing for quick replacement and minimal preparation time.



Bone cement needle and syringe





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Bronnen:

(1) Ziekenhuis Oost-Limburg. (n.d.). Vertebroplasty. ZOL. Retrieved December 12, 2024, from Ziekenhuis Oost-Limburg. (z.d.). Vertebroplastie. ZOL
(2) National Institute for Public Health and the Environment (RIVM). (n.d.). Health effects of ionising radiation. Retrieved January 5, 2025, from https://www.rivm.nl/straling-en-radioactiviteit/blootstelling-en-gezondheidsrisico/gezondheidseffecten-van-ioniserende-straling